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Guided Inquiry E-Modules for Quadratic Functions: Boosting Computational Thinking, Problem Solving, and Self-Efficacy

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Abstrak

Penelitian ini bertujuan mengembangkan e-perangkat pembelajaran berbasis inkuiri terbimbing untuk meningkatkan kemampuan berpikir komputasional, pemecahan masalah, dan self-efficacy siswa SMA. Metode Research and Development (RnD) dengan model ADDIE (Analisis, Desain, Pengembangan, Implementasi, Evaluasi) digunakan dalam proses pengembangannya. Subjek uji coba melibatkan siswa kelas X-9 (n=34) untuk uji lapangan dan kelas X-10 (n=36) untuk uji terbatas, dengan desain one-group pretest-posttest. Data dikumpulkan melalui angket, tes, observasi, dan wawancara, kemudian dianalisis menggunakan skala Likert, uji gain, dan uji hipotesis multivariat (Hotteling's T^2). Hasil penelitian menunjukkan bahwa e-perangkat pembelajaran fungsi kuadrat yang dikembangkan memenuhi kriteria kevalidan (minimal "baik"), kepraktisan (respon guru-siswa "baik" & keterlaksanaan 80-100%), dan keefektifan. Keefektifan ditunjukkan oleh pengaruh signifikan terhadap kemampuan siswa, peningkatan N-gain kategori sedang, dan persentase ketuntasan belajar yang baik. Produk ini terbukti mampu memfasilitasi peningkatan tiga kemampuan target secara integratif.
Kata Kunci: e-perangkat pembelajaran; fungsi kuadrat; inkuiri terbimbing

Abstract

This study aims to develop guided inquiry-based e-learning tools to improve high school students' computational thinking, problem-solving, and self-efficacy skills. The Research and Development (R&D) method, utilising the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), was employed in the development process. The test subjects involved students from class X-9 (n=34) for field testing and class X-10 (n=36) for limited testing, with a one-group pretest-posttest design. Data were collected through questionnaires, tests, observations, and interviews, then analysed using the Likert scale, gain test, and multivariate hypothesis test (Hotteling's T^2). The results showed that the developed quadratic function e-learning device met the criteria of validity (at least "good"), practicality (teacher-student response "good" & feasibility 80-100%), and effectiveness. Effectiveness was demonstrated by a significant effect on student ability, an increase in the N-gain to the moderate category, and a good percentage of learning mastery. This product has been proven to facilitate the integrated improvement of the three target abilities.
Keywords: e-tools learning; quadratic function; guided inquiry learning

I. INTRODUCTION

The 21st century emphasizes the role of knowledge in various innovations such as artificial intelligence, biotechnology, and renewable energy to address global issues. Advances in technology and communication, particularly the internet, have facilitated access to a wealth of worldwide information and learning resources, making it essential for humans to possess 21st-century skills to thrive. Education plays a vital role in preparing this generation by equipping them with relevant skills and expertise. According to Law No. 20 of 2003 and various studies, education must be adaptable to the times and include skills such as critical thinking, collaboration, problem-solving, effective communication, and technological literacy. The Framework for 21st Century Learning identifies problem-solving as a key skill that supports students in facing the challenges of the 21st century (Trilling & Fadel, 2009).

Problem-solving is an essential skill because everyone faces problems in life that may not always be school-related, but rather situations that require resolution when goals must be achieved without a clear solution. PISA (Program for International Student Assessment) is an international evaluation initiated by the OECD (Organisation for Economic Co-operation and Development) to assess the extent to which students can apply their knowledge in mathematics, reading, and science to solve problems in everyday life. The PISA study recorded the average score for Indonesian students' mathematics skills as 379 (OECD, 2019), far below the international average of 487 from 79 participating countries. This achievement is consistent with the trend in previous years, where Indonesia has routinely been ranked in the bottom 10 (Hewi & Shaleh, 2020). In line with this, researchers surveyed students in class X-E7 at a public high school in Surakarta using a Google Form regarding the difficulties they face while learning mathematics. The survey revealed that 44.5% of students struggled to solve real-world problems, despite understanding the material provided by the teacher.

Students' low problem-solving skills identify difficulties in solving problems, including challenges in understanding problems (Fitri & Abadi, 2021; Sriwahyuni & Maryati, 2022), challenges in developing problem-solving strategies (Fitri & Abadi, 2021; Sholihah & Afriansyah, 2018; Sriwahyuni & Maryati, 2022), difficulties in implementing problem solving (Fitri & Abadi, 2021; Sholihah & Afriansyah, 2018; Sriwahyuni & Maryati, 2022), and issues in concluding and not double-checking (Fitri & Abadi, 2021; Fitria et al., 2016; Sriwahyuni & Maryati, 2022). These difficulties reflect students' lack of proficiency in several basic skills, such as determining the necessary information, organizing learning steps, and generalizing. This is related to a skill called computational thinking.

PISA 2022 recognizes the need for students to understand computational thinking concepts through mathematics learning, taking into account the rapid development of technology (OECD, 2020). Computational thinking skills are currently considered essential skills that every student needs to have, on par with reading, writing, and arithmetic skills (Hu, 2011; Román-González et al., 2017; Zhong et al.,

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2016; Nurlaelah, Usdiyana, & Fadilah, 2024). In practice, students' computational thinking skills are predominantly in the low category. Based on a survey of 34 students from a public high school in Surakarta, 74% of students were unable to achieve a final computational thinking score above the minimum passing grade of 75. One of the difficulties students face in understanding problems using computational thinking skills is that they struggle to reach the generalization stage, which involves formulating general solutions applicable to various situations (Julianti et al., 2022).

Students' low problem-solving and computational thinking skills are closely tied to their self-perceptions. Students' self-confidence in their ability to manage their learning and master the learning process (self-efficacy) determines their academic achievement, including problem-solving and computational thinking skills (Bandura, 1993; Pajares & Miller, 1994; Weese et al., 2016). Self-efficacy is a person's belief in their ability to complete a task (Schunk, 1991; Afriansyah et al., 2024). Several analytical studies have found that students' self-efficacy in mathematics learning is in the moderate category. Research conducted at SMKS Sukapura, Nugraha & Prabawati (2019) found that the average self-efficacy of students was 62, with 35% of students having high self-efficacy, 30% in the moderate category, and 35% in the low category. This also occurred at SMA Negeri 3 Pati, where students felt that mathematics was complex unless the teacher provided assistance.

