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Enhancing Elementary Students' Geometry Concept Understanding through GeoGebra and Color Nets Integration

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ABSTRACT

This study addresses the limited conceptual understanding of geometry (specifically the nets of cubes and cuboids) among Grade V students, who often rely on memorization rather than spatial reasoning. The research investigates the effect of combining GeoGebra, an interactive digital tool, with color nets as non-digital visual media to enhance comprehension. A pre-experimental one-group pretest-posttest design was used involving 21 students. Data were collected through concept tests and behavioral questionnaires, analyzed using descriptive statistics and a paired sample t-test. The findings revealed a significant improvement in students' geometry concepts after the intervention. Behavioral analysis also indicated positive attitudes toward mathematics learning with GeoGebra and color nets. The improvement is attributed to the media's interactive and visual strengths, supporting students' spatial reasoning. This study suggests that integrating digital and tangible media fosters deeper conceptual grasp and engagement in elementary geometry learning.

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1. INTRODUCTION

The basic principle of using technology in mathematics learning is that technology can improve students' conceptual understanding of mathematical ideas and develop intuition skills in mathematics (Putrawangsa & Hasanah, 2018). Therefore, the technology applied in learning must be appropriate, including GeoGebra. In addition, the use of technology in learning can be supported by non-digital media that can provide meaningful learning activities. Implementing meaningful learning is very important because there are many advantages (Rasim *et al*., 2021). GeoGebra can be supported with non-digital media in the form of colour nets to bring more meaningful mathematics learning.

GeoGebra is helpful for teachers and students. The GeoGebra program can be installed personally on a laptop or device. Thus, its use is not limited to school, like commercial applications (Hohenwarter & Fuchs, 2008). Even GeoGebra can be accessed online. Furthermore, GeoGebra can be used by students aged 10-18 years, from simple construction to formula integration. In using GeoGebra by students, teachers need to be advisors who provide support/assistance when needed. The results of student experiments using GeoGebra should be the basis for class discussions and require more time for the teacher to concentrate on fundamental ideas and mathematical reasoning (Hohenwarter & Fuchs, 2008).

The software can be used with students aged 10 to 18, starting with simple constructions and integrating functions. Whether students explore mathematics alone or in groups, the teacher should be an advisor in the background who gives support when help is needed. The students' results of their experiments with GeoGebra should be the basis for discussions in class. It gives teachers more time to concentrate on fundamental ideas and mathematical reasoning (Zulnaidi *et al*., 2020).

Several recent studies have shown the effectiveness of using GeoGebra in learning mathematics. Using GeoGebra-assisted learning modules can improve formative test learning outcomes on the material of building space with the research subjects of grade VIII junior high school students (Rhilmanidar et al., 2020). Meanwhile, some researchers (Latri *et al*., 2020) tested the effectiveness of GeoGebra media in improving prospective elementary school teachers' understanding of geometry concepts. GeoGebra media has also proven effective and positively affects the mathematical abilities of vocational students (Nurdin *et al*., 2019).

Although many studies show the effectiveness of GeoGebra media in learning mathematics, research has yet to be conducted that specifically examines the effectiveness of GeoGebra media combined with non-digital media for elementary school students on geometry material. Therefore, this study is novel because it applies GeoGebra media and colour nets to improve elementary school students' ability to understand geometry concepts. This research fills the void of previous research and enriches the literature on applying GeoGebra media to geometry material for elementary school students.

Geometry and spatial understanding are fundamental to learning mathematics. They offer ways to interpret and reflect the physical environment and can be useful tools for studying other topics in mathematics" (p. 23). Specifically, the skill standards that students in grades 3-5 should master in geometry include using visualisation, spatial reasoning, and geometric modelling to solve problems: (i) create and describe images, objects, patterns, and paths; (ii) construct and draw geometric objects; (iii) identify and construct a three-dimensional object from a two-dimensional representation of that object; (iv) identify and draw a two-dimensional representation of a three-dimensional object; (v) recognise geometric ideas and

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relationships and problems that arise in the classroom or everyday life; (vi) use geometric models to solve problems in other areas of mathematics such as number and measurement.

Based on learning observations for two weeks in class V SDN 2 Candi in the geometry material of the nets of cubes and cuboids, several problems were found, among others: (i) students only memorise the patterns of the nets of cubes and cuboids without understanding how they are formed; (ii) students have difficulty in imagining which net patterns are correct and incorrect, thus affecting students' ability to analyse the shape of the net; (iii) the gap in students' ability to memorise the nets of cubes and bars.

The low achievement of learning towards understanding the concept of geometry is a problem identified in this study. This study hypothesises that using GeoGebra media and colour nets can improve the understanding of geometry concepts on the material of the nets of cubes and cuboids. The solution is to implement GeoGebra and colour nets as visual and interactive media. This study aims to explore the effect of GeoGebra media and colour nets in improving understanding of geometry concepts and analyse the impact of these media on student behaviour in learning geometry.

Using GeoGebra as an interactive medium is expected to form a better understanding of geometry concepts related to the material of the nets of cubes and cuboids. The expected results are the achievement and significant improvement of the ability to understand the concept of geometry, as well as an increase in student behaviour towards learning mathematics in geometry material.

The purpose of this study is to investigate the effectiveness of integrating GeoGebra and color nets in improving Grade V students' conceptual understanding of geometry, particularly the nets of cubes and cuboids. The novelty of this research lies in its combined use of digital and non-digital media (GeoGebra as an interactive tool and color nets as tangible visual aids) to enhance students' spatial reasoning and engagement. Unlike prior studies that focused solely on digital tools, this study offers a holistic instructional approach tailored to the cognitive needs of elementary learners, demonstrating its practical significance for improving mathematical comprehension in foundational education.

2. METHODS

The research method used in this research is a pre-experimental design with a One-Group Pretest-Postest Design. The subjects of this research were fifth-grade students of elementary school (SDN 2) in Candi, Indonesia.

The research design used is the One-Group Pretest-Posttest Design, where one group becomes the control and experimental classes. Initially, the research subjects became the control class by not being treated or using conventional learning (Q1). Then, the research subjects also became the experimental class by being treated using GeoGebra media and colour nets in learning mathematical geometry (Q2). For more details, this research design is shown in **Table 1**.

Table 1. Research design.

Pretest	Treatment	Posttest
Q_1	X	Q_2

Note: O_1, X, and O_2 are pretest score, treatment, and posttest score.

The sampling technique used in this study is total sampling, also called census sampling, where all population members are sampled. This sampling is used because the population is

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relatively small, less than 30 people. The population in this study was 21 students as research subjects.

The variables to be measured in this study are the understanding of geometry concepts on the material of the nets of cubes and cuboids and student behaviour towards learning mathematical geometry. Concept understanding will be measured through tests prepared and validated previously.

The research instrument consists of a concept understanding test that contains questions designed to test the understanding of geometry concepts of cube and cuboid net material. The test form used is multiple choice. Before the test tool is made, the question grid is made first. Furthermore, questionnaires and interviews were used to measure students' behaviour towards mathematics learning.

The data collection technique is done by giving a test on the understanding of geometry concepts. The test will be given before and after treatment. The collected data will be analysed using descriptive statistical techniques.

Data analysis involves descriptive statistics, such as mean, median, quartile, standard deviation, and t-test using One Sample Kolmogorov-Smirnov. The descriptive statistical analysis describes or gives a general description of the data obtained, namely the value of student learning outcomes using GeoGebra and colour nets on geometry material. N-gain scores are also used to measure the effectiveness of using GeoGebra and cuboid nets in understanding geometric concepts. The results of the N-gain calculation are then interpreted using the following criteria (see **Table 2**).

Table 2. Criteria of N-Gain.

Category	Range
High	(g) ≥ 0,7
Medium	0,7 ≥ (g) ≥ 0,3
Low	(g) ≥ 0,3

Data analysis also involves the interpretation of the results of conceptual understanding tests and behavioural questionnaires to obtain a comprehensive understanding of the effectiveness of the use of Geogebra and Color Nets media on students' knowledge of geometric concepts and behaviour in learning mathematics. The interpretation of behavioural assessments is determined with the following ranges (see **Table 3**).

Table 3. Interpretation of behaviour scale.

Interpretation	Information
1,00-1,80	Highly Negative
1,81-2,60	Negative
3,41-4,20	Positive
4,21-5,00	Highly Positive

The scores given for the questionnaire assessment start from SS (Strongly Agree) = 5, S (Agree) = 4, N (Neutral) = 3, TS (Disagree) = 2, STS (Strongly Disagree) = 1, support positive behaviour, while support negative behaviour, the scores given start from SS (Strongly Agree) = 1, S (Agree) = 2, Neutral (N) = 3, TS (Disagree) = 4, STS (Strongly Disagree) = 5.

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3. RESULTS AND DISCUSSION

3.1. Analysis of Pretest Results of GeoGebra Utilization and Color Mesh Media in Concept Understanding

The initial stage of this study began by conducting a pretest to measure the level of understanding of the concept of geometry material and student behaviour before being given treatment using GeoGebra and nets on the material of the cubes and cuboids. The pretest results of the research subjects as a control class were used to test the initial ability of students' concept understanding of geometry material on the nets of cubes and cuboids (see **Table 4**).

Table 4. Pretest results using normality test.

Descriptive Statistic	Value
N	21
Mean	72.8571
Standard Deviation	11.89237
Minimum	60
Maximum	100
Asymp. Sig. (2 tailed)	0.39 [c]

Based on **Table 4**, the value of Sig. (2 tailed), amounting to 0.39 above 0.005, then the data is typically distributed and indicates that the test tested to the subject has represented the ability of all students equally. The students' understanding of the concept in the initial test is the same.

The pretest results show that in the initial condition, students have a similar understanding of geometry concepts on the material of the nets of cubes and cuboids. Conducting a pretest is essential as an initial description of the concept and understanding of the research subject before learning to use GeoGebra media and colour net media. Pretests are conducted to determine the initial abilities that students have mastered and prepare students for the learning process. Previous studies have used pretests to determine the extent to which a material has been learned by students (Magdalena *et al*., 2021).

The pretest results can be used as a reference to see the increase in concept understanding after using GeoGebra media and colour nets. Furthermore, treatment was carried out on the research subjects, and a posttest was carried out to evaluate the understanding of concepts after treatment.

3.2. Analysis of Posttest Results using Geogebra and Color Mesh Media on Concept Understanding

The final stage in this study is a posttest, which aims to measure the increase in understanding of geometry concepts in the material of the nets of cubes and cuboids and student behaviour after using GeoGebra media and colour nets. This posttest aims to evaluate the effectiveness of using GeoGebra and colour nets in improving concept understanding and student behaviour. Through the posttest, there is expected to be a significant increase after being treated with GeoGebra media and colour nets.

The post-test was given after learning to determine whether the students' ability to understand geometry concepts on the material of the cube-cuboids nets that were given learning using GeoGebra and colour nets was better than before treatment (see **Table 5**).

The data in **Table 5** shows the value of Sig. (2 tailed) is 0.200, and because Sig. (2 tailed) is more than 0.005, the data is usually distributed. Analysis of posttest data shows no significant

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difference in understanding the concept of geometry on the material of the nets of cubes and cuboids between students. The research subjects experienced a substantial increase in achievement in understanding the idea of geometry compared to learning with conventional methods and media.

The posttest results are consistent with previous research that understanding geometry math concepts can be improved using GeoGebra. Using GeoGebra in learning mathematics has proven effective and gives students a positive perception of learning mathematics; even GeoGebra, accessed online, benefits mathematics learning and diversity in classroom learning (Arbain & Shukor, 2015). In addition, the benefits of using GeoGebra in learning are also shown in previous studies (Shadaan & Leong, 2013). GeoGebra-supported learning can improve students' concept understanding compared to textbook-based learning.

The effectiveness of GeoGebra has been tested in improving learning outcomes. Using GeoGebra significantly affects learning outcomes (Fitriyah *et al*., 2023); compared to Cabri 3D, GeoGebra is more effective in improving learning outcomes. The same thing was also stated by previous studies (En-nhiri *et al*., 2025), that students who get GeoGebra-assisted learning get better learning outcomes and improvements than groups with conventional learning for high, middle, and low categories.

Using GeoGebra and Color Nets has shown an increase in post-test scores. Furthermore, the value is processed by conducting a Paired Sample T-Test to see the significance of the difference between the pretest and posttest results.

Table 5. Posttest results using normality test.

Descriptive Statistics	Value
N	21
Mean	45.713
Standard Deviation	20.38907
Minimum	20
Maximum	80
Asymp. Sig. (2 tailed)	0.200 [c]

3.3. Analysis of Paired Sample T-Test Results

After knowing the results of the pretest and posttest scores, it is necessary to do a t-test. The t-test aims to compare whether the average value of a population or two populations has a significant difference. Meanwhile, the t-test is divided into two procedures: one-sample T-test and two-sample T-test.

The t-test used in this study is a two-sample t-test (Paired Sample Test), in which the paired samples used are the same subject but experience different treatments (see **Table 6**).

Table 6. Paired sample t-test results.

Test	*N*	Descriptive Statistic	Paired T-Test		
		M (Std. D)	T	*Df*	Sig. (2 tailed)
Pretest	21	45.71 (20.3)	-7.844	20	0.000
Posttest	21	72. 85 (11.8)			

The paired sample t-test aims to test whether there is an influence on reading comprehension ability before and after using Reading Workshop-based teaching materials. Data processing in the form of pretest and posttest scores uses a paired sample t-test to test the difference in pretest and posttest scores based on the following hypotheses. Ho: There is no significant influence on reading comprehension ability on reading comprehension ability

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before and after using reading workshop-based teaching materials. Ha: There is a considerable influence on students' reading comprehension ability before and after using reading workshop-based teaching materials. The testing criteria in the paired sample t-test are as follows: If significance > 0.05, then Ho is accepted; if significance < 0.05, then Ho is rejected.

