e-ISSN : 3090-5354
Vol. 2, No.1, April 2026

Development of Technology-Enhanced Guided Inquiry Parabolic Motion Learning Devices with Sport Education to Improve High School Students' Critical Thinking

Widi Astutik[1*], Wasis[1], Budi Jatmiko[1], Noer Risky Ramadhani[2]

[1]Universitas Negeri Surabaya, Surabaya, Indonesia
[2]Mae Fah Luang University, Chiang Rai, Thailand

DOI : https://doi.org/10.26740/jdpe.v2i1.52270

Sections Info

Article history:
Submitted: March 28, 2026
Final Revised: April 6, 2026
Accepted: April 6, 2026
Published: April 23, 2026

Keywords:
Guided Inquiry;
Learning Tools;
Parabolic Motion;
Sport Education.

ABSTRACT

Objective: *This study aims to develop a parabolic motion learning tool based on a guided inquiry model with a sports education approach to improve the critical thinking skills of high school students.* ***Method:*** *This research is a research and development (R&D) study using the ADDIE model, which includes analysis, design, development, implementation, and evaluation. The subjects consisted of 11th-grade high school students involved in both limited and extensive trials. The research instruments included a tool validation sheet, a learning implementation observation sheet, a student response questionnaire, and a critical thinking skills test. Data analysis was conducted using validity, reliability, N-gain, normality, homogeneity, paired t-test, and ANOVA.* ***Results:*** *The results showed that the developed learning tool met the criteria for highly valid with a percentage between 84% and 98%; practical based on the learning implementation category (very good) and student response (87.88%), and effective based on the increase in the N-gain value in the moderate category (0.59–0.62). The statistical test results also showed a significant increase between pretest and posttest scores, and no significant differences between classes, demonstrating the consistent effectiveness of the learning tools.* ***Novelty:*** *The novelty of this research lies in the integration of a guided inquiry model with a sports education approach in physics instruction on parabolic motion to train critical thinking skills through contextual learning based on sports activities, a practice that has not been widely explored in previous research.*

INTRODUCTION

In this era of rapid modernization and technological development, education is required to prepare students with 21st-century skills to face increasingly complex global challenges. The Partnership for 21st Century Learning framework emphasizes that essential skills students must possess include character, citizenship, communication, collaboration, creativity, and critical thinking (OECD, 2021). Among these skills, critical thinking is a fundamental competency because it plays a role in supporting problem-solving abilities, rational decision-making, and the ability to generate innovative solutions to future challenges. By mastering critical thinking skills, Indonesia's golden generation of 2045 is expected to not only be an adaptive workforce but also visionary individuals with global competitiveness (World Economic Forum, 2020).

Critical thinking skills are crucial because education must essentially shape individuals capable of understanding and solving real-world problems. Students need to be accustomed to critical thinking to analyze information, evaluate arguments, and draw logical conclusions (Saavedra & Ofper, 2012). Facione (2011) defines critical thinking as an intellectual process involving reflective and analytical thinking that encourages students to actively engage in the learning process. Through this process, students are encouraged to ask questions, develop ideas, and find innovative solutions to complex problems. Therefore, education should not only focus on transferring knowledge but also on developing higher-order thinking skills, which are essential for modern life.

However, empirical evidence indicates that students' critical thinking skills remain relatively low. An international study showed that despite an 18% increase in Indonesia's performance in literacy and mathematics between 2018 and 2022, Indonesia still ranks 62nd out of 70 countries, below the OECD average (OECD, 2023). This situation indicates that Indonesian students' critical thinking skills still need improvement, as reflected in the results of the PISA survey (Budiarti, 2023).

The low PISA scores indicate students' weak mastery of literacy, numeracy, and science skills oriented toward contextual problem-solving. This suggests that students have not received optimal instruction in developing critical thinking skills such as the ability to analyze data, evaluate information, and draw logical conclusions. Research by Handayni et al. (2024) indicates that four indicators of critical thinking skills interpretation, analysis, evaluation, and inference remain in the low category. Research by Khoirunnisa & Dwikoranto (2021) also indicates that students' critical thinking skills in solving physics problems are still relatively low. Furthermore, research by Sari (2016) found that 86.9% of high school students have low levels of critical thinking skills in physics learning.

Preliminary research conducted by researchers also revealed a similar situation in the parabolic motion topic. The data showed that less than 50% of students possessed adequate critical thinking skills across all indicators. A total of 55.55% of students demonstrated interpretive skills, 47.22% understood concepts, 36.11% evaluated, and only 33.33% made accurate inferences. These findings indicate a persistent gap between expected competencies and the actual state of students' critical thinking skills in physics learning, particularly in parabolic motion.

Students' low critical thinking skills are influenced by various factors, both internal and external. Internal factors include individual characteristics, learning motivation, and self-confidence, while external factors include the learning environment and the teacher's teaching approach (Hayati & Setiawan, 2022). One of the main causes of low critical thinking skills is the use of learning models that are less able to encourage active student engagement. Therefore, innovative learning models are needed that can optimally develop critical thinking skills.

One learning model proven to improve critical thinking skills is the guided inquiry model. Research by Hattie & Donoghue (2016) shows that inquiry-based learning strategies significantly contribute to improving critical thinking skills. Zion & Mendelovici (2021) also stated that the guided inquiry approach can help students develop critical thinking skills through a systematic investigative process. Research by Alfieri et al. (2020) showed that the implementation of guided inquiry can improve students' critical thinking skills and academic achievement. Furthermore, research by Furtak et al. (2021) also showed that inquiry-based learning can improve students' critical thinking skills in science and science lessons. This indicates that the guided inquiry model has great potential for application in physics learning in secondary schools.

However, the implementation of the guided inquiry model still has several limitations. One major weakness is the lack of a learning context relevant to students' real lives, resulting in abstract learning (Furtak et al., 2021). Therefore, an approach is needed that can contextualize physics learning to make it more meaningful. One approach that can be used is sports education, which integrates physics concepts with sports activities.

Sports education-based learning allows students to directly observe physics phenomena in real-life contexts. Sports activities such as basketball, volleyball, and shot put can be used as contexts for learning about parabolic motion, making physics concepts more concrete and easier to understand (Nathan & Sawyer, 2022). Research by Adair (2021) shows that sports can be an engaging context for understanding physics concepts because they allow students to directly experience physics principles such as force, velocity, and kinetic energy.

Furthermore, research by Giancoli (2021) shows that the movements in shot put involve various physics concepts, such as Newton's Laws and vertical motion. Research by Johnson (2020) also shows that contextual learning through sports activities can improve student learning outcomes and skills. Research by Serway and Jewett (2020) states that the shot put movement is a concrete example of parabolic motion. Rizki (2021) also explains that analyzing parabolic motion through sports activities can be done by measuring the throwing angle and initial velocity, helping students understand the concept more deeply.

Based on previous research, it can be concluded that the guided inquