Effect of GeoGebra - supported 5E learning model on students' understanding of the area of a trapezium: A quasi-experimental study

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Abstract*: This study examines the impact of integrating GeoGebra software with the 5E instructional model on fifth-grade students' understanding of the formula for the area of a trapezium. This quasi-experimental research involved 90 fifth-grade students in southern Vietnam, divided into experimental and control groups. The experimental group received instruction through GeoGebra-supported 5E learning, while the control group was taught using traditional methods. Data were collected using pre- and post-tests to assess students' mathematical achievement. Results indicate a statistically significant improvement in the post-test scores of the experimental group compared to the control group, suggesting that the GeoGebra-supported 5E model effectively enhances students' comprehension and retention of the trapezium area formula. Qualitative analysis further revealed increased student engagement and positive attitudes towards mathematics in the experimental group. These findings highlight the potential of GeoGebra and the 5E instructional model in creating an interactive and student-centered learning environment that fosters deeper mathematical understanding. The study contributes to the growing body of evidence supporting technology integration in mathematics education and provides practical implications for educators aiming to improve student outcomes in geometry.*

Keywords: GeoGebra, 5E Instructional Model, Trapezium Area Formula, Mathematics Education, Dynamic Geometry Software, Student-Centered Learning, Quasi-Experimental Design.

INTRODUCTION

Student-centred education methods have profoundly impacted mathematics teaching practices, and information and communication technologies (ICTs) are essential in this process (Abdulrahaman et al., 2020; Abedi, 2023; Tran-Duong, 2024). In this regard, the Viet Nam Mathematics Curriculum, updated in recent years (Ministry of Education and Training, 2018) highlights the use of dynamic computer software and ICTs, which can be used to construct students' premises and knowledge in teaching mathematics and concepts because computer technology gives the possibility of creating many abstract mathematical concepts and concrete relationships.

Moreover, students often find mathematical lessons challenging and disengaging; however, by integrating computers and technological tools in classrooms, they can learn more effectively through hands-on, interactive experiences (Abdulrahaman et al., 2020; Abedi, 2023). According to (Bülbül & Güler, 2020; Ng, Shi, & Ting, 2020; Nurjanah et al., 2020) computer-aided environments supported by dynamic geometry software provide a strong communication between teachers and students. Through this communication, students engage in high-level thinking activities, such as hypotheses, tests, rejections and generalizations, and play an active role in mathematical activities (Uwurukundo, Maniraho, & Tusiime Rwibasira, 2022). Such a learning environment contributes to students' mathematics achievement, problem-solving, and higher-level learning skills (Uwurukundo, Maniraho, & Tusiime Rwibasira, 2022). Computer-aided environments support investigating invariants, reasoning with relationships, considering specific cases, and generalizing geometric ideas (Bülbül & Güler, 2022). Many studies show that technology in mathematics education positively affects students' conceptual knowledge (Gürbüz & Birgin, 2012; Tatar & Zengin, 2016; Uwineza, Uworwabayeho, & Yokoyama, 2024), academic achievement (Erbas & Yenmez, 2011), attitude (Uwurukundo et al., 2024; Zengin, 2017), interest and motivation (İlhan, 2021; Pando Cerra et al., 2022), mathematical knowledge (Ng, Shi, & Ting, 2020), spatial thinking skill (Dilling & Vogler, 2021), instrumental genesis process (Ruiz-López, 2018) and performance (Ji, Guo, & Song, 2024).

Compared to traditional teaching methods, technology-enhanced mathematics instruction provides both teachers and students with a wider range of teaching and learning options. These include the ability to visualize and animate mathematical concepts through multiple representations (Abraham & Prediger, 2024; Beltrán-Meneu et al., 2024; Reis & Ozdemir, 2010; Triet & Loc, 2020), enhance student engagement, personalize learning, offer numerous experiments and observations, and support conceptual understanding, ultimately promoting better retention of knowledge (Hanh et al., 2021; Khormi, 2023; Kugblenu, 2022; Kusuma & Auliana, 2024; Tran-Duong, 2024). Research across various educational levels-primary, middle, and high school has consistently shown that technology-assisted mathematics instruction leads to improved student achievement in mathematics (Loc et al., 2022; Martinovic, 2023; Tong et al., 2024; Triet, 2021; Triet & Loc, 2020; Turk & Akyuz, 2016; Yohannes & Chen, 2023; Zhang et al., 2023), as well as enhanced retention (Alabdulaziz et al., 2021; Birgin & Topuz, 2021; Radović et al., 2020) and positively affects attitudes towards mathematics (Jaya & Suparman, 2022; Lin & Cheng, 2022; Romero Albaladejo & García López, 2024). Chen et al. (2021) indicate that teachers can use 3D dynamic geometry software (DGS) to teach better solving the surface of solid figures, and students can use them to understand the solution process better. Additionally, meta-analytic studies by Li and Ma (2010); Ran, Kasli and Secada (2020); Ran, Kim and Secada (2022); Suparman, Marasabessy and Helsa (2024) and Goagoses et al. (2024) further confirm that technology-enhanced mathematics instruction has a positive impact on students' mathematical performance from kindergarten through 12th grade.

Nowadays, many types of educational software (Cabri II, Cabri 3D, Geometer's Sketchpad, etc.) are used as learning tools in learning and teaching mathematics. In this context, use of Cabri 3D for fifth-grade-level folding nets' activities (Seo & Lee, 2021), solid volume measurement (Gülburnu, 2022) and use of Cabri II for seventh-grade-level geometry (Hai, 2006) have a positive effect on students' achievement and attitude. Isiksal and Askar (2005) conducted a study with 7th-grade students. They found that groups using dynamic geometry software had significantly improved the teaching coordinates of plane points, symmetry, and line graphics, while those using Excel software and groups received more teacher-centred instruction. Similarly, some studies have shown that computer-aided instruction increases student performance more than teacher-focused instruction in the teaching of circles (Bretscher, 2023; Ganesan & Eu, 2020), angles and triangles (Bokosmaty, Mavilidi, & Paas, 2017; Bulut & Kal, 2022; Yao, 2020), polygons (Dana-Picard & Hershkovitz, 2023; Erbas & Yenmez, 2011), and quadrilateral geometric transformation and surface (Lehmann, 2022; Panorkou, 2021).

