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Integrating Dynamic Geometry Software into the 6E Instructional Model to Enhance Students' Mathematical Communication Skills and Learning Autonomy

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ABSTRACT

The integration of technology into mathematics teaching is increasingly recognized as a key strategy for developing 21st century competencies, including mathematical communication skills and learning autonomy. This research aims to examine the effect of the 6E Instructional Model (IM) integrated with Dynamic Geometry Software (DGS) in enhancing students' mathematical communication skills and learning autonomy. This study employed a quasi-experimental design with a non-equivalent control group, involving class X students at SMK Negeri 5 Sukoharjo, Central Java, selected through cluster random sampling. A total of 69 students participated, comprising 35 students in the experimental group and 34 students in the control group. Data on mathematical communication skills were obtained from pre and post tests using essay questions, while data on learning autonomy came from questionnaires before and after the intervention. It was found that the average post-test score of the experimental group was 82.40, which was greater than the average post-test score of the control group, which was 74.24, and the average final scale score of the questionnaire for the experimental group was 105.11, which was greater than the average final scale score of the control group, which was 90.38, meaning that there was a significant difference between the mathematical communication skills and learning autonomy of students who received 6E-IM with DGS and students who received conventional learning.. The data analysis used was the Independent Sample T-test, which showed that the significance value were less than 0.05, means 6E-IM with DGS can significantly enhance students' mathematical communication and independent learning. This study contributes empirical evidence to support the use of technology-enhanced instructional approaches in mathematics education.

Keywords: Dynamic Geometry Software, Independent Learning, Mathematical Communication, 6E Instructional Model

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Introduction

High-quality learning serves as a crucial foundation for students to comprehend complex concepts and solve problems effectively (Zubaidah, 2016). In mathematics education, mathematical communication plays a vital role as it enables students to interpret, evaluate, and articulate mathematical ideas clearly (Siregar, 2016). This skill not only supports problem-solving but also facilitates students in constructing arguments, making generalizations, and developing logical reasoning (Asyriah N, 2018). Moreover, mathematical communication involves the ability to analyze and evaluate the mathematical thinking of others, making it one of the essential competencies that should be systematically developed. According to the Principles and Standards for School Mathematics by the National Council of Teachers of Mathematics (NCTM), indicators of mathematical communication include the ability to express mathematical ideas, analyze and evaluate mathematical reasoning, and use mathematical terms, language, symbols, and structures to model situations or problems (Maulyda, 2020). In addition to communication skills, solving mathematical problems also requires learning autonomy, which involves students' initiative, responsibility, and intrinsic motivation in the learning process. In an era of rapid information development, the ability to learn independently is becoming increasingly important (Fricticarani et al., 2023).

The results of diagnostic tests conducted by several secondary schools in Sukoharjo in the 2023/2024 academic year show that more than 65% of students have difficulty explaining the steps to solve story problems with logical arguments, and 70% are unable to present mathematical solutions in an easily understandable visual form (Internal Data from the Sukoharjo District Education Office, 2024). Although this data was collected in the 2023/2024 academic year, it reflects the persistent challenges in mathematical communication that informed the design of the present study conducted in the 2024/2025 academic year. These baseline conditions were further confirmed through direct observation and pre-test results conducted prior to the intervention. Similarly, in mathematics learning at school, most Grade X students have difficulty communicating mathematical ideas orally and in writing, thereby reducing their interest in learning and their understanding of the material. In addition to poor mathematical communication skills in learning, students often rely on teachers or friends to complete mathematical tasks because they lack initiative and motivation to learn independently. Their research states that independent learning influences mathematical literacy by 70%. This positive influence means that the higher the students' independent learning, the higher their mathematical literacy (Inayah et al., 2024).

According to the results of a survey on student independent learning at five secondary schools in Sukoharjo at the beginning of the second semester of 2023/2024, it was revealed that the average score for student independent learning was in the 'less independent' category, with a percentage of 58% (School Academic Survey Report, 2024). This is indicated by students' high dependence on teacher guidance in every step of problem-solving, low initiative in seeking alternative solutions or additional learning resources beyond textbooks, and difficulty in reflecting on their own learning mistakes or successes. While efforts to obtain more recent diagnostic data are ongoing, the 2023/2024 data remains the most comprehensive available baseline for this region and continues to reflect the current learning challenges observed in the classroom. Similarly, in mathematical literacy activities at school involving 22 learning groups, the average student participation rate was 42.94%, indicating that students enjoy solving calculation problems independently, while 57.06% of students did not participate in numeracy activities, meaning they lack the independence to attempt solving problems on their own. From the results of teachers' self-reflection with their peers in the learning community, it was found that there are still teachers who apply conventional learning models (lectures and memorisation of formulas), even though the student-centred independent curriculum with various learning models has been implemented. Conventional learning is more favoured by teachers due to comfort, habit, and classroom management that is perceived as more structured from the teachers' perspective (Nasution & Ahmad, 2018).