Based on issues related to problem-solving, computational thinking, and self-efficacy, as well as the important role these three skills play in the 21st century, a learning model is needed that addresses these issues. Guided inquiry learning is one alternative solution. Inquiry-based learning is a learning process that encourages students to activate their full thinking potential in a systematic, critical, logical, and analytical manner when exploring a problem, enabling them to discover concepts independently with confidence (Trianto in Lovisia, 2018).

The implementation of guided inquiry learning requires learning tools that are valid, practical, and effective in order to facilitate students' computational thinking, problem-solving, and self-efficacy skills. The development of electronic learning tools, such as teaching modules and student worksheets, is highly suitable for the current conditions that necessitate online learning, given the need for the ability to access and analyze information in the 21st century (Herlina et al., 2022). Furthermore, in this digital era, integrating technology into learning can provide numerous benefits, such as helping students model problems, providing visual aids, and enabling them to discover concepts that solve problems. Teachers, as educators, play a crucial role in the development and practical application of e-learning tools in the classroom. However, the development of e-learning tools presents challenges for some teachers, including difficulties in creating learning media that can simultaneously measure attitudes, skills, and knowledge, as well as a lack of knowledge and skills in the field of ICT (Nugroho & Hastuti, 2019; Tobing & Novitasari, 2022). Therefore, e-learning tools with a guided inquiry approach have great potential for development in mathematics learning, especially in the context of quadratic functions.

The topic of quadratic functions has excellent potential for developing 21st-century skills, particularly problem-solving and computational thinking. This material is not only related to understanding algebra, but also requires students to build mathematical models, develop solution strategies, and make generalizations from various forms of representation, such as graphs, tables, and functions.

Learning quadratic functions through inquiry-based learning requires graphics software that enhances understanding of quadratic functions by performing simulations, function transformations, modeling, and problem-solving, while also providing an answer-checking system to support independent learning (Sokolowski, 2013). In line with this importance, Desmos is a free online graphing calculator. Desmos enables students to explore concepts, be creative, check for errors, and engage in deep thinking about mathematics instruction (Orr, 2017).

However, there has been no research that develops electronic-based tools with guided inquiry learning that simultaneously facilitates computational thinking, problem-solving, and self-efficacy, especially in the context of quadratic function material. Related development research was conducted by Mumpuni (2018) in a study titled "Web Desmos-Assisted Online Learning for Quadratic Function Graph Material in Grade X High School." The resulting learning media proved to be valid, practical, and effective. This shows that the media is suitable for use in the learning process, with its effectiveness evident in the fact that 28 out of 35 students achieved the minimum passing grade. Although this learning medium is considered adequate in terms of learning outcomes, it remains unclear whether it is effective for computational thinking, problem-solving, and self-efficacy.

II. Method

This study used the Research and Development (R&D) method to develop e-learning tools for quadratic functions in the form of guided inquiry-based e-teaching modules and e-worksheets. These products were designed to support students' computational thinking, problem-solving, and self-efficacy skills, while also evaluating their quality in terms of validity, practicality, and effectiveness.

The development process follows the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. In the initial stage, known as analysis, researchers collect information about learning needs, materials, and student characteristics to serve as the basis for designing learning tools. In the design stage, researchers develop digital-based e-tools, such as e-teaching modules and e-LKPD, through the Desmos platform, which involves product design and evaluation with ability tests and self-efficacy questionnaires. The development stage encompasses the implementation of the design, the development of e-teaching modules and e-

LKPD, as well as consultation and validation with experts, prior to testing the product in a limited class. The implementation stage involved applying the validated tools in schools and making adjustments based on the feedback received. In the evaluation stage, researchers reviewed the trial results and refined the products based on suggestions and input.

Product testing was conducted through limited testing and field testing. The subjects of the limited testing were 36 students in class X-10, and the subjects of the field testing were 34 students in class X-9. Field testing was conducted using a one-group pretest-posttest design. This study collected quantitative data from device validation, questionnaires, observations, and tests, as well as qualitative data from interviews and comments to assess the practicality, effectiveness, and quality of the learning device. The validity instrument for guided inquiry-based mathematics e-learning tools included a validation sheet developed by expert lecturers and mathematics teachers to evaluate the suitability of the material and the integration of computational thinking, problem-solving, and self-efficacy skills. The practicality instrument included student and teacher response questionnaires to assess the application of the tools in the learning process. At the same time, the effectiveness of these instruments is assessed through tests and questionnaires that evaluate students' computational thinking, problem-solving, and self-efficacy skills.

The test instrument consists of questions designed to measure computational thinking and problem-solving abilities. For example, there is a function $f(x) = ax^2 + 4x + c$. If the value of $a < -1$ and the value of $c > 1$, evaluate (true/false/uncertain and provide reasons) the following statements: The coefficient of x^2; the coefficient of x and the constant have positive values; If the graph intersects the x -axis at (-1,0) and (3,0), the value of a is -2; the graph of the function does not intersect the x-axis; the graph of the function always descends to the right of the negative y-axis (quadrant IV); all quadratic functions have a vertex.

The validity and practicality test results were calculated using the Likert scale and then converted using Widoyoko's (2009) qualitative criteria table, as shown in Table 1. The product was considered valid if it achieved at least a good rating. The practicality test was also evaluated based on the percentage of learning implementation and categorized according to Arikunto & Jabar (2014), as shown in Table 2. The media rated the practicality of the learning implementation as very good. The effectiveness of the product is declared to have been achieved if it meets three leading indicators: there is a significant difference between the results before and after use based on hypothesis testing, there is an increase in learning outcomes as shown by the N-gain score, and many students succeed in achieving scores above the minimum passing grade.

Table 1.
Conversion of Questionnaire Results for Validity Testing

No	Quantitative score range	Qualitative criteria
1.	$X > \underline{X}_i + 1{,}8\, SB_i$	Very Good

No	Quantitative score range	Qualitative criteria
2.	$(\underline{X}_i + 0{,}6\, SB_i) < X \le \underline{X}_i + 1{,}8\, SB_i$	Good
3.	$(\underline{X}_i - 0{,}6\, SB_i) < X \le (\underline{X}_i + 0{,}6\, SB_i)$	Fairly Good
4.	$(\underline{X}_i - 1{,}8\, SB_i) < X \le (\underline{X}_i - 0{,}6\, SB_i)$	Poor
5.	$X \le (\underline{X}_i - 1{,}8\, SB_i)$	Very Poor

Table 2.
Percentage of Implementation Rate

No	Percentage of Learning Implementation	Category
1.	$80\% < X \le 100\%$	Very Good
2.	$65\% < X \le 80\%$	Good
3.	$55\% < X \le 65\%$	Fairly Good
4.	$55\% < X \le 65\%$	Poor
5.	$X \le 40\%$	Very Poor

To examine the differences in pretest and posttest results for the three variables, a multivariate test (mean vector test for two paired samples) was employed. Before the data underwent multivariate testing, the assumption of multivariate normality was first checked using the Henze-Zirkler test. For the N-gain value, categorization was performed based on the interpretation of the N-gain score in Table 3, as outlined by Arikunto & Jabar (2014). The developed product was considered adequate if the gain value was in the minimum moderate category. Meanwhile, for the percentage of student mastery, categorization was also carried out based on Table 4, as described by Lakdawala et al. (2002). The developed product was considered adequate if the gain value was in the minimum good category.