Based on the Paired Sample T-test test results, there is a relationship between the pretest and posttest. The Paired Sample T-Test test results show a significant number between the pretest and posttest scores with a significance value (2-tailed) p = 0.000 <0.05. This study's null hypothesis (Ho) is rejected, and the alternative hypothesis (Ha) is accepted. Thus, there is a significant difference between the two tests.

Based on the Paired Sample T-Test results above, using GeoGebra media and Color Nets can improve the understanding of geometry concepts in grade V students.

The T-Test results above show that using GeoGebra and colour nets can improve elementary school students' understanding of geometry concepts, in line with previous related research.

GeoGebra can be combined with other media and strategies to improve understanding of geometry concepts. As (Jelatu & Ardana, 2018; Nurzannah *et al*., 2021; Kirana *et al*., 2025) stated, the REACT strategy assisted by GeoGebra can produce higher achievement of students' knowledge of geometry concepts than students in conventional groups.

GeoGebra is an effective software for teaching and learning geometry, especially for developing countries like India, where technology in education is quite challenging to reach, especially in rural areas, because GeoGebra can be run offline (Bhagat & Chang, 2015). This is in line with the geographical conditions of Indonesia, where there are still many areas that need to be improved in terms of access to the internet. By applying GeoGebra in learning, students' concept understanding in learning mathematics can be improved.

3.4. Analysis of Student Behavior towards Understanding Geometry Concepts using Geogebra and Color Nets

Student behaviour analysis was conducted to evaluate the effect of using Geogebra and Color Nets in learning mathematics on geometry material. Measurement of student behaviour can provide knowledge about behavioural changes that occur after being treated using Geogebra and colour nets. The results of this analysis can be used further to understand the effect of using Geogebra and Color Nets in learning Geometry (see **Table 7**).

Table 7. Aspects of geometry learning.

Aspect of Geometry Learning	Mean	Information
Student behaviour towards geometry learning using Geogebra	4.25	Highly Positive
Student behaviour towards geometry learning using colour nets	3.85	Positive
Student behaviour towards geometry problems given	3.65	Positive
Average aspects of learning geometry mathematics	3.9	Positive

The study results showed positive student behaviour towards geometry learning and very positive behaviour towards geometry learning using Geogebra. In addition, students also behaved positively towards the use of colour nets in geometry learning and towards the geometry problems given.

Positive student behaviour can be seen from student interest in geometry learning using Geogebra and Color Nets, student involvement in group discussions and overall learning, student responses to stimuli from media and teachers, and student creativity in solving problems.

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The positive findings of using Geogebra align with previous findings that examined student responses to learning using Geogebra in mathematics learning with geometry material, especially cube and cuboid nets. Geogebra-based learning media is superior to conventional media in increasing student motivation and creativity.

The same thing is also supported by a literature review from previous studies (Uwurukundo *et al*., 2022). The use of Geogebra shows the positive significance of student behaviour towards geometry in terms of student interest, involvement and active learning, self-efficacy and self-regulation, and increasing positive behaviour.

Using Geogebra and colour nets showed significant positive student behaviour towards mathematics learning. Students showed higher interest, enthusiasm, and motivation in mathematics learning in understanding geometry concepts. Based on the results of interviews with students, they can appreciate geometry concepts more easily, in an honest, engaging, and applicable way through using Geogebra and colour nets. Geogebra helps students see the actual shape of the net and allows students, especially those with limitations in spatial intelligence, to do so. Thus, the results of this study have an essential impact on the development of geometry learning in elementary schools. Geogebra and colour nets can improve student behaviour and motivation towards geometry learning in elementary schools and encourage the development of more engaging and interactive learning.

4. CONCLUSION

Using GeoGebra and colour mesh media can improve the understanding of elementary school students' mathematical concepts on geometry material related to the nets of cubes and blocks after implementing mathematics learning using GeoGebra and colour nets. In addition, GeoGebra and colour nets used in mathematics learning positively impact students' attitudes towards learning geometry. Thus, they positively affect students' ability to understand the concept of nets of cubes and blocks.

This study has shown that the use of GeoGebra and colour nets can improve elementary school student's ability to understand geometry concepts in the material of the nets of cubes and blocks. However, this study has yet to explore further the effect of GeoGebra and colour nets on the higher-order thinking skills of elementary school students, which will impact other mathematical abilities related to geometry material. Therefore, further research is recommended to explore how using GeoGebra affects higher-order thinking skills and other mathematical abilities.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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