The Learning Cycle 5E model has a significant impact on students' mathematical abilities in sequences when compared to scientific learning (Lubis et al., 2023). The 6E learning model integrated with Augmented Reality can enhance students' geometric thinking skills (Apreza Sies et al., 2025; Ulya et al., 2021). Students who use the 7E cycle learning model have higher mathematical communication than those who use conventional learning methods (Nurochmah et al., 2021). The Learning Cycle 9E model with a STEAM approach is effective in improving mathematical communication (Kholifah, 2024). In addition to these mathematical communication skills, the effectiveness of student-centred learning models in improving mathematical communication and independent learning can be optimised when supported by interactive learning media (Robiana & Handoko, 2020).

DGS has been recognized as an effective tool to support mathematics learning, particularly in geometry. DGS offers an interactive and visual learning environment that enables teachers to present mathematical concepts more concretely (Jelatu et al., 2020). DGS allows users to construct and manipulate geometric objects dynamically, thereby facilitating an exploratory approach to understanding mathematical relationships (Widiastuti et al., 2023). DGS plays a significant role in enhancing students' conceptual understanding by enabling them to visualize, experiment with, and solve geometric problems in a dynamic manner (Rahadyan & Halimatussadiah, 2020). Among the various DGS platforms available, such as Cabri Geometry and Sketchpad, GeoGebra is one of the most widely used due to its accessibility and comprehensive features (Guven, 2012). In line with these developments, the present study employed GeoGebra as an instructional tool to support the learning of geometric concepts.

GeoGebra is one of the most frequently used tools because it is free and has many features (Sumarni, 2014; Sugiarni et al., 2025). GeoGebra is a sophisticated tool that can help develop students' mathematical visual thinking skills through its various features. These features include automatically or manually creating graphs (point and line feature), line intersection feature, and can even be used as a substitute for a whiteboard. Through the use of GeoGebra, students can present their mathematical thinking visually and symbolically, thereby strengthening their mathematical communication skills (Arnanda et al., 2021;

Basri et al., 2025; Isharyadi et al., 2026). GeoGebra-assisted learning videos are effective in enhancing independent learning during instruction (Nuritha & Tsurayya, 2021). There is an influence of the GeoGebra-assisted 5E Learning Cycle model on students' mathematical problem-solving abilities and independent learning (Hasibuan et al., 2023; Mustikaningsih et al., 2025).

Previous studies have shown that the Learning Cycle Model or Instructional Model with 5E, 7E, 9E, and the Learning Cycle Model or Instructional Model with GeoGebra learning media can improve students' mathematical communication or independent learning alone. This motivated the researcher to conduct a study that differs from previous studies by simultaneously improving students' mathematical communication and independent learning through the 6E Instructional Model, which was not previously explored, with the assistance of GeoGebra educational media. The stages in the 6E Instructional Model include: (1) Engage, where the teacher strives to condition students, provide stimuli to motivate them, and arouse their curiosity about the material to be studied, while also enhancing their understanding of basic knowledge; (2) Explore, where the teacher groups students so they can discuss and solve the problems given; (3) Explain: the teacher gives each group the opportunity to present the results of their discussion, which is then responded to by the other groups, (4) Elaborate (reinforcing), where the teacher reinforces the discussion outcomes and encourages students to draw conclusions, enabling them to develop conceptual understanding in solving problems independently, (5) Evaluate, where teachers assess the learning process and outcomes and encourage students to reflect on the learning process by providing mutual feedback, and (6) Extend, where teachers challenge students to connect concepts to different and more complex problems and analyse various relevant learning resources.

Based on the above rationale, this study aims to determine the differences in improving mathematical communication and independent learning between students who experienced the 6E Instructional Model integrated with GeoGebra and students who received conventional instruction. The choice of the 6E Instructional Model as a more constructivist approach is in accordance with student-centered learning in solving mathematical problems. By integrating GeoGebra learning media, students can improve digital literacy according to the needs of their time. This research is expected to identify specific phases in the 6E learning cycle model that have the most influence on improving mathematical communication, such as the Explore stage which gives students the opportunity to answer curiosity and try to solve problems, as well as the Elaborate stage which facilitates students using GeoGebra to present and validate their ideas. The research also hopes to explain how GeoGebra, as a visualization and manipulation tool, facilitates independent learning, such as the emergence of students' willingness to experiment independently with GeoGebra thereby reducing dependence on it. Previous research only focused on one competency, namely mathematical communication or learning autonomy in one intervention. This research has the advantage of measuring the combined impact of the 6E Instructional Model with GeoGebra on both competencies simultaneously. Some case studies only explain the success of a model without comparing it with other learning models, but this research will provide stronger evidence about the relative effectiveness of the 6E Instructional Model with GeoGebra. The integration is designed to align GeoGebra with the structure of the 6E Instructional Model mathematical communication is expected to be enhanced through the explore, explain, and elaborate stages, in which students collaboratively investigate problems, express mathematical ideas, analyze and evaluate reasoning, and use appropriate mathematical symbols and representations to model real or abstract situations using GeoGebra. These collaborative activities culminate in group presentations of solutions, reinforcing communication skills. On the other hand, independent learning is targeted in the evaluate and extend stages, where students independently reflect on their learning, draw conclusions, and engage with more complex problems or project-based tasks. GeoGebra functions as a cognitive and visual aid throughout these stages, supporting learners in developing deeper understanding and autonomy. Thus, this study positions the 6E Instructional Model with GeoGebra integration as a strategic framework to foster both communicative competence and self-directed learning in mathematics.

Methods

Research Design

The design used in this research is a quantitative approach with a quasi-experimental method. Quantitative as a scientific method because it fulfils scientific principles, namely concrete, objective, measurable, rational, and systematic (Balaka, 2022). The quasi-experimental design used is Non-equivalent Control Group Design which compares the treatment group (experimental group) with the control group, where the two groups are not equivalent. Both groups were given a pre-test and an initial questionnaire scale, then subjected to treatment. The experimental group received treatment in learning using 6E Instructional Model and DGS, while the control group continued to use the conventional learning model, namely expository. In the control group, learning was conducted using the expository method, where the teacher explained material through lectures, provided examples of problems, and assigned practice exercises without the use of dynamic geometry software or group-based exploration activities. The use of the 6E Instructional Model and DGS (GeoGebra) is theoretically a student-centered approach and is very much in line with constructivism theory. The Engage and Explore stages encourage students to build their own understanding through interaction with concepts. GeoGebra functions as a construction tool that allows students to manipulate mathematical objects, make conjectures, and test hypotheses. Meanwhile, conventional learning is teacher-centered (teacher-centered), where knowledge is transferred from teacher to student. This is in line with behaviorism theory, where learning is a response to stimuli, and relies on text and verbal explanations which can burden students' working memory. Previous research has proven that the 6E Instructional Model is overall more effective in improving learning outcomes, understanding concepts, and attitudes towards science and mathematics compared to conventional learning approaches. Combining this model with technology like GeoGebra amplifies its effectiveness. This empirical research shows that a learning model that encourages discussion and presentation at the Explain and Elaborate stages of the 6E Instructional Model significantly increases students' ability to articulate mathematical ideas. Integration with GeoGebra allows students to demonstrate their ideas visually and interactively, so that communication becomes clearer and more concrete, not just verbal or written, and increases students' learning motivation and independence because they can experiment, carry out independent exploration, and get direct feedback from manipulating mathematical objects. In the Explore and Elaborate stages the 6E Instructional Model specifically provides space for students to take control of their own learning process, reducing dependence on teacher guidance. This is a direct indicator of greater learning autonomy.

According to Sugilar & Juandi (2013), the non-equivalent Control Group Design scheme can be described like this following Table 1.

Table 1. *Scheme of non-equivalent Control Group Design*
Group Pre-test Treatment Post-test

Group	Pre-test	Treatment	Post-test
Experiment	T1	X	T2
Control	T1	0	T2

Table 1 shows that a population is a collection of subjects or observation values that have certain characteristics.

Participants

The population in this study were grade X students at at SMK Negeri 5 Sukoharjo, Central Java, in the 2024/2025 academic year which was divided into 11 study groups with a total of 310 students. Sampling in this study used a random sampling technique, which is a sampling method in which each member of the population has the same opportunity to be selected as part of the sample (Etikan, 2017). The main purpose of this technique is to obtain a representative sample, which can represent the entire population fairly without bias. The random sampling technique used is cluster random sampling. Group random sampling divides the population into groups, then randomly selects several groups to become experimental groups and control groups (Firmansyah & Dede, 2022). The experimental group consisted 35 students, while the control group consisted with 34 students, both groups selected randomly.

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Instrument and Data Collection

The research steps carried out were the preparation of a learning implementation plan using the 6E Instructional Model and DGS, limited testing of mathematical communication skills and independent learning, carrying out pretests and the initial scale of the questionnaire, implementing learning, carrying out posttests and the final scale of the questionnaire, and testing hypotheses. The data collection techniques used in the research were test and questionnaire. While the test is a series of questions, worksheets, or the like that are used to measure the knowledge, skills, talents, and abilities of the research subject (Ghufron & Sutama, 2011). The test in this study was administered to determine the improvement in students' mathematical communication skills before and after participating in learning using 6E Instructional Model and DGS. The items in the test instrument were arranged according to the grid as shown in Table 2.

Table 2. *Test Instrument Grids*

Number	Basic Competence	Subject Matter	Problem Indicator	Problem Number	Mathematical Communication Ability Indicator
1.	Explain and find functions (especially linear functions, quadratic functions, and rational functions) formally including notation, origin, and symbolic expressions, as well as sketch their graphs.	Linear Functions and Quadratic Functions	Identify linear functions and quadratic functions	1, 2 3	K1, K2 K2
			Draw graphs of linear functions and quadratic functions	1, 2	K1, K2
2.	Analyse the characteristics of each graph (intersection points with axes, cusp, asymptotes) and changes in the graph of a function due to transformations of the graph.		Analyse the effect of coefficients on the graphs of linear functions and quadratic functions	1, 2	K1, K2
			Solve contextual problems related to linear functions and quadratic functions	4 5	K3, K2 K3, K2

Table 2 shows that, this test was given at the beginning before the learning began (pre-test) and at the end (post-test) after the learning process of 4 meetings. The test instrument used is in the form of a description question (essay) with the material of linear functions and quadratic functions as many as 5 items that can show the ability of students to meet the indicators of mathematical communication skills to be studied.

Meanwhile, the questionnaire instrument uses a Likert scale which has gradations from very positive to very negative, namely (1) Always, (2) Often, (3) Sometimes, (4) Rarely, and (5) Never. This instrument includes 7 indicators of independent learning with 26 statements. The way to presented table like this following Table 3.

Table 3. *Questionnaire Grid*

Number	Independent learning Indicator	Question Number	Number of Questions
1	Ability to set learning goals	1, 2, 3	3
2	Ability to manage time and study management	4, 5, 6, 7	4
3	Ability to choose and apply learning strategies	8, 9, 10, 11	4
4	Ability to reflect on the process and evaluate learning outcomes	12, 13, 14, 15	4
5	Having motivation and responsibility for learning	15, 17, 18, 19	4
6	Having initiative and creativity in learning	20, 21, 22, 23	4
7	Ability to communicate and collaborate	24, 25, 26	3

Table 3 shows that, the questionnaire was given to obtain information on the increase in student independent learning before and after using 6E instructional Model and DGS. This questionnaire is a closed questionnaire given in the form of a google form, where students can express their opinions and their hearts according to the conditions. The questionnaire will be given at the beginning before the learning begins (initial scale) and at the end (final scale) after the learning process of 4 meetings.

This validity testing consists of content, criterion, and construct validity tests, with three validators examining the suitability of test and questionnaire items against their grids. For construct validity, a pilot test was conducted involving 24 students from a class not included in the main study, prior to the implementation of the research. This pilot was carried out in june of the 2024/2025 academic year to ensure the instruments functioned as intended before being administered to the actual participants. Meanwhile, normality testing uses Pearson Correlation by comparing the calculated r value in the total score with the table r using a significance level of $\alpha = 0.05$. If the calculated r value is greater than the table r value, the instrument item is considered valid. Reliability testing of valid instrument items uses Cronbach's Alpha as a coefficient to determine how consistently the questions in the instrument measure the same variable. If the Cronbach's Alpha value is greater than 0.6, the instrument is considered reliable or consistent (Izah et al., 2024). The value of 0.6 is used as the minimum threshold in reliability testing, as it is considered sufficient to measure the internal consistency of an instrument.

The difficulty level of a test item is the proportion of test participants who answer the item correctly (Ghufron & Sutama, 2015). The difficulty level of a test item ranges from 0.0 to 1.0, indicating that the difficulty level of a test item is greatly influenced by the ability level of the test participants. The discrimination of a test item is an index that indicates the ability of a test item to distinguish between high-performing groups (top group) and low-performing groups (bottom group) among test participants.

Discrimination is considered adequate for a test item if it is equal to or greater than 0.25. The higher the discrimination of a test item, the better the item is.

The normality test used in this study was the Kormogorov-Smirnov test at a significance level of $\alpha = 0.05$. The data tested is said to be normally distributed if the Sig. value in the column corresponding to the Kormogorov-Smirnov test > α. The Kolmogorov-Smirnov test was selected over the Shapiro-Wilk test because the total sample size exceeded 50 participants ($n = 69$), making the Kolmogorov-Smirnov test more appropriate for larger samples, as it provides stable results when the sample size is sufficient (Razali & Wah, 2011). In this study, the Levene's Test for homogeneity was used with a significance level of $\alpha = 0.05$. The two data sets tested are said to be homoscedastic if the Sig. value $\geq \alpha$.

Data Analysis

The data analysis used in this research is the independent sample t-test, namely a parametric statistical test used to compare the averages of two groups that are not related to each other (Paisal et al., 2021). The independent sample t-test is used if the research data is normally distributed and both variances are homogeneous. The decision-making criteria are the difference between the average (mean) post test results of the experimental group and the average post-test results of the control group. A significant difference can be proven by a Sig (2-tailed) < α, which means that H_0 is rejected and H_1 is accepted. However, if a Sig (2-tailed) $\geq \alpha$ value is obtained, it means that H_0 is accepted and H_1 is rejected.

As a reinforcement of the research results, to find out to what extent students' mathematical communication skills and independent learning have increased after obtaining 6E Instructional Model and DGS, N-Gain (Normalized Gain) can be used. Decision making criteria are by comparing the average value between the pre-test and post-test obtained by the experimental group and the control group.

Results and Discussion

Results

The results of the analysis of answers to the pre-test from the experimental group can be seen in this following Table 4.

Table 4. *Experimental Group Pre-test Results*

	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5
	K1, K2	K1, K2	K2	K2, K3	K2, K3
N	35	35	35	35	35
Mean	3.09	2.74	2.74	2.46	2.34
Std. Dev.	1.07	1.04	0.95	0.98	0.87
	N (K1)	70		N (K3)	70

Mean	2.91	Mean	2.40
Std. Dev.	1.06	Std. Dev.	0.92
N (K2)	175		
Mean	2.67		
Std. Dev.	1.01		

Table 4 shows that the average test score for K1 (expressing mathematical ideas orally, in writing, and through visual representation) was 2.91. This score indicates that students' mastery of this first indicator reached 58.29%, meaning that students experienced difficulty expressing mathematical ideas orally, in writing, and through visual representation. Meanwhile, the average test score for K2 (analyzing and evaluating mathematical ideas both orally and in writing) was 2.67. This score indicates that students' mastery of this second indicator only reached 53.60%, meaning that most students experienced difficulty analyzing and evaluating mathematical ideas both orally and in writing. In addition, the average test score for K3 (using mathematical terms, language or symbols, and their structures to model mathematical situations or problems) was 2.40. This score indicates that students' mastery of this third indicator has only reached 48.29%, meaning that most students have difficulty using mathematical terms, language or symbols, and their structures to model mathematical situations or problems. The variation in mean scores across the five problems (ranging from 2.34 to 3.09) reflects the intentional differences in difficulty level embedded in the instrument design. Problems 1 and 2, which addressed basic identification and graph sketching (K1, K2), yielded higher scores, while Problems 4 and 5, which required contextual problem-solving involving modeling with symbols (K2, K3), were more cognitively demanding. This is consistent with the difficulty index analysis conducted during instrument validation, where Problems 4 and 5 were classified at a moderate-to-difficult level compared to Problems 1 and 2.