Table 3.
Percentage of Completion Number of Students

No	Percentage of Students Who Have Completed Their Studies	Category
1.	$80\% < X \le 100\%$	Very Good
2.	$65\% < X \le 80\%$	Good
3.	$55\% < X \le 65\%$	Fairly Good
4.	$55\% < X \le 65\%$	Poor
5.	$X \le 40\%$	Very Poor

Table 4.
Interpretation of N-Gain Scores

No	N-Gain Score (g)	Category
1.	$g > 0{,}7$	High
2.	$0{,}3 \ge g \ge 0{,}7$	Medium
3.	$g < 0{,}3$	Low

This study has obtained permission from the school to collect data for development research. Student confidentiality is maintained and participation is voluntary without consequences for student academic grades.

III. Result and Discussion

A. Analysis Phase

SMA Negeri 03 Pati has been implementing the Merdeka Curriculum for two years, but still faces challenges in mathematics learning, particularly in relation to teachers' adaptation to student-centered learning approaches and the use of technology. Currently, teachers use Google as a reference, but students often copy information without a thorough understanding, which can cause difficulties when explaining their work. This problem is exacerbated by the fact that most students lack confidence and rely on their friends. In quadratic equations and quadratic functions, students often encounter obstacles in understanding and applying concepts, which is reflected in scores that frequently do not meet the minimum passing grade. Observations indicate that students in class X9, who are obedient and have average cognitive abilities, tend to be less active in discussions and require additional guidance in the learning process.

B. Design Phase

During the design phase, designs were developed for e-LKPD products and teaching modules, as well as assessment instruments, including tests for computational thinking, problem-solving, and self-efficacy. The teaching modules discuss quadratic functions through four materials, utilising a guided inquiry approach to enhance students' computational thinking, problem-solving skills, and self-efficacy. The e-LKPD was designed using Desmos and Canva, integrating real-world contexts to facilitate understanding and learning. The product design includes tests to measure computational thinking and problem-solving skills with specific indicators, as well as a self-efficacy questionnaire to evaluate students' confidence in using learning media.

C. Development Phase

During the one-month development phase, researchers implemented the design concept by developing e-Teaching Modules and e-LKPD. The e-Teaching Modules cover identity, general information, and four learning materials on quadratic functions, including formative and summative assessments. These e-Teaching Modules are designed with a guided inquiry approach to enhance students' computational thinking, problem-solving, and self-efficacy skills. The e-LKPD was developed using Desmos and Canva to present activities that align with the inquiry syntax and facilitate these skills. Computational thinking and problem-solving tests, as well as a self-efficacy questionnaire, were also designed to evaluate students' skills. All products were then tested for validity by two validators and declared valid after several revisions.

D. Implementation Phase

The implementation stage of e-LKPD development involves limited trials and field trials.

a. Limited Trial:

Conducted on March 5, 2024, in class X-10 at SMA Negeri 3 Pati with 36 students. The objective was to evaluate the readability, language, and usability of the e-LKPD. Students were divided into groups and given different e-LKPD materials. They provided feedback, which was then discussed together.

b. Field Trial:

Held from March 4 to 22, 2024, in class X-9 of SMA Negeri 3 Pati through four meetings, each lasting two teaching periods. Meeting 1 (March 7, 2024): Using the guided inquiry e-Module and Desmos e-LKPD to explore quadratic functions with the help of Desmos graphs. The learning process included observation, data collection, and analysis of graphs of quadratic functions. Constraints included limited time and heavy applications on students' mobile phones. Session 2 (March 14, 2024): Focused on the axis of symmetry and optimal values in the context of the Angry Birds game. Learning includes observing phenomena, collecting data, and exploring graphs using Desmos. Evaluation and conclusions are made by comparing the results of the quadratic functions obtained. Meeting 3 (March 15, 2024):

Regarding the formulation of quadratic functions using known characteristics. The inquiry process is partly done in class and partly as homework. Discussions on constructing quadratic functions based on intersection points and peak points are held. Meeting 4 (March 21, 2024): Solving everyday problems with quadratic functions, using the context of P3K box sizes. Students evaluate the maximum volume and analyze data with Desmos. The lesson ends with discussion, conclusions, and reflection. On March 22, 2024, students took a post-test to assess their computational thinking, problem-solving, and final self-efficacy. During the learning process, teachers provide guidance and references through e-LKPD, as well as helping students with scaffolding as needed.

E. Evaluation Phase

After conducting field trials, several evaluations were made on the developed e-teaching modules and e-LKPDs. The answer keys for the assessment questions in the e-teaching modules require revision, and the activities need to be adjusted to accommodate the learning time. This is because learning is often ineffective in the evaluation syntax. Regarding the e-LKPD, there was no evaluation of its content and substance. Instead, information needs to be added to the main screen of the e-LKPD to make it easier for other teachers to use. This information includes learning outcomes, objectives, materials, tutorials for sharing the e-LKPD with students, and links to related teaching modules.

F. Product Validity Analysis Results

Validity tests were conducted on the teaching e-module, e-LKPD, computational thinking, and self-efficacy test instruments, as well as the self-efficacy questionnaire instruments, student and teacher response sheets, and learning implementation observation sheets.

a. Teaching e-module

The results of the teaching e-module validation are described in Table 5.

Table 5. E-Teaching Module Validation Results

Table 5.
E-Teaching Module Validation Results

Product	Validator	Interval Quantitative Score	Qualitative Criteria	Actual Score	Result Validation Product
e-learning modules	Subject Matter Experts, Media Experts, and Teachers	$X > 117{,}6$	Very Good	116	Good
		$117{,}6 < X \leq 95{,}2$	Good		
		$95{,}2 < X \leq 72{,}8$	Fairly Good		
		$72{,}8 < X \leq 50{,}4$	Poor		
		$X \leq 50{,}4$	Very Poor		

b. E-LKPD

The results of the e-LKPD validation are outlined in Table 6.