In recent years, another educational software utilized in mathematics teaching is GeoGebra, which combines geometry with analyzing processes (Yohannes & Chen, 2023). GeoGebra is a free, open-source mathematical software program that combines mathematical, algebraic and computation features (Haciomeroglu et al., 2009). GeoGebra is an interactive software system developed for students from primary school to the university level and is used to provide a better understanding of mathematics concepts and topics (Pari Condori, Mendoza Velazco, & Auccahuallpa Fernández, 2020). GeoGebra integrates dynamic geometry and computer algebra possibilities in one tool that supports all points, lines, and conic constructions (Hohenwarter, Hohenwarter, & Lavicza, 2009). GeoGebra also promotes the project of mathematics, several presentations, experimentation and guided learning of discoveries (Diković, 2009). Therefore, GeoGebra has been translated into many languages and is frequently used by students, teachers and researchers worldwide.

Many studies on different levels of education have shown that computer-assisted instruction supported by Geogebra software has a significant impact on students' achievement (Alabdulaziz et al., 2021; Birgin & Acar, 2022; Zulnaidi, Oktavika, & Hidayat, 2020), attitude (Gün & Küçük, 2023) and motivation (Abdullah et al., 2020). It has been expressed in some studies that GeoGebra provides students with opportunities to explore connections between mathematical objects and graphical representations (Olsson, 2019; Pari Condori, Mendoza Velazco, & Auccahuallpa Fernández, 2020), visual communication (Muminovic, Hadziabdic, & Musanovic, 2023; Vallo, 2021),

It has also been shown in other studies that GeoGebra-supported instruction of mathematics subjects such as plane geometry increases students' academic achievement compared to instruction where educational software is not used (Kontrová & Šusteková, 2020; Loc et al., 2022; Triet, 2021). In addition, it is indicated in some studies that the use of GeoGebra supports collaborative learning (Birgin & Acar, 2022; Birgin & Topuz, 2021), 6E learning cycle (Kusumah & Martadiputra, 2022; Schallert-Vallaster & Lavicza, 2021) and experiential learning (Age & Machaba, 2023).

In the current trend of transitioning from content-oriented instruction to competency-based education in secondary schools, the 5E instructional model is being extensively researched and applied by many educators. This model is based on five different stages of learning: Engage, Explore, Explain, Elaborate and Evaluate. It is one of the learning models most suitable for the constructivist approach and one of the most influential models that can be applied in such learning environments. It can allow students to question, increase curiosity, explore, and explain their discoveries (Bybee et al., 2006). The 5E learning enables students to discover new concepts by using their prior knowledge and enables them to relate these concepts to their prior knowledge. It is one of the most well-known and well-recognized teaching models that use a collaborative approach (Schallert, Lavicza, & Vandervieren, 2022). This model promotes students' ability to think critically and creatively and enhances their understanding of concepts in mathematics. The 5E instructional model effectively improved students' conceptual and procedural knowledge related to the concept of identities (Ünlüer & Kurtuluş, 2021). This 5E strategy is intended to encourage students to study mathematics by enjoying their interest in new concepts and involving them in the learning process through phased lessons (Omotayo & Adeleke, 2017).

Research by Tezer and Cumhur (2017), Loan (2018) and Hanh and Quyen (2020) has demonstrated the positive effects of using the 5E instructional model in mathematics education.

However, studies that integrate GeoGebra with the 5E instructional model are scarce. Furthermore, research on applying GeoGebra in teaching the area formula for trapezium at the primary school level remains limited. Therefore, this study aims to compare the effectiveness of the 5E instructional model supported by GeoGebra with traditional teaching methods in instructing the formula for the area of trapezium to 5th-grade students. Since, the following research questions and hypotheses have been formulated:

RQ1: During the intervention, is there a significant difference between the group where the Geo5E method was implemented and the group where the TIM was implemented in terms of levels of academic achievement in the area of trapezium?

Hypothesis 1: There is a significant difference between the post-test academic achievement scores of the group where the TIM method was implemented and the group where the Geo5E was implemented.

RQ2: Is there a significant difference between the group where the Geo5E method was implemented and the group where the TIM was implemented in terms of the scores of the post-test of academic achievement in mathematics?

Hypothesis 2: The achievement scores obtained from the academic achievement post-test are higher in the group where the TIM method is implemented than in the group where the Geo5E method is implemented.

METHODS

Research design

This study used a quasi-experimental design with a non-equivalent pre-test and post-test control group. A quasi-experiment design is helpful for applying interventions without changing the research groups' learning settings. This design enables the researcher to conduct a study in without random assignment of the subjects because of the various timetables that the classes followed; it will not be possible to randomly group the students (Strunk & Mwavita, 2024). For this reason, two fifth-grade classes from the same public middle school were selected, and one of these two groups was appointed as a control group, while the other group was appointed as an experimental group. While GeoGebra-supported 5E instruction (Geo5E) was carried out in the experimental group, no intervention was made in the control group, and instruction continued via traditional instruction method (TIM).

This quasi-experimental research was implemented during the first term of the academic year. One of the researchers was a primary teacher, and the instruction was conducted with both groups. This teacher had experience and knowledge in the application of the GeoGebra activities within the learning environment.

At the beginning of the study, an Area of Trapezium Achievement Test (ATAT) was taken to the experimental and control groups as a pre-test. As a result, in Figure 1, a quasi-experimental design is presented.