After analyzing the students' difficulties from the pretest results, learning was carried out using the 6E instructional model and DGS for the experimental group and the conventional learning model for the control group, each for four meetings. The distribution of material at each meeting can be seen as following in Table 5.

Table 5. *Material Distribution*

Activities	Material
1	Describe and identify linear functions, and analyze changes in linear function graphs
2	Describe and identify quadratic functions, and analyze changes in the graph of quadratic functions
3	Solving contextual problems of linear functions
4	Solve contextual problems of quadratic functions

Table 5 shows that, the learning process for the material on linear functions and quadratic functions was carried out in 4 meetings, with 6E instructional Model and DGS (GeoGebra) given to the experimental group, while conventional model learning was given to the control group.

In each learning activity of 6E Instructional Model and Geogebra the teacher conveys the aims and objectives of learning with material on linear functions and quadratic functions using the free GeoGebra application on each student's handphone, although occasionally students will be invited to study in the computer laboratory. Specifically, three out of four learning sessions were conducted using GeoGebra on students' mobile phones, while one session was held in the computer laboratory to support activities requiring more precise graph manipulation and larger screen displays. The teacher explains the indicators that students must understand according to the distribution of material for each meeting. The teacher invites students to apperceive the material at the previous meeting.

Starting the core activities at the engage stage, the teacher conditions the learning activities by providing stimulus questions to motivate students' interest and raise students' curiosity about the material to be studied through pictures of contextual examples of linear functions that can be depicted using the GeoGebra application. Then, through questions and answers, the teacher tries to increase students' understanding of basic knowledge regarding the benefits of the material to be studied. Students give examples of the application of linear functions in everyday life orally.

Continuing the learning process, after the engage stage where students really pay attention and are fully involved in learning, the teacher groups students in the explore stage. Students in their groups try to describe various possible forms of linear functions or quadratic functions, as in the following Figure 1.

Figure 1. *Explore Stage*

Figure 1 shows that students are able to draw and identify linear function graphs, as well as analyze changes in their graphs using GeoGebra effectively. Students and their groups will strive to learn independently by changing various input coefficient values followed by changes in the graph. After students explore various forms of graphs of linear functions, the teacher gives problems on students' worksheets which are solved in discussion.

At the explain stage, the teacher facilitates students to present the results of the discussion, express opinions in groups in providing solutions to the problems presented. This stage also provides opportunities for other groups to provide responses, communicate with each other by defending each other's opinions or receiving input from other groups. Activities at this stage are shown in the following Figure 2.

Figure 2. *Explain stage*

Figure 2 shows that students are able to communicate their mathematical ideas in analyzing linear function graphs using GeoGebra correctly.

This is followed by the elaborate stage, where the teacher provides reinforcement of problem-solving solutions that have been discussed, presented and communicated between groups, so that a conclusion is reached. The teacher tries to motivate students to develop the concept of understanding in solving problems independently.

In evaluating knowledge and learning experience at the evaluation stage, the teacher assesses the learning process with observation sheets and assesses student learning outcomes by providing problems that can be solved independently. In this problem, students are asked to describe and identify linear functions, as well as analyze changes in their graphs. Based on the results of identification and analysis of students' answers depicting linear function graphs using GeoGebra, it can be seen that most students were able to answer correctly.

Students use the GeoGebra application to draw graphs, analyze changes in the graph, and draw conclusions. Furthermore, at the end of the meeting, in the extend stage the teacher tries to expand students' knowledge of linear function material, by providing challenges for students to be able to connect concepts to different, more complex problems.

The results of each stage of 6E Instructional Model and GeoGebra integration which help improve mathematical communication skills and learning autonomy are shown in Figure 3.

Engage Stage	Explore Stage	Explain Stage	Elaborate Stage	Evaluate Stage	Extend Stage
Students pay full attention to the teacher presenting examples of graphing functions using GeoGebra, which fosters curiosity to learn more about the material.	Students are able to draw and identify function graphs and independently analyze changes in graphs using GeoGebra. Students are also able to mathematically communicate various changes in coefficient values, which are then followed by changes in the graph.	Students are able to correctly communicate their mathematical ideas in analyzing linear function graphs using GeoGebra and present them independently.	Students independently use GeoGebra to strengthen their understanding of various problem contexts and function graphs.	Students are motivated to be more independent and active in learning using GeoGebra as an interactive learning medium that encourages creativity.	Students expand their knowledge as a challenge in independently communicating mathematically about a contextual problem using GeoGebra.

Figure 3. The results of 6E Instructional Model and GeoGebra

After the learning was carried out, a post-test and questionnaire were then given as the final scale to the experimental group and control group. To determine the differences in mathematical communication abilities of students who received 6E Instructional Model and DGS, N-Gain (Normalized Gain) was used, by comparing the average (mean) scores between the pretest and posttest obtained by the experimental group and the control group, as shown in the following Table 6.

Table 6. *Descriptive Statistics Mathematical Communication Ability*

	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain Experiment	35	.33	.90	.6235	.15215
N-Gain Control	34	.17	.56	.4387	.09640

Table 6 shows that, the average N-Gain of experimental groups 0.62 is significantly higher than control groups 0.44. This proves that 6E Instructional Model and DGS is effective in improving mathematical communication skills.

Meanwhile, to determine the differences in independent learning of students who received 6E Instructional Model and DGS, N-Gain was used, by comparing the average (mean) scores between the initial scale and the final scale obtained by the experimental group and the control group, as shown in the following Table 7.

Table 7. *Descriptive Statistics of Student Independent learning*

	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain Experiment	35	.16	.86	.5146	.13305
N-Gain Control	34	-.11	.71	.2552	.15320

Table 7 shows that, the average N-Gain of the first and second experimental groups 0.51 is higher than control groups 0.26. These findings confirm the significant contribution of 6E Instructional Model and DGS to increasing student independent learning. Overall, the statistical data analysis above shows differences in mathematical communication skills and independent learning between students who received 6E Instructional Model and DGS and students who received conventional learning. The implications of this research highlight the great potential of technology integration in learning design.

After the data on the variable's mathematical communication ability and independent learning were normally distributed and homogeneous, then a hypothesis test was carried out using the independent sample t-test. From the pre-test and post-test data on mathematical communication skills, the independent sample t-test results were obtained which can be seen in the following Table 8.

Table 8. *Group Statistics Mathematical Communication Ability*

	Class	N	Mean	Std. Deviation	Std. Error Mean
Results	Posttest_Experiment	35	82.40	8.070	1.364
	Posttest_Control	34	74.24	7.890	1.353

Table 8 shows that, there is a difference in the average (mean) post-test results for experimental group is 82.40 (μ_1), which is greater than the average post-test results for control group 74.24 (μ_2). So that it fulfils the hypothesis H_1: $\mu_1 \neq \mu_2$, which means that H_1 is accepted, namely that there is a significant difference between mathematical communication skills between students who receive 6E Instructional Model and Dynamic Geometry Software and students who receive conventional learning. This significant difference is also proven in Table 9.

Table 9. *Independent Sample T-Test of Mathematical Communication Ability*

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Results	Equal variances assumed	.010	.921	-4.248	67	.000	-8.165	1.922	-12.001	-4.328
	Equal variances not assumed			-4.249	66.997	.000	-8.165	1.921	-12.000	-4.330

The near-identical t-statistics and p-values under both equal variances assumed and not assumed conditions are explained by the homogeneity of variance confirmed by Levene's Test (F = 0.010, p = 0.921), which shows that the variances of the two groups are not significantly different. When variances are highly similar, the Welch correction (used in the unequal variances row) produces minimal adjustment to the degrees of freedom and test statistic, resulting in nearly equivalent values across both rows. This pattern is consistent and expected given the homogeneous nature of the data.

From the pre-test and post-test data on student independent learning, the independent sample t-test results were obtained which can be seen in the following Table 10.

Table 10. *Group Statistics Student Independent learning*

	Class	N	Mean	Std. Deviation	Std. Error Mean
Results	Final Scale_Experiment	35	105.11	8.848	1.496
	Final Scale_Control	34	90.38	8.958	1.536

Table 10 shows that, there is a difference in the average (mean) result of the final scale of the questionnaire for experimental group 105.11 (μ_1) which was greater than the average posttest result for control group 90.38 (μ_2). So that it fulfills the hypothesis H_1: $\mu_1 \neq \mu_2$, which means that H_1 is accepted, namely that there is a significant difference between independent learning between students who receive 6E Instructional Model with DGS and students who receive conventional learning. This significant difference is also proven in Table 11.

Table 11. *Independent Sample T-Test of Student Independent learning*

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Results	Equal variances assumed	.354	.554	-6.873	67	.000	-14.732	2.144	-19.011	-10.453
	Equal variances not assumed			-6.871	66.883	.000	-14.732	2.144	-19.011	-10.452

Discussion

From the results of the study, it has answered the problem formulation which proves that the hypothesis is fulfilled, namely there is a difference in the increase in mathematical communication skills between students who received 6E Instructional Model with DGS and students who received conventional learning, and there is a difference in the increase in mathematical communication skills between students who received 6E Instructional Model with DGS and students who received conventional learning. This difference is shown during the learning process, where students are very enthusiastic about discussing solving linear function and quadratic function problems using the Geogebra application. The difference in the increase in students' communication skills meets three indicators, namely (1) expressing mathematical ideas through oral, written, and visual depictions, (2) analyzing and evaluating mathematical ideas both orally and in writing, and (3) using mathematical terms, language or symbols, and their structures to model mathematical situations or problems).