Table 6.
e-LKPD Validation Results

Product	Validator	Interval Quantitative Score	Qualitative Criteria	Actual Score	Result Validation Product
e-LKPD	Subject Matter Experts and Teachers	$X > 126$	Very Good	116	Good
		$102 < X \leq 126$	Good		
		$78 < X \leq 102$	Fairly Good		
		$54 < X \leq 78$	Poor		
		$X \leq 54$	Very		

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Product	Validator	Interval Quantitative Score	Qualitative Criteria	Actual Score	Result Validation Product
			Poor		
	Media Experts	$X > 79{,}8$	Very Good	79	Good
		$64{,}6 < X \leq 79{,}8$	Good		
		$49{,}4 < X \leq 64{,}6$	Fairly Good		
		$34{,}2 < X \leq 49{,}4$	Poor		
		$X \leq 34{,}2$	Very Poor		

c. Computational thinking test instruments, problem-solving tests, and self-efficacy questionnaires

The results of the test and questionnaire validation are described in Table 7.

Table 7.
Test and Questionnaire Validation Results

Product	Validator	Interval Quantitative Score	Qualitative Criteria	Actual Score	Result Validation Product
Computational Thinking Test Instrument	Subject Matter Expert Lecturer	$X > 33{,}6$	Very Good	34	Very Good
		$27{,}2 < X \leq 33{,}6$	Good		
		$20{,}8 < X \leq 27{,}2$	Fairly Poor		
		$14{,}4 < X \leq 20{,}8$	Poor		
		$X \leq 14{,}4$	Very Poor		
Problem Solving Test Instrument		$X > 33{,}6$	Very Good	34	Very Good
		$27{,}2 < X \leq 33{,}6$	Good		
		$20{,}8 < X \leq 27{,}2$	Fairly Good		
		$14{,}4 < X \leq 20{,}8$	Poor		
		$X \leq 14{,}4$	Very Poor		
Self-efficacy Questionnaire Instrument		$X > 21$	Very Good	20	
		$17 < X \leq 21$	Good		
		$13 < X \leq 17$	Fairly Good		
		$9 < X \leq 13$	Poor		
		$X \leq 9$	Very Poor		

d. Questionnaire and Observation Instruments for Learning Implementation Response

The validation results are summarized in Table 8.

Table 8.
Questionnaire Response and Observation Sheet Validation Results

Product	Validator	Interval Quantitative Score	Qualitative Criteria	Actual Score	Result Validation Product
Student Response Questionnaire	Media Expert Lecturer	$X > 29{,}4$	Very Good	25	Good
		$23{,}8 < X \leq 29{,}4$	Good		
		$18{,}2 < X \leq 23{,}8$	Fairly Poor		
		$12{,}6 < X \leq 18{,}2$	Poor		
		$X \leq 12{,}6$	Very		

Product	Validator	Interval Quantitative Score	Qualitative Criteria	Actual Score	Result Validation Product
			Poor		
Teacher Response Questionnaire		$X > 29,4$	Very Good	27	Good
		$23,8 < X \leq 29,4$	Good		
		$18,2 < X \leq 23,8$	Fairly Good		
		$12,6 < X \leq 18,2$	Poor		
		$X \leq 12,6$	Very Poor		
Observation Sheet on Learning Outcomes		$X > 29,4$	Very Good	30	Very Good
		$23,8 < X \leq 29,4$	Good		
		$18,2 < X \leq 23,8$	Fairly Good		
		$12,6 < X \leq 18,2$	Poor		
		$X \leq 12,6$	Very Poor		

G. Product Practicality Analysis Results

The practicality of the product was collected through student and teacher response questionnaires. The results of the product's practicality are described in Table 9.

Table 9.
Product Practicality Results

Product	Validator	Interval Quantitative Score	Qualitative Criteria	Actual Score	Result Validation Product
Questionnaire sheet for responses to e-LKPD	Student	$X > 46,2$	Very Good	37,6	Good
		$37,4 < X \leq 46,2$	Good		
		$28,6 < X \leq 37,4$	Fairly Good		
		$19,8 < X \leq 28,6$	Poor		
		$X \leq 19,8$	Very Poor		
	Teacher	$X > 46,2$	Very Good	47	Very Good
		$37,4 < X \leq 46,2$	Good		
		$28,6 < X \leq 37,4$	Fairly Good		
		$19,8 < X \leq 28,6$	Poor		
		$X \leq 19,8$	Very Poor		
Questionnaire sheet for responses to the e-teaching module	Teacher	$X > 63$	Very Good	62	Good
		$51 < X \leq 63$	Good		
		$39 < X \leq 51$	Fairly Good		
		$27 < X \leq 39$	Poor		
		$X \leq 27$	Very Poor		

Practicality was also reviewed from the perspective of the feasibility of learning activities by teachers in the implementation of e-teaching modules. The results of the feasibility of learning with mathematics teacher observers are described in Table 10.

Table 10.
Learning Outcomes

The meeting	Percentage of learning implementation by teachers	Percentage of learning implementation by students
1	92%	82%
2	96%	92%
3	96%	92%

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The meeting	Percentage of learning implementation by teachers	Percentage of learning implementation by students
4	96%	96%

H. Product Effectiveness Analysis Results

a. Test Result Analysis

The data from the computational thinking, problem solving, and self-efficacy tests of the X9 class students are described in Table 11.

Table 11.
Pre-test and Post-test Data

Component	Pre-CT	Post-CT	Pre-PS	Post-PS	Pre-SE	Post-SE
Many Samples	30	30	30	30	30	30
Highest Value	56,7	96,7	40	90	71	88
Lowest Value	33,3	33,3	20	50	35	63
Average	43,6	76,4	25,7	75,8	59,1	77,9
Standard Deviation	4,79	13,3	7,39	11	9,03	6,44
N-gain	**0,58**		**0,67**		**0,46**	
N-gain Category	**Medium**		**Medium**		**Medium**	

After implementing guided inquiry-based quadratic function learning using the developed tools, there was an increase in the average scores for computational thinking, problem solving, and student self-efficacy. This improvement was moderate, with the percentage of students achieving the minimum passing grade reaching 70% (21 out of 30 students) for the computational thinking test, 66.7% (20 out of 30 students) for the problem-solving test, and 73.3% (22 out of 30 students) for the self-efficacy score. All of these categories showed improvement after the treatment.

b. Normality Test

The Shapiro Wilk test with a significance level of 0.05 was used with the decision criterion in this test being that H_0 is rejected if $p-value<0.05$. H_0 in this test is that the test data is normally distributed. The results of the data normality test are shown in Table 12.