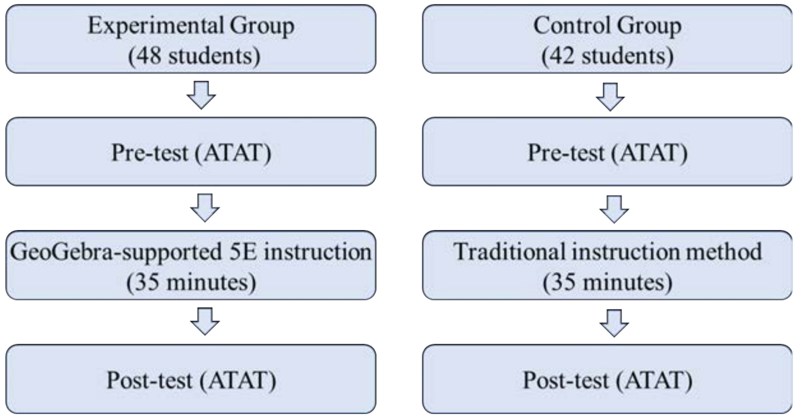


Figure 1. Experimental design of the study. Abbreviation: ATAT = Area of Trapezium Achievement

The participants

The study group consisted of 90 fifth-grade students (aged 10–11 years old) from a public middle school in a district of a city located in southern Vietnam. The control group was made up of 48 students (21 girls, 27 boys), and the experimental group consisted of 42 students (19 girls, 23 boys). It was determined that the socioeconomic status of students in both groups was similar, with most students coming from lower- to middle-class families. In addition, the public middle school in this study was chosen due to the presence of a highly equipped computer laboratory with PCs. All students in this study had previously taken technological courses that had developed their computer literacy.

Data collection tool and data analysis

The main instruments used for data collection were the trapezium achievement test (pre-test and post-test), informal classroom assessment and observation.

The pre-test was used to assess the geometrical knowledge and skills before the intervention on the area of trapezium formula learning in both control and experimental groups. The post-test enabled the researcher to make a comparison between the teaching area of the trapezium formula using instructional teaching methods and teaching using the 5E instructional model with the help of GeoGebra software. Two tests were designed to collect data for this study. Quantitative data was collected through pre-test, post-test using achievement tests. The same test was used to collect data before and after treatment.

ATAT consists of 6 items, including 2 multiple choice, 2 fill in the blanks and 2 essay questions (see Appendix). In multiple-choice and fill-in-the-blank items, 1 point was scored for 'correct answers' and zero points for 'wrong' or 'empty answers'. In the score items that required written answers in the conceptual understanding test, 2 points were awarded for a "completely correct answer", 1 point for a "partly correct answer" and zero points for a "false" or "empty answer". The conceptual understanding test scores ranged from between 0 and 10. Two independent coders scored the answer responses to ensure the scoring reliability for items in the conceptual understanding test that required written responses. The scoring reliability was calculated as high (> 0.70) according to Strunk and Mwavita (2024)

The achievement test data administered as pre-and post-tests were checked and transferred onto the Jamovi program (Glenberg & Andrzejewski, 2024). Descriptive and inferential analyses were conducted based on the basic questions and objectives of the research.

In this current study, Shapiro–Wilk's normality tests were performed to decide whether there was a normal distribution. As a result, it was determined that the data were not normally distributed. For that reason, it was decided to use the non-parametric analysis method to test the difference between experimental and control groups. The pre- and post-test scores were reported via the non-parametric Mann-Whitney U Test and the Wilcoxon Signed Rank Test within the framework of the research questions.

The purpose and objectives of the study were explained to all the participants. All the 90 primary school students consented to participate in this study by signing consent and assent forms. Before the assent of students, permission was sought from the schools' head teachers and directors of studies so that the researcher could access the schools and, later on, the classrooms. In addition, all participants voluntarily took part in this study and, therefore, were free to leave at any point during the study. The participants did not write their names on the tests, making them anonymous and confidential solely for research purposes.

The 5E instructional model lesson plan

In the experimental group, instruction was carried out in the computer laboratory, where there was an interactive board and computers. Each GeoGebra activity and worksheet was completed with pairs on a computer. The teacher-guided students during the completion of GeoGebra activities and directed them in areas that may have been misunderstood. The role of the teacher was to guide students through questions and motivate students to explore mathematical features within the computer environment. Also, the results obtained after the completion of each activity were shared and discussed within the classroom. The following lists specific tasks performed at each stage.

Phase 1 (Engage): The teacher prompts students to observe the trapezium ABCD designed using GeoGebra (Figure 2) and answer questions to review the properties of trapeziums. Students then discuss in groups to raise any questions about trapeziums. The teacher concludes by highlighting the key point to explore: "Which formula is used to calculate the area of a trapezium?" and leads into the lesson, stimulating interest in the new content.

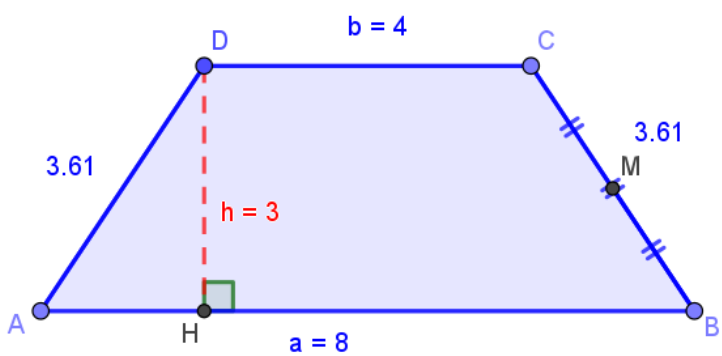


Figure 2. The trapezium ABCD designed using GeoGebra

Phase 2 (Explore): The teacher provides each group with a set of tools, including a trapezium, a ruler, and scissors. Guided questions help students cut and rearrange the trapezium into a previously learned shape. Students discuss and perform the task, then present their methods and predict the area formula based on previous knowledge and the teacher's GeoGebra demonstrations. Students may also be guided to manipulate trapezium cut-and-paste effects within GeoGebra (Figure 3-6).