GeoGebra integration into the 6E Learning Cycle model can be done at every stage (Pratiwi, 2016). In the Engage stage, GeoGebra is used to provide stimulus questions to motivate students' interest and curiosity (Khasanah & Nugraheni, 2022). In the Explore stage, GeoGebra is used in discussions to draw graphs of linear and quadratic functions with various coefficient changes, identify parts of the graph, and explore graphs from contextual problems (Fitria, 2025). In the Explain stage, GeoGebra is used to present graphs of linear and quadratic functions, visualize graph changes, and respond to and explain solutions to contextual problems (Maulidia et al., 2025). In the Elaborate stage, GeoGebra is used to guide students in verifying calculation results and drawing function graphs according to given criteria until they can draw conclusions (Sholikha & Siswono, 2023). In the Evaluate stage, GeoGebra is used to evaluate students' understanding through independently assigned problems (Maryani, 2021). In the Extend stage, GeoGebra is used to challenge students to connect concepts with material, thus encouraging students to carry out independent projects on contextual problems about linear and quadratic functions (Maulidia et al., 2025).

According to (Şahin & Kiliç, 2023), all stages of the 6E Learning Cycle model can facilitate students in setting learning goals, time management and learning management skills (Engage stage), choosing and implementing learning strategies (Explore stage), communication and collaboration skills (Explain stage), having motivation and responsibility for learning (Elaborate stage), the ability to reflect on the process and evaluate learning outcomes (Evaluate stage), and having initiative and creativity in learning (Extend stage). Increased learning autonomy is seen from students' active participation in group discussions, courage to express opinions, and initiative in finding solutions to problems (Setiadi, 2021).

Statistical data analysis of mathematical communication skills shows that there is a difference in the average posttest results of the experimental group which is greater than the average posttest results of the control group. This fulfills the hypothesis that the average posttest results of the experimental group are not the same as the average posttest results of the control group. The results of this research are in accordance with the research results of Nurochmah et al. (2021) which explains that the increase in mathematical communication skills of students who use the Learning Cycle 7E learning model is higher than students who use conventional learning. In line with this, Lubis et al. (2023) stated that there is a significant influence between the use of the 5E Learning Cycle model on students' mathematical communication skills. Meanwhile, the increase in learning outcomes in students' mathematical communication skills taught with Geogebra Software in trigonometry material was higher compared to learning outcomes without using Geogebra Software (Rahmatika et al., 2022). There is a very large influence of the 5E Learning Cycle model on students' mathematical communication skills in sequence material when compared to scientific learning (Istikomah et al., 2021).

From the results of the independent sample t-test, a significance value of $0.00 < 0.05$ was obtained, which also shows that hypothesis is accepted, namely that there is a significant difference in mathematical communication skills between students who received 6E Instructional Model with DGS and students who received conventional learning. The results of this research are supported by Widiastuti et al. (2023) who explained in their research that the 5E learning cycle was able to improve students' communication skills in learning mathematics. Likewise, Nurfazlin Nova et al. (2024) in his research stated that the RPP and LKPD with the 5E Learning Cycle model that had been produced were effective in improving mathematical communication skills. In line with this, Rahmy et al. (2020) stated that the 7E learning cycle can be used to improve junior high school students' mathematical communication skills based on their thinking style. Meanwhile, the application of GeoGebra learning media can improve students' mathematical communication skills in the subject Systems of Linear Equations in Two Variables (Arnanda et al., 2021). Through the use of GeoGebra, students can present their mathematical thinking visually and symbolically, which strengthens their mathematical communication skills.

Meanwhile, analysis of statistical data on independent learning shows that there is a difference in the average (mean) results of the final scale of the experimental group's questionnaire which is greater than the average of the results of the final scale of the control group's questionnaire. This fulfills the hypothesis that the average posttest results of the experimental group are not the same as the average posttest results of the control group. The results of this research are in line with Runisah (2018) who stated that the achievement and increase in independent learning in the Learning Cycle group was better than the conventional group. The results of the independent sample t-test obtained a significance value of $0.00 < 0.05$, which indicates that hypothesis is accepted, namely that there is a significant difference in independent learning between students who received 6E Instructional Model with DGS and students who received conventional learning. This is in line with the research results of Nuritha & Tsurayya (2021) which explains that learning videos and GeoGebra are effectively used as media or tools to assist students in learning mathematics which can increase student independent learning.

The results of this study align with those of (Fasa et al., 2020), who concluded that students who received the GeoGebra-assisted PBL model demonstrated greater learning autonomy than those who received the expository model. This is also consistent with the research of Maharani et al. (2024), who concluded that students who implemented the GeoGebra-assisted Discovery Learning model demonstrated greater improvement in mathematical critical thinking skills and learning autonomy than those who implemented the conventional learning model. Learning with the 5E Learning Cycle, supported by software, demonstrated positive learning autonomy in students who enthusiastically participated in the learning process (Pitriani, 2018). Students were trained to understand the material independently. This learning process fostered curiosity, fostered active participation in discussions, and fostered conceptual expression within groups.

This difference was demonstrated during the learning process, where students consciously and independently learned linear and quadratic functions using the GeoGebra application. Students even provided peer tutoring assistance to clarify solutions to problems presented without waiting for teacher direction. The difference in students' increased learning autonomy met three indicators: the ability to set learning goals, the ability to manage time and learning, the ability to select and implement learning strategies, the ability to reflect on the process and evaluate learning outcomes, the ability to motivate and take responsibility for learning, the ability to take initiative and be creative in learning, and the ability to communicate and collaborate.