Table 12.
Normality Test Result

Test	HZ	p-value	MVN
Henze-Zirkler	0.5366	0.6788	YES

Based on the Henze-Zirkler test, the p-value statistic for the HZ test is 0.679, which is greater than 0.05. This indicates that the three variables of post-test and pre-test differences for students' computational thinking, problem-solving, and self-efficacy abilities in the data follow a multivariate normal distribution.

b. Hypothetical Test

The Hottelings T^2 test with a significance level of 0.05 was conducted with the decision criterion in both tests being that H_0 is rejected if $p-value<0.05$. H_0 in this test is that there is no effect of treatment on the ability being tested. The results of the data normality test are shown in Table 13.

Table 13.
Hypothetical Test Result

Test	Value Test	p-value	Result
Hottelings T^2	759.54	0	Rejected H_0

At a significance level of $\alpha=0.05$, the p-value obtained from Hottelings' test is $0<0.05$, concluding that the scores for computational thinking, problem solving, and self-efficacy among 10th grade high school students studying quadratic functions before and after learning with the developed e-device have increased.

I. Validity Analysis of Guided Inquiry-Based Quadratic Function e-Learning Tools to Facilitate Computational Thinking, Problem Solving, and Self-Efficacy Skills

Guided inquiry-based learning tools for quadratic functions have demonstrated a high level of validity for e-LKPD and e-teaching modules. Evaluation by validators indicates that the e-teaching modules meet the validity criteria, including the completeness of components, the suitability of the material to the curriculum, appropriate assessment, and learning activities that support the development of computational thinking, self-efficacy, and problem-solving skills. Meanwhile, the e-LKPD is also considered valid, with accurate media, suitable materials, and clear instructions that facilitate the development of students' abilities. Input from validators includes avoiding filling in blanks that limit student creativity and clarifying the difference between conclusion activities in inquiry syntax and learning conclusions.

Thus, the developed e-teaching modules, e-LKPD, test instruments, and questionnaires were declared fit for use after undergoing a revision stage.

J. Practical Analysis of Guided Inquiry-Based Quadratic Function Learning Tools to Facilitate Computational Thinking, Problem Solving, and Self-Efficacy Skills

Limited trials were conducted prior to the learning process to evaluate the practicality of the products, resulting in revisions to the e-LKPD and e-teaching modules. The e-LKPD was revised to correct errors in writing and sentence structure, as well as to enhance its features, while the e-teaching module was adjusted to accommodate changes in time allocation due to Ramadan. After field testing, the e-teaching modules were revised again to correct the assessment answer keys and adjust the activities to match the learning time. Meanwhile, the e-LKPD required additional information on the main screen to facilitate its use by teachers. The results of the practicality test showed that the responses of students and teachers to the e-LKPD and e-learning modules were in the good category, with students feeling helped and more interested in learning through mobile phones, and teachers assessing the e-learning modules as tools that support student-based learning and the discovery of quadratic function formulas.

Based on this, the e-learning modules and e-LKPD that were developed were deemed practical after undergoing the revision process.

K. Analysis of the Effectiveness of Guided Inquiry-Based Quadratic Function e-Learning Tools to Facilitate Computational Thinking, Problem Solving, and Self-Efficacy Skills

Guided inquiry-based learning tools for quadratic functions have been proven effective in supporting improvements in students' computational thinking, problem-solving, and self-efficacy. Hypothesis testing showed a significant effect, with improvements in each variable falling into the moderate category. Most students also successfully achieved the minimum passing grade with good results, thus meeting the effectiveness criteria.

The improvement in computational thinking cannot be separated from the influence of the use of learning tools that have been developed, namely, e-teaching modules and e-LKPD. Computational thinking skills improved after the treatment was carried out. Based on the post-test results, students were able to perform the decomposition process in the factorization of quadratic functions to obtain the intersection point with the X-axis. In addition, students were able to correctly identify the values of a, b, and c in a quadratic function (student decomposition profiles are shown in point 1a of Figure 1). In terms of algorithmic skills, students were able to analyze and carry out steps to determine a value if certain information was known. The improvement in algorithmic ability can also be observed in students who can graph a quadratic function by determining the intersection point, identifying the peak point, and then graphing it (the student decomposition profile is shown in point 1b of Figure 1). In terms of abstraction ability, students can identify the concept of intersection points in terms of their determinants (as shown in point 1c of Figure 1). In pattern recognition skills, students can identify patterns of relationships between the discriminant value and the values of a and c. Students can also demonstrate the similarity of the values of quadratic function forms (a student's pattern recognition profile can be observed in point 1d of Figure 1). In terms of generalization skills, students can interpret a quadratic function graph in a general sense. Students can also convert a quadratic function into another quadratic function (student generalization profiles are shown in point 1e of Figure 1).