The supportive role of GeoGebra: Teachers use GeoGebra software to construct a trapezium ABCD and perform operations such as cutting and rearranging it into a triangle. The process of deriving the formula for the area of a trapezium using GeoGebra software overcomes the limitations of the traditional cutting and rearranging method. These limitations arise from a pedagogical situation that occurs immediately after the teacher performs the operations to transform the initial trapezium into a triangle. Specifically, students face difficulties in comparing the areas of the two shapes, as the original trapezium is completely transformed into a triangle. By using GeoGebra, teachers can address this challenge. As a result, the software allows the trapezium to retain its original shape even after the cutting and rearranging process, thereby helping students understand the conservation of area.

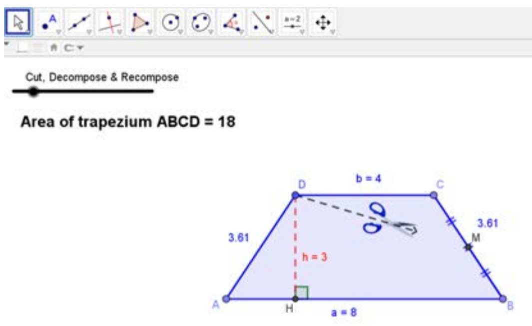


Figure 3. Cut the trapezium

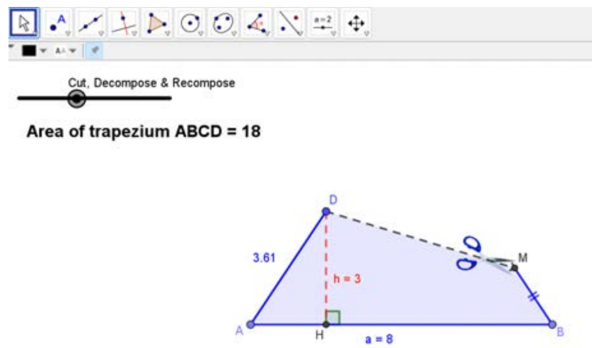


Figure 4. Cut the trapezium into two pieces

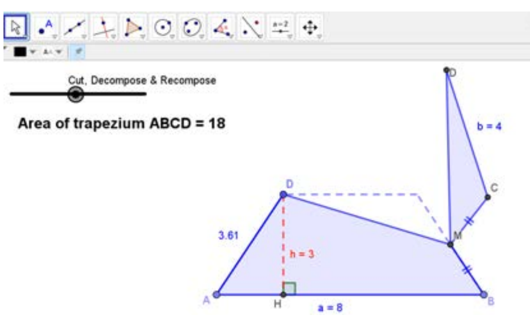


Figure 5. Decompose the trapezium

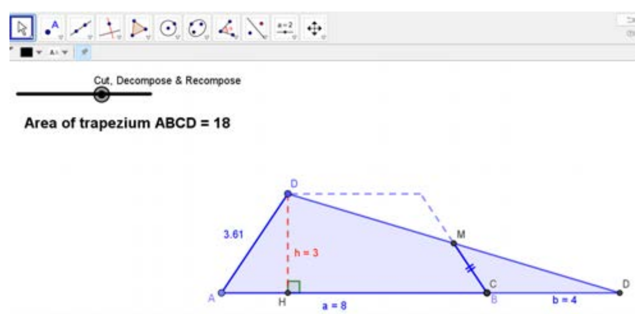


Figure 6. Recompose the trapezium into a triangle

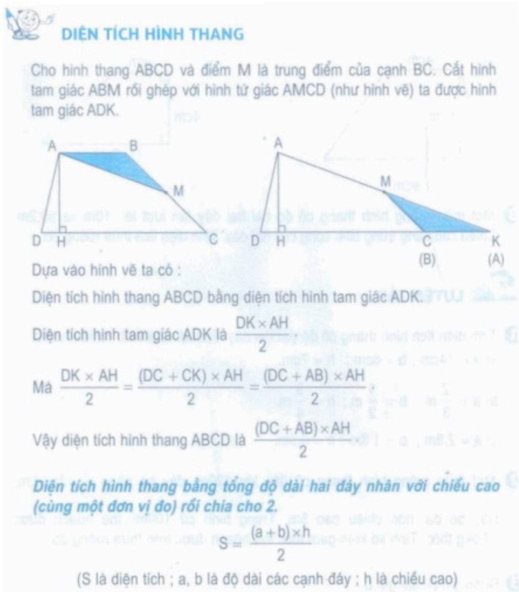
Phase 3 (Explain): Groups present, prove, and explain their predicted trapezium area formulas. The teacher gives feedback and uses GeoGebra to demonstrate the validity of the knowledge.

Phase 4 (Elaborate): Students apply the trapezium area formula to solve similar problems or real-world scenarios.

Phase 5 (Evaluate): Students self-assess and peer-assess within group collaboration. The teacher evaluates student progress toward educational objectives through a quick test.

The instructional model lesson plan

The instruction for the control group was held within the student's regular classroom. The layout of the classroom was in a traditional seating format, including rows of desks, and the students were arranged in the same order as before. Importantly, the students did sit at their desks with a 'pair friends'. The control group instructs topics by following official fifth-grade mathematics curriculum textbook activities (Hoan et al., 2012).



DIỆN TÍCH HÌNH THANG

Cho hình thang ABCD và điểm M là trung điểm của cạnh BC. Cắt hình tam giác ABM rồi ghép với hình tứ giác AMCD (như hình vẽ) ta được hình tam giác ADK.

Dựa vào hình vẽ ta có :

Diện tích hình thang ABCD bằng diện tích hình tam giác ADK.

Diện tích hình tam giác ADK là $\frac{DK \times AH}{2}$

Mà $\frac{DK \times AH}{2} = \frac{(DC + CK) \times AH}{2} = \frac{(DC + AB) \times AH}{2}$.

Vậy diện tích hình thang ABCD là $\frac{(DC + AB) \times AH}{2}$

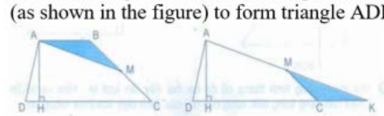
Diện tích hình thang bằng tổng độ dài hai đáy nhân với chiều cao (cùng một đơn vị đo) rồi chia cho 2.

$$S = \frac{(a + b) \times h}{2}$$

(S là diện tích ; a, b là độ dài các cạnh đáy ; h là chiều cao)

AREA OF A TRAPEZIUM

Given trapezium ABCD, point M is the midpoint of side BC. Cut triangle ABM and rearrange it with triangle AMCD (as shown in the figure) to form triangle ADK.



Based on the figure, we have:

The area of trapezium ABCD equals the area of triangle ADK.

The area of triangle ADK is: $\frac{DK \times AH}{2}$

Since: $\frac{DK \times AH}{2} = \frac{(DC+CK) \times AH}{2} = \frac{(DC+AB) \times AH}{2}$

Thus, the area of trapezium ABCD is: $\frac{(DC + AB) \times AH}{2}$

The area of a trapezium is calculated as the sum of the lengths of its two parallel sides multiplied by the height (with the same unit of measurement), then divided by 2.

$$S = \frac{(a + b) \times h}{2}$$

Where:

- S is the area,
- a and b are the lengths of the parallel sides (bases),
- h is the height (perpendicular distance between the bases).

Figure 7. Examples of the mathematics curriculum activities utilized

Examples of the mathematics curriculum activities utilized for instruction are provided in Figure 7. The instruction was primarily carried out through teachers-centered instruction. In this process, the teacher was generally in the role of exemplifying and explaining the subject as well as from time to time, the teacher checked the level of learning for the subjects and concepts being presented by querying and proving feedback to student. Furthermore, students generally remained passive during the teaching process, listened to the instruction and interacted with the teacher regarding the teacher's questions. Following the lecture, sample questions from the textbook were solved within the course for reinforcement of the student' knowledge and understating. Also, the student–teacher and student–student interaction took place during the problem solving process and part of the lessons that were missing and/or misunderstood were revised to complete the instruction. In addition, exercise questions from the textbook were given to the students as homework. In summary, the instructional approach for the control group generally relied on direct instruction, question–answer method and demonstrations of critical concepts for students on the board.

RESULTS

Statistical analysis of pre-test and post-test results

Research question one: Is there a significant difference in the pre-test mean scores of experimental group and control group students used for this study.

Hypothesis 1: There is no significant difference between the pre-test mean scores of experimental group and control group students used for this study.

Research question two: Is there a significant difference in the test scores of students taught with 5E instructional model with the help of GeoGebra and the traditional teaching methods about area of trapezium formula?

Hypothesis H2: There is a significant difference between the mean score of geometry achievement test when exposed to the 5E instructional model with the help of GeoGebra in improving students' archivement of area of trapezium formula and those taught with traditional instruction method.

Descriptive statistics analysis of pre and post test results for both groups

To answer these research question, the pre-test scores of students mean, standard deviation, minimum and maximum of pre-test and post-test for both experimental and control groups of area of trapezium formula test scores were presented.

	pre.Geo5E	pre.TIM	post.Geo5E	post.TIM
N	48	42	48	42
Mean	2.48	2.21	9.02	7.95
Median	3.00	2.00	9.00	8.00
Standard deviation	0.652	0.717	0.956	1.68
Minimum	1	1	7	4
Maximum	3	3	10	10
Skewness	-0.881	-0.345	-0.652	-0.568
Kurtosis	-0.254	-0.950	-0.512	-0.695
Shapiro-Wilk p	< .001	< .001	< .001	0.002

Table 1. Descriptive statistics results for the pre-test and post-test test scores

As shown in Table 1, before intervention the pre-test score of mean, median and standard deviation scores of experimental groups were 2.48, 3.00 and 0.652, respectively. On the other hand, the pre-test mean score and standard deviation of control group were 2.21, 2.00 and 0.217, respectively. The pre-test scores of mean, median and standard deviations in both groups were relatively the same. Depending on their results, the prior knowledge or their understanding of area of trapezium formula was similar for experimental and control groups.

The results of area of trapezium formula tests after the treatment of experimental group by 5E leaning with the help of GeoGebra and control group by traditional teaching method were listed in Table 1. The post-test mean scores of the experimental groups were 9.02, median 9.00 and standard deviation 0.956, while the post-test means scores of the control group was 7.95, median 8.00 and standard deviation 1.68. Based on the results, the understanding of area of trapezium formula after treatment was gradually changed in each group. The mean and standard deviation post-test scores of experimental and control groups were varied and there was a significant difference between the two groups. The understanding of area of trapezium formula after intervention on experimental groups that were learned by 5E learning model of teaching with the help of GeoGebra approaches had resulted in better understanding of the control groups, which were learnt by traditional teaching methods about area of trapezium formula. This implies that the 5E learning model with the GeoGebra-assisted approach was an effective method for improving students' mathematics achievement on the area of a trapezium formula compared to traditional instructional methods.

Inferential statistics analysis of pre-test and post-test

Since the study consisted of groups formed of less than 50 members, the Shapiro-Wilk test was used to determine whether the data were normally distributed (Glenberg & Andrzejewski, 2024;

Strunk & Mwavita, 2024). Q-Q plot, box and whisker plots, and kurtosis and skewness coefficients were also analyzed (Field, 2024; Strunk & Mwavita, 2024).

Statistical analyses (Shapiro–Wilk test, Q-Q plot, box and whisker plot, and kurtosis and skewness coefficients) of the quantitative pre-test and post-test mathematics achievement test responses were not normally distributed.

The results of Table 1 show that the skewness and kurtosis values related to the pre-test and post-test scores of the groups were between -1 and +1. In addition, according to Shapiro–Wilk's normality test values in Table 1, it was determined that the pre-test and post-test scores of groups were not normally distributed ($p < 0.05$).

Independent Samples T-Test

		Statistic	p
pre.Geo5E-TIM	Mann-Whitney U	804	0.069

Note. H_a $\mu_{\text{Geo5E}} \neq \mu_{\text{TIM}}$

Table 2. The Mann Whitney U test results based on the pre-test scores of the achievement test

Since, before the experimental process, the independent samples U-test for pre-test scores of groups was conducted. Table 2 demonstrates that there was no significant difference between the pre-test scores of the experimental group (Class 5.2, Mean = 2.48, Median = 3.0) and control group (Class 5.4, Mean = 2.21, Median = 2.0) [$U = 804$, $p = 0.069 > 0.05$]. Thus, it was indicated in these results that the experimental and control groups had similar prior knowledge prior to the experimental process.

A Mann–Whitney U test was performed on the scores to determine if the difference was statistically significant. The result of the test is presented in . As shown in Table 1 and Table 3, the Mann Whitney U test results based on the pre-test scores of the achievement test, the performance (Mean = 9.02, Median = 9.0) of the students in the experimental group was significantly better than the performance (Mean = 7.95, Median = 8.0) of the students in the control group ($U = 640$, $p = 0.002 < 0.05$).

Independent Samples T-Test

		Statistic	P
Geo5E-TIM	Mann-Whitney U	640	0.002

Note. H_a $\mu_{\text{Geo5E}} \neq \mu_{\text{TIM}}$

Table 3. The Mann Whitney U test results based on the post-test scores of the achievement test

The Hodges–Lehmann estimate's location parameter is the median difference between the two groups. The rank-biserial correlation (rB) can be considered an effect size and interpreted the same as Pearson's r, so 0.366 is a medium effect size (Glenberg & Andrzejewski, 2024). Thus, hypothesis 1 was supported.

Paired sample t-test for both group between pre-post test scores

The scores in pre-test and post-test of the students for the mathematics achievement test are presented in Table 1. The post-test scores of experimental group (Mean = 9.02, Median = 9.0, Standard deviation = 0.956) were found to be higher than their pre-test scores (Mean = 2.48, Median = 3.0, Standard deviation = 0.652). The control group pretest-posttest mean scores and standard deviation were also obtained as (pre mean = 2.21 post mean = 7.95, pre standard deviation = 0.717 post standard deviation = 1.68).

Control group students taught by traditional teaching methods also had better post-test scores than those of their pre-test scores, but the change was relatively more minor than in the experimental groups in terms of both mean and standard deviation results. As a result, an experimental group of students taught with 5E leaning with the help of GeoGebra performed better understanding the area of trapezium formula than the control group students taught with traditional instruction methods.

The results of the Shapiro–Wilk test were as follows (preEG-test = 0.001< 0.05; preCG-test = 0.001< 0.05; postEG-test = 0.001 < 0.05; postCG-test = 0.002< 0.05). The results of the Wilcoxon signed rank test, which is a non-parametric test for significant difference between these tests, are given in Table 4.

Table 4 shows the results of the Wilcoxon signed rank test on whether or not there is a significant difference between achievement in the area academic achievement test of students before and after experimental intervention.

Paired Samples T-Test

			Statistic	p	Mean difference	SE difference
pre.Geo5E	post.Geo5E	Wilcoxon W	1176	< .001	6.50	0.0727
pre.TIM	Post.TIM	Wilcoxon W	903	< .001	6.00	0.1706

Note. H_a $\mu_{\text{Measure 1 - Measure 2}} \neq 0$

Table 4. Wilcoxon signed ranks test results based on scores of the academic achievement pre-test scores and post-test scores

The results showed a significant difference between pre-test and post-test results in the academic achievement test of the students participating in the experimental group (W = 1176, p <0.001 < 0.05) and the control group (W = 903, p <0.001 < 0.05). Therefore, this shows that there is a significant difference in pre-test and post-test results in favor of the post-test. However, experimental group students recorded a higher mean score with 6.50 mean differences between pre- and post-test, while control group students recorded a relatively low mean score with 6.00 mean differences between pre- and post-test. The results show that the 5E leaning with the help of GeoGebra was associated with a significant improvement in achievement of students in understanding of area of trapezium formula. Thus, hypothesis 2 was supported.

Qualitative analysis

In Phase 1, with the goal of helping students recall previously learned knowledge about trapezoids and identify problems related to trapezoids that need solving, the teacher used a laptop to open the GeoGebra software to construct trapezoid ABCD. The trapezoid had a shorter base AB = 4 cm, a longer base CD = 8 cm, and a height AH = 3 cm. Using the functionality of GeoGebra's tools, the teacher constructed the figure, while students observed and answered questions aimed at uncovering issues related to the area of the trapezoid. Through observation and reasoning, all students answered the teacher's questions correctly and were able to identify problems that required solving regarding the trapezoid.

In Phase 2, the objective was for students to predict the formula for calculating the area of the trapezoid. The teacher posed an exploratory question: "To calculate the area of this trapezoid, what kind of figure do you think we should cut and rearrange it into, based on previously learned methods of calculating area?" In response, students discussed in groups and used the provided cut-out tools to rearrange the trapezoid. The teacher then summarized and reviewed the students' work by having them interact with GeoGebra's control panel. Afterward, the teacher posed another task: "After cutting and rearranging, how does the original trapezoid's area compare to the newly formed triangle?" For this task, students analyzed and predicted the area formula for the trapezoid through reasoning using paper and pencil. Thanks to GeoGebra, the original shape of the trapezoid was preserved after rearrangement, allowing students to visualize the conservation of area and independently discover the formula for the trapezoid's area based on the triangle area formula learned earlier.

In Phase 3, based on the observations and analysis from Phase 2, students generalized the formula for calculating the area of a trapezoid. Three groups of students responded, "to calculate the area of a triangle, you multiply the base length by the height (using the same unit) and divide by two." The teacher then formalized the trapezoid area formula as: $S = (a + b) \times h : 2$ (where S is the area, a and b are the lengths of the two bases, and h is the height).

In Phase 4, using the results from Phase 3, students solved real-life problems related to trapezoid area calculations.

Throughout Phases 1 to 4, students engaged in group work, self-assessment, and peer evaluation. All students successfully completed the quick test provided by the teacher, demonstrating active participation and high interactivity among students, with GeoGebra software, and with the teacher. This created opportunities for all students to engage in constructing knowledge.

Through this experimental lesson, students were able to perform the learning activities set by the teacher, meeting the lesson's objectives. The students reinforced their knowledge through independent discovery and inquiry, fostering a positive learning environment with high interactivity among students, GeoGebra, and the teacher. This provided a platform for all students to participate and construct their understanding of the concepts.

Results of the teacher observation survey

From the Table 5, the results showed that, all the observing teachers (3/3, 100%) highly appreciated the experimental pedagogical lesson because it fostered students' interest in learning; the lesson was more dynamic, and the activities of both teachers and students during the class were well-coordinated and seamlessly integrated. After the experimental teaching session, all teachers (3/3, 100%) agreed that students comprehended the lesson better and grasped the content more effectively, and their problem-solving abilities and skills would be superior to those in regular classes. A significant 100% of the teachers concurred with the experimental lesson plan due to its feasibility and effectiveness. In the teaching method outlined in the experimental lesson plan, students play a central role, independently exploring and discovering geometric knowledge. Teachers serve merely as guides and facilitators in helping students uncover these concepts. The majority of teachers expressed a desire to change their methods of teaching geometry to align with the experimental approach, as it was observed that students in the experimental class were more engaged in building the lesson, understood the material better, and demonstrated enhanced problem-solving abilities in the subject matter.

Evaluation Criteria	Assessment Levels				
	1	2	3	4	5
Lesson Plan					
The lesson plan is easy to implement					3
The lesson plan incorporates innovative teaching methodologies.					3
The lesson plan delivers high effectiveness.					3
The lesson plan stimulates students' curiosity and exploration of new knowledge.					3
Teacher in the Classroom					
The teacher seamlessly integrates the use of software into the lesson's progression.					3
The teacher employs effective approaches to problem-solving.					3
The teacher provides excellent guidance for students in addressing problems.					3
Students in the Classroom					
Students are active, proactive in discovering knowledge, and have opportunities to be creative.					3
Students understand the lesson and are engaged in learning.					3

1 - Strongly Disapprove; 2 - Disapprove; 3 - No Opinion; 3 - Approve; 4 - Strongly Approve

Table 5. Results of teacher observation survey

Results of student survey

Results of the survery are presented in Table 6. All students (100%) in the experimental class felt excited and interested when observing the products designed by the teacher using the GeoGebra software. In the experimental pedagogical lesson, 40 (83.33%) of the students self-assessed as understanding the lesson, and they expressed a desire to learn math lessons according to the 5E instructional model integrated with GeoGebra software in future classes. An impressive 46 (95.83%) of the students in the experimental class indicated that they could apply the theoretical knowledge to solve related exercises better than other lessons that did not employ the 5E leaning supported by GeoGebra software.

Evaluation Criteria	Assessment Levels				
	1	2	3	4	5
I greatly appreciate the instructional materials and visualizations created using GeoGebra software.					48
Integrating GeoGebra into lessons significantly enhances my ability to comprehend mathematical concepts quickly.				8	40
I can effectively apply theoretical knowledge to solve related mathematical problems.				2	46
I strongly aspire for mathematics lessons consistently incorporating GeoGebra software to foster engagement and deeper understanding.					48

1 - Strongly Disagree; 2 - Disagree; 3 - Neutral; 4 - Agree; 5 - Strongly Agree

Table 6. Results of students survey

DISCUSSION AND CONCLUSIONS

In this study, the effect of GeoGebra-assisted 5E learning on Grade 5 students' formulaic understanding of the area of the trapezium was investigated. The two approaches selected for this study were 5E learning approaches supported by GeoGebra software and a conventional teaching approach alone to learning the area of the trapezium formula. In this way, the GeoGebra-assisted 5E learning was carried out in the experimental group, while the conventional method was continued in the control group.

According to the data obtained in the study, the pre-test scores of the experimental and control groups in the achievement test, which was prepared according to the subject "the area of the trapezium formula", were found to be close to each other. This shows that students' prior knowledge was similar. When the Wilcoxon signed ranks results of the pre-test and post-test scores in the experimental and control groups were presented, a significant difference was found in both groups in favour of the post-test. As a result of the data analysis, it was found that the Geo5E, used in the experimental group, and the TIM, used in the control group, both led to an increase in the students' levels of achievement when the scores of the methods were considered. In other words, effective results were obtained in both methods. When the Mann–Whitney U test scores of the control and experimental groups were presented, a significant difference was found in favour of the post-test scores of the experimental group. According to this result, it was found that Geo5E significantly increased students' mathematics achievement compared to the TIM. Similarly, Hiep and Tai (2022) have revealed that GeoGebra software on area of trapezium formula in 5 grade is more effective on students' mathematics achievement than the traditional instruction method.