The results of this study align with those of Hidayat et al. (2023), who concluded that student learning autonomy has a strong and significant relationship with students' mathematical communication. Furthermore, the results of this study align with those of Winda et al. (2023), who concluded that student learning autonomy has a positive effect on mathematical communication skills by 57.7%. The contribution of learning autonomy and self-efficacy to mathematical communication is 51.55% (Kurnia & Mulyani, 2020). A significant effect of learning autonomy on mathematical communication skills in eighth-grade students at SMP Negeri 1 Comal (Ulya et al., 2023). Consistent with this study, Afiani (2017) concluded that there is a significant effect of Mathematical Communication Skills and Learning autonomy jointly on Mathematics Learning Achievement in seventh-grade students at MTs Daarussalaam, South Jakarta. There is a significant association between students' learning autonomy and mathematical communication skills (Hutapea et al., 2013).

Furthermore, the results of this study align with the research of Hakiki & Sundayana (2022) which concluded that students with high independence have better mathematical communication skills than students with medium and low independence, while students with medium independence have better mathematical communication skills than students with low independence. There is a positive relationship between mathematical communication skills and learning autonomy (Aprila & Fajar, 2022). There is a significant influence of mathematical communication skills and learning autonomy together on the mathematical problem-solving abilities of private MTs students in South Tangerang City. This is evidenced by the obtained sig value = 0.000 < 0.05 and Fhitung = 20.857 (Sarini, 2019).

The results of the experimental group supported internal factors, such as students' familiarity with technology, as is the nature of the times. However, students' varying levels of digital literacy influenced how quickly and effectively they adopted GeoGebra. Students who were already familiar with technology may have shown faster improvement. Teacher adaptation to the 6E intructional model also contributed to the success of this study, where teachers who were accustomed to conventional methods may have required additional training to master the role of facilitator in the 6E Instructional Model. This success was also supported by the availability of infrastructure, such as reliable internet connections and the availability of computer devices for students so that they did not rely on students' mobile phones in various conditions.

Meanwhile, the control group using conventional learning showed an increase in mathematical communication skills and student learning autonomy, although not as high as the experimental group. This increase could also be due to internal factors, such as students already possessing a strong foundational knowledge or those who take the initiative to learn additionally outside of class. Traditional teacher-centered learning, which typically involves lectures or practice exercises, also has its own advantages. Because conventional teacher-centered learning provides a clear and directed structure and helps students grasp basic concepts, direct delivery of material by the teacher can be faster and more efficient, allowing for broader topic coverage in a limited time. Despite its benefits, conventional learning also faces several challenges that serve as the basis for exploring new learning models. Students tend to be passive and less engaged in the learning process, which can hinder in-depth understanding. Even without visual aids, students often struggle to visualize abstract mathematical concepts. This can hinder the development of their mathematical intuition.

Conclusion

Based on the research findings, it was concluded that the integration of Dynamic Geometry Software (GeoGebra) into the 6E Instructional Model significantly enhances students' mathematical communication skills and learning autonomy compared to conventional instruction. GeoGebra is effectively utilized in each phase of the 6E model: from engaging student interest and exploring function graphs, to supporting the presentation and explanation of mathematical ideas, and facilitating reflection and extension through contextual problem-solving. Students involved in the 6E Instructional Model and GeoGebra based learning showed improvements in expressing mathematical ideas verbally, in writing, and visually; analyzing and evaluating mathematical concepts; and modeling mathematical situations using appropriate symbols and structures. Moreover, the use of GeoGebra also strengthened students' learning autonomy by fostering initiative, learning strategies, and the ability to manage and reflect on their own learning processes.

The implications of these findings indicate that technology integration, particularly GeoGebra, within the 6E Instructional Model holds great potential for improving mathematics learning quality. GeoGebra can serve as both a didactic and pedagogical resource for teaching linear and quadratic functions and can be utilized by teachers and curriculum developers to create interactive and meaningful learning experiences. This study reinforces the relevance of constructivist theory within the context of mathematics education in Indonesia and offers practical contributions to the development of instructional models that promote active, communicative, and independent learning. In addition, the results of this research open new opportunities for future research on developing adaptive learning modules that are integrated with GeoGebra and adapted to students' learning styles or initial levels of understanding, using the 6E Intructional Model and GeoGebra to encourage students' critical thinking skills, applying this model at different levels of education (for example, elementary school, college) or on more diverse mathematics topics (for example, statistics, calculus), exploring in more depth the role of teachers and the impact of collaboration between students.

Despite these contributions, this study has several limitations that should be acknowledged. First, the study was conducted in a single school (SMK Negeri 5 Sukoharjo), which limits the generalizability of the findings to other educational contexts. Second, the intervention was carried out over only four meetings, which may not be sufficient to capture the long-term effects of the 6E Instructional Model with GeoGebra on students' mathematical communication skills and learning autonomy. Third, students' varying levels of prior digital literacy with GeoGebra were not controlled as a covariate, which may have influenced the outcomes. Future research is encouraged to address these limitations by expanding the sample across multiple schools, extending the duration of the intervention, and incorporating digital literacy as a variable.

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