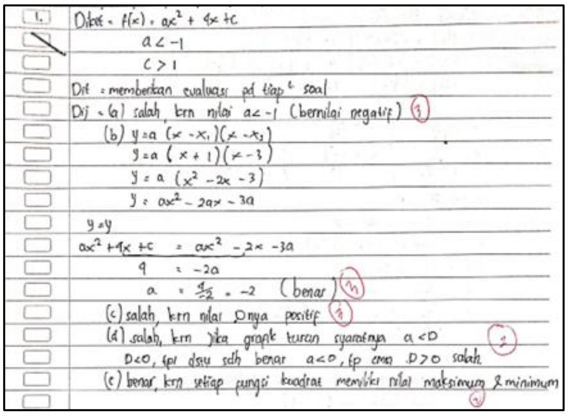

Figure 1. Student Computational Thinking Profiles

The guided inquiry approach encourages students to actively engage in the process of discovering concepts, making the learning experience more meaningful (Kuhlthau et al., 2007). Computational thinking skills comprise several supporting skills, including algorithms, decomposition, pattern recognition, generalization, and abstraction. Algorithms are related to the skill of creating a sequence of steps to find solutions or concepts. In guided inquiry learning, algorithm skills are integrated into the syntax of answering questions. Students using Desmos e-LKPD are allowed to sequence steps before discovering concepts, such as determining the formulas $x = -b/2a$ and $y = -D/4a$. The second skill is decomposition. Decomposition involves breaking down problems into several sub-problems to be worked on one by one. In inquiry-based learning, decomposition is often a key component in the process of answering questions and evaluating solutions. Decomposition skills are developed by analyzing each step that students have arranged. Students begin their exploration by determining the intersection points of the quadratic function $f(x) = ax^2 + bx + c$, and then finding the coordinates of x between the two intersection points. After obtaining the value of x, students substitute the x-coordinate into the quadratic function until they find the formula $y = -D/4a$. The next skill is pattern recognition and generalization. These two aspects are interrelated because pattern recognition is the beginning of the generalization process. Pattern recognition and generalization are integrated into the process of answering questions through to evaluation. As in the same example, the process of determining the formula $x = -b/2a$ begins by examining the pattern of several Angry Birds throws that have been drawn by students. Pattern recognition can lead students to observe that the peak of the throw is always in the middle of the slingshot and the target. In another example, during the first meeting, students practice pattern recognition skills by observing various types of graphs, such as reviewing the direction and coefficient a in the function. This pattern recognition triggers students' ability to generalize. In pattern recognition, if students know the location of the peak of the throw, the idea arises that the x-coordinate at the peak point can be obtained by finding the midpoint between the slingshot and the target, which is then explored to derive the formula $x = -b/2a$ and $y = -D/4a$. Then, the last skill in computational thinking is abstraction. Abstraction is related to sorting the information used. Abstraction skills are integrated into the inquiry process, namely, answering questions. An example is identifying elements in a graph that can be used to construct a quadratic function.

The essence of how products can facilitate computational thinking lies in allowing students to learn how to transform concrete ideas into more abstract concepts. This process involves various activities, such as simulations to collect data, creating graphs of quadratic functions, observing graph patterns, and identifying relationships between different elements, including the roles of coefficients a, b, and c in quadratic functions. This is reinforced by the findings of Sung & Black (2020), which suggest that student activity in transforming concrete knowledge into abstract concepts influences students' thinking ability profiles. The use of interactive simulation tools, such as Desmos, can assist students in the learning process of quadratic functions. This finding aligns with research by Mumpuni (2018) and Chechan et al. (2023), which suggests that Web-based learning media assisted by Desmos is effective in enhancing high school students' understanding of quadratic functions.

Improvements in problem-solving cannot be separated from the influence of the use of learning tools that have been developed, namely, e-teaching modules and e-LKPD. Students' problem-solving skills also improved after the treatment was implemented. After learning, students were able to understand problems, develop solutions, implement the strategies they had designed, and double-check their work. For example, students were able to identify information in questions, such as writing down the capital and income functions of a company. After that, students can plan problem-solving, such as identifying procedures for determining functions and finding peak values. After planning the problem, students can implement the problem-solving plan, such as completing the procedure with the correct calculations. Finally, students can proceed to the rechecking stage, where they relate the peak value to the context of the problem being asked. The students' problem-solving profile is shown in Figure 2.

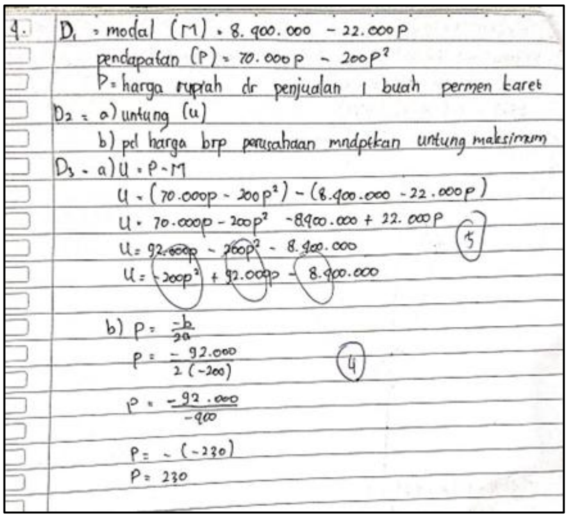

Figure 2. Student Problem Solving Ability Profile

This is because guided inquiry learning provides a meaningful context for students to learn. Problems are easier to understand when they are represented in a meaningful way. The problems or phenomena raised in quadratic function learning include contexts that are familiar to students, such as museum buildings, Angry Birds games, bridge construction, and first aid kits. Learning with this context is easier for students to understand because they have encountered it in their daily lives. Understanding problems contributes directly to success in solving them (Ormrod et al., 2020; Robertson, 2020). In addition, the improvement of problem-solving skills is also influenced by guided inquiry learning through designed tools, which train students to apply systematic problem-solving steps, starting from identification, representation, selection, and application of strategies to evaluation of results. (Eggen & Kauchak, 2012).

In this study, problem-solving skills encompass identifying problems, devising plans for solutions, implementing these solutions, and evaluating their effectiveness. The first skill is identifying problems. This skill is integrated into the inquiry process, namely observing phenomena and asking questions. For example, in the fourth meeting, students understood Dina's problem of making a first aid kit box with a length of (x+3) cm, a width of (9-x) cm, and a height of 3 cm. With these dimensions, the teacher posed a question for investigation: What is the value of x that yields the maximum volume? At this stage, students began to think that this was a problem because, to determine the volume, the dimensions must be nominal. However, the dimensions given still contained the variable x, which meant that the value of x needed to be determined in order to obtain the maximum volume. In this case, students' understanding of the problem could be improved through thinking activities that focus on what was known and what was being asked. The second problem-solving skill is strategizing in composing solutions to problems. This skill is integrated with the inquiry process, namely answering questions. In the process of answering questions, students identify the concepts used to obtain the value of x and the most significant volume, namely the concepts of axis of symmetry and optimum value. In answering the questions, students draw sketches of the problem. Through these activities, students estimate the steps to solve the problem. The third problem-solving skill is implementing the solution. Students practice their problem-solving skills by analyzing data using the identified concepts. The final problem-solving skill is rechecking. This is where the Desmos graph plays a crucial role in problem-solving, which is necessary to evaluate students' results. If the results obtained are inaccurate, students reevaluate the process. Based on this, the learning tools developed can facilitate students' problems through their connection with the guided inquiry process. The results of this study align with those of Situmorang et al. (2023), who found that the inquiry learning model has a moderate correlation with students' ability to solve math problems related to quadratic functions.

After implementing guided inquiry learning using the developed tools, students' self-efficacy increased, as shown in Figure 3. The highest dimension of self-efficacy was strength. Students felt confident in the process of discovering quadratic function concepts and had a never-give-up attitude in solving quadratic function problems. Meanwhile, the lowest dimension of self-efficacy was generality. At this stage, students were not yet very confident in their mathematical abilities in every situation.