The results also align with previous research indicating the benefits of integrating GeoGebra in mathematics education achievement (Alabdulaziz et al., 2021; Birgin & Acar, 2022; Zulnaidi, Oktavika, & Hidayat, 2020) (Bülbül & Güler, 2020; Hiep and Tai, 2022). Studies have shown that GeoGebra fosters active learning and conceptual understanding, which is consistent with our findings. Moreover, similar improvements in students' mathematical achievements were reported when using technology-enhanced environments, highlighting the effectiveness of combining ICT tools with student-centered instructional models (Kusumah & Martadiputra, 2022; Schallert-Vallaster & Lavicza, 2021).

The 5E model facilitated active engagement, exploration, and elaboration of mathematical concepts, allowing students to dynamically visualize and manipulate geometric shapes. GeoGebra's interactivity enabled students to construct and deconstruct the trapezium, leading to a deeper understanding of the area formula. This approach provided a more concrete learning experience compared to traditional instruction, which may explain the significant improvement in the experimental group's post-test scores.

These findings suggest that GeoGebra-assisted 5E learning can be generalized to other mathematical concepts and different grade levels to enhance conceptual learning. Integrating technology in a structured instructional model improves students' understanding and promotes critical thinking and problem-solving skills. Educators should consider adopting similar approaches to foster a more interactive and student-centered learning environment. During the implementation of GeoGebra and the 5E instructional model, we encountered several challenges, but also found effective strategies to overcome them. First, some students struggled with familiarizing themselves with GeoGebra, especially those with limited exposure to technology, which led to a lack of confidence in using the tool. To address this, we conducted initial training sessions, provided detailed instructional materials, and encouraged students to engage in self-directed practice through hands-on exercises. Second, integrating the 5E model with GeoGebra sometimes proved challenging in balancing the different stages of the model, particularly in managing classroom time effectively. To overcome this, we carefully designed activities to ensure they were mutually supportive, helping students transition smoothly from the exploration phase to the application phase without disrupting the lesson flow. Finally, issues with infrastructure, such as limited access to computers or unreliable internet connections, sometimes hindered the effective use of GeoGebra. To mitigate these constraints, we adapted by using students' mobile devices and offline versions of GeoGebra, ensuring that learning could continue uninterrupted despite technological limitations. Despite these challenges, we firmly believe that the integration of GeoGebra and the 5E model has yielded encouraging results, fostering enhanced critical thinking and student engagement while reinforcing long-term learning outcomes.

The study's strength lies in its quasi-experimental design, allowing for a comparative analysis between GeoGebra-assisted learning and traditional methods. However, the study was limited to a small sample size from a single school, which may affect the generalizability of the results. Future research could involve a larger, more diverse sample and explore the long-term effects of GeoGebra-assisted learning on students' mathematical achievements.

GeoGebra-assisted 5E learning significantly improves students' understanding of the area of trapezium formula compared to traditional instructional methods. This study provides valuable insights into integrating dynamic mathematics software in teaching geometry, advocating for its broader application in mathematics education to enhance students' conceptual and procedural knowledge.

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APPENDIX

AREA OF TRAPEZIUM ACHIEVEMENT TEST (ATAT)

(Vietnamese version)

A. Trắc nghiệm:

Khoanh tròn vào chữ cái trước câu trả lời đúng

Câu 1: Một hình thang có đáy lớn 5*m*, đáy bé 3*m* và chiều cao 2*m*. Diện tích của hình thang đó là:

A. $8{,}5m^2$ B. $8m^2$ C. $9m^2$ D. $7{,}5m^2$

Câu 2: Một hình thang có diện tích $360m^2$, biết tổng hai đáy là 48*m*. Chiều cao của hình thang đó là:

A. 18*m* B. 15*m* C. 16,5*m* D. 17*m*

B. Tự luận:

Câu 1: Điền từ thích hợp vào chỗ chấm

Muốn tính diện tích hình thang ta lấy ………… độ dài hai đáy nhân với ………………... (cùng một đơn vị đo) rồi chia cho 2.

Câu 2: Một hình thang có đáy bé bằng 5*cm*; đáy lớn bằng 9*cm* và chiều cao bằng 70*mm*. Tính diện tích của hình thang đó.

Bài giải

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Câu 3: Một mảnh vườn hình thang có chiều cao 22*m*; đáy bé bằng 17,5*m* và đáy lớn bằng 26,5*m*. Người ta dự định dùng $\frac{1}{4}$ diện tích mảnh vườn để trồng xoài, diện tích còn lại dùng để trồng cam. Tính diện tích phần đất dùng để trồng cam.

Bài giải

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AREA OF TRAPEZIUM ACHIEVEMENT TEST (ATAT)

(English version, translated by the authors)

A. Multiple Choice:

Circle the letter in front of the correct answer.

Question 1: A trapezium has a larger base of 5m, a smaller base of 3m, and a height of 2m. The area of the trapezium is:

A. 8.5m² B. 8m² C. 9m² D. 7.5m²

Question 2: A trapezium has an area of 360m², and the sum of its two bases is 48m. The height of the trapezium is:

A. 18m B. 15m C. 16.5m D. 17m

B. Essay Questions:

Question 1: Fill in the blanks.

To calculate the area of a trapezium, we take ………… the sum of the lengths of the two bases and multiply it by ………………... (in the same unit of measurement), then divide by 2.

Question 2: A trapezium has a smaller base of 5cm, a larger base of 9cm, and a height of 70mm. Calculate the area of the trapezium.

Solution:

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Question 3: A trapezium-shaped plot of land has a height of 22m, a smaller base of 17.5m, and a larger base of 26.5m. It is planned that $\frac{1}{4}$ of the plot will be used for planting mangoes, and the remaining area will be used for planting oranges. Calculate the area of the land used for planting oranges.

Solution:

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