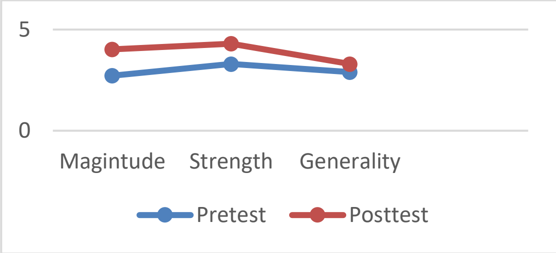

Figure 3. Student Self-Efficacy Profile

This is due to group activities that allow students to discuss and exchange ideas as they explore concepts (Sopari et al., 2022). Guidance and direction from teachers to each group also helps students in the learning process. As a result, when students thoroughly understand the material, their level of confidence in their learning abilities increases. This aligns with Tsai et al. (2014), who suggest that one factor influencing student self-efficacy is a person's experience of success and failure. In addition, the increase in students' self-efficacy after guided inquiry learning is inseparable from how the learning tools developed can facilitate the three dimensions of self-efficacy itself. The first dimension is magnitude, which is related to how confident students are in their ability to complete complex tasks. The increase in the magnitude dimension in the tools developed is achieved by providing step-by-step solutions. The guided inquiry process leads students to gradually discover a concept, from presenting problems to formulating conclusions. The second dimension is strength, which is students' determination in solving problems. Strength in this development can be facilitated by allowing students to discuss and providing assistance in the form of references and appropriate scaffolding from teachers, either directly or through instructions. Finally, the last dimension is generality, which relates to how confident students are in their abilities in other areas of mathematics learning. The improvement in generality in this learning is that students are allowed to actively engage in solving problems. The contexts in the device can be linked to material in other mathematics lessons. An example is the P3K context for determining maximum volume, which can be linked to calculus, particularly the concept of derivatives. The finding that the developed device is capable of increasing self-efficacy is supported by the research results of Sulistiyo & Wijaya (2020), which demonstrate that the inquiry approach has been proven effective in strengthening students' self-efficacy, particularly in the context of high school mathematics learning.

Although the results show that the e-learning tools developed are practical, this study has limitations in terms of sample size. The trial was conducted in only two classes in one school, so the results cannot be generalized widely. However, these e-tools are designed to be flexible, allowing teachers to adapt them to the needs of their classes. Teachers can modify certain parts of the e-modules, such as the context of questions or visualizations on Desmos, to better suit local conditions or student characteristics. For further development, it is recommended that a comparative study be conducted between guided inquiry and open inquiry learning across cultures to see the effectiveness of each approach in facilitating 21st-century skills.

IV. CONCLUSION

The study's results concluded that the guided inquiry-based quadratic function e-learning tools met the validity criteria to a good standard. These tools also demonstrated good practicality, with student and teacher responses to the e-LKPD and e-teaching modules falling into the good category, and the percentage of learning implementation ranging from 80% to 100% in each meeting. In addition, this e-tool is efficacious in improving high school students' computational thinking, problem-solving, and self-efficacy skills, as indicated by moderate gain scores and more than 65% of students achieving the minimum competency standard at the end of the learning process. Based on these conclusions, educators can integrate this tool into online and offline learning, making adjustments to the local context, and replicate its use in other materials that require 21st-century skills.

REFERENCES

Afriansyah, E. A., Nurjamilah, E., Sumartini, T. S., Hamdani, N. A., & Maulani, G. A. F. (2024, November). Students Mathematical Understanding of Social Arithmetic in Terms of Student Self-Efficacy. In *4th International Conference on Education and Technology (ICETECH 2023)* (pp. 691-708). Atlantis Press.

Arikunto, S., & Jabar, C. S. A. (2014). *Evaluasi Program Pendidikan: Pedoman Teoritis Praktisi Pendidikan. In Prosedur Penelitian Suatu Pendekatan Praktik-Revisi ke X*. Bumi Aksara.

Bandura, A. (1993). Perceived Self-Efficacy in Cognitive Development and Functioning. Educational Psychologist, 28(2). https://doi.org/10.1207/s15326985ep2802_3

Chechan, B., Ampadu, E., & Pears, A. (2023). Effect of using Desmos on high school students' understanding and learning of functions. Eurasia Journal of Mathematics, Science and Technology Education, 19(10), 1–21. https://doi.org/10.29333/ejmste/13540

Eggen, P., & Kauchak, D. (2012). Educational Psychology: Windows on Classrooms. In Educational Psychology: Windows on Classrooms, Global Edition (9th ed.). Pearson Education.

Fitri, A., & Abadi, A. M. (2021). Kesulitan siswa SMA dalam menyelesaikan soal matematika pada materi peluang. Jurnal Riset Pendidikan Matematika, 8(1), 95–105. https://doi.org/10.21831/jrpm.v8i1.17004

Fitria, C., Sujadi, I., & Subanti, S. (2016). Analisis kesulitan metakognisi siswa dalam memecahkan masalah sistem pertidaksamaan linear dua variabel ditinjau dari tipe kepribadian guardian, artisan, rational, dan idealist kelas x smkn i jombang. Jurnal Elektronik Pembelajaran Matematika, 4(9), 824–835.

Herlina, H., Ramlawati, R., & Hasri, H. (2022). Pengembangan Perangkat Pembelajaran Elektronik Berbasis STEAM untuk Meningkatkan Minat dan Hasil Belajar. Chemistry Education Review (CER), 5(2). https://doi.org/10.26858/cer.v5i2.32731

Hewi, L., & Shaleh, M. (2020). Refleksi Hasil PISA (The Programme For International Student Assesment): Upaya Perbaikan Bertumpu Pada Pendidikan Anak Usia Dini). Jurnal Golden Age, 4(01), 30–41. https://doi.org/10.29408/jga.v4i01.2018

Hu, C. (2011). Computational thinking - What it might mean and what we might do about it. ITiCSE'11 - Proceedings of the 16th Annual Conference on Innovation and Technology in Computer Science, 223–227. https://doi.org/10.1145/1999747.1999811

Julianti, N. H., Darmawan, P., & Mutimmah, D. (2022). Computational Thinking Dalam Memecahkan Masalah High Order Thinking Skill Siswa. Prosiding Seminar Nasional MIPA, 2(1), 1–7.

Kuhlthau, C. C., Maniotes, L. K., & Caspari, A. K. (2007). Guided Inquiry: Learning in the 21st Century. In IASL Annual Conference Proceedings (2nd ed.). Greenwood Publishing.

Lakdawala, V. K., Zahorian, S. A., González, O. R., Amit Kumar, H., & Leathrum, J. F. (2002). An instrument for assessing knowledge gain in a first course in circuit theory. ASEE Annual Conference Proceedings. https://doi.org/10.18260/1-2--10335

Lovisia, E. (2018). Pengaruh Model Pembelajaran Inkuiri Terbimbing terhadap Hasil Belajar. Science and Physics Education Journal (SPEJ), 2(1), 1–10. https://doi.org/10.31539/spej.v2i1.333

Mumpuni, P. W. (2018). Pengembangan media pembelajaran online berbantuan web desmos untuk materi grafik fungsi kuadrat pada sma kelas x [Universitas Jember].

Nugraha, I. F., & Prabawati, M. N. (2019). Self-efficacy siswa kelas XI dalam pembelajaran matematika di SMKS Sukapura. Prosiding Seminar Nasional & Call For Papers, 281–286.

Nugroho, F. A., & Hastuti, H. (2019). Constraints of geography teacher of sma n 1 ngaglik in developing the 2013 curriculum learning devices in sleman regency. Geosfera Indonesia, 4(1), 44–55. https://doi.org/10.19184/geosi.v4i1.9294

Nurlaelah, E., Usdiyana, D., & Fadilah, N. (2024). The Relationship Between Computational Thinking Ability and Logical Mathematical Intelligence. *Mosharafa: Jurnal Pendidikan Matematika*, *13*(1), 87-96. https://doi.org/10.31980/mosharafa.v13i1.1978

OECD. (2019). Programme for international student assessment (PISA) results from PISA 2018. In OECD: Vol. I. https://doi.org/10.1787/5f07c754-en

OECD. (2020). *PISA 2022 MATHEMATICS FRAMEWORK*.

Ormrod, J., Anderman, E. M., & Anderman, L. H. (2020). Educational psychology: Developing learners. In Educational psychology: Developing learners (10th ed.). Upper Saddle River, N.J. : Pearson/Merrill Prentice Hall.

Orr, J. (2017). Function Transformations and the Desmos Activity Builder. The Mathematics Teacher, 110(7), 549–551. https://doi.org/10.5951/mathteacher.110.7.0549

Pajares, F., & Miller, M. D. (1994). Role of Self-Efficacy and Self-Concept Beliefs in Mathematical Problem Solving: A Path Analysis. Journal of Educational Psychology, 86(2), 193–283. https://doi.org/10.1037/0022-0663.86.2.193

Robertson, S. I. (2020). Analogical problem solving. In Problem Solving. https://doi.org/10.4324/9780203457955-18

Román-González, M., Pérez-González, J. C., & Jiménez-Fernández, C. (2017). Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test. Computers in Human Behavior, 72. https://doi.org/10.1016/j.chb.2016.08.047

Schunk, D. H. (1991). Self-Efficacy and Academic Motivation. Educational Psychologist, 26(3–4). https://doi.org/10.1080/00461520.1991.9653133

Sholihah, S. Z., & Afriansyah, E. A. (2018). Analisis Kesulitan Siswa dalam Proses Pemecahan Masalah Geometri Berdasarkan Tahapan Berpikir Van Hiele. Mosharafa: Jurnal Pendidikan Matematika, 6(2), 287–298. https://doi.org/10.31980/mosharafa.v6i2.317

Situmorang, D. E., Simanjuntak, R. M., & Sinaga, R. F. (2023). Pengaruh Model Inquiry Learning terhadap Kemampuan

Pemecahan Masalah Matematisdan Minat Belajar Peserta Didik pada Materi Fungsi Kuadrat di Kelas X DPIB SMK Negeri 5 Medan T.A. 2023/2024. *Innovative: Journal Of Social Science Research*, 3(5), 79–91.

Sokolowski, A. (2013). Modelling Transformations of Quadratic Functions: A Proposal of Inductive Inquiry. In Australian Senior Mathematics Journal (Vol. 27, Issue 2, pp. 45–54).

Sopari, Y. W., Daniarsa, Y., & Ulfatushiyam, N. (2022). Pembelajaran Inkuiri Terbimbing Untuk Meningkatkan Kemampuan Berpikir Kritis, Komunikasi Matematis, Self-Efficacy Matematis. Pasundan Journal of Mathematics Education : Jurnal Pendidikan Matematika, Vol 12 No 1, 60–75. https://doi.org/10.23969/pjme.v12i1.5278

Sriwahyuni, K., & Maryati, I. (2022). Kemampuan Pemecahan Masalah Matematis Siswa pada Materi Statistika. Plusminus: Jurnal Pendidikan Matematika, 2(2), 335–344. https://doi.org/10.31980/plusminus.v2i2.1830

Sulistiyo, M. A. S., & Wijaya, A. (2020). The effectiveness of inquiry-based learning on computational thinking skills and self-efficacy of high school students. Journal of Physics: Conference Series, 1581(1). https://doi.org/10.1088/1742-6596/1581/1/012046

Sung, W., & Black, J. B. (2020). Factors to consider when designing effective learning: Infusing computational thinking in mathematics to support thinking-doing. Journal of Research on Technology in Education, 53(4). https://doi.org/10.1080/15391523.2020.1784066

Tobing, M. D., & Novitasari, D. (2022). Analysis of Teacher Difficulties in Teaching Comparative Writing Using E-Learning. Indonesian Journal of Education Methods Development, 19, 1–9. https://doi.org/10.21070/ijemd.v19i.657

Triling, B., & Fadel, C. (2009). Century Skills. 21St Century Skill, Book.

Tsai, C. L., Chaichanasakul, A., Zhao, R., Flores, L. Y., & Lopez, S. J. (2014). Development and Validation of the Strengths Self-Efficacy Scale (SSES). Journal of Career Assessment, 22(2), 221–232. https://doi.org/10.1177/1069072713493761

Weese, J. L., Feldhausen, R., & Bean, N. H. (2016). The impact of STEM experiences on student self-efficacy in computational thinking. ASEE Annual Conference and Exposition, Conference Proceedings, 2016-June, 1–12. https://doi.org/10.18260/p.26179

Widoyoko, E. P. (2009). *Evaluasi Program Pembelajaran. Pustaka Pelajar*.

Zhong, B., Wang, Q., Chen, J., & Li, Y. (2016). An exploration of three-dimensional integrated assessment for computational thinking. In Journal of Educational Computing Research (Vol. 53, Issue 4, pp. 562–590). https://doi.org/10.1177/0735633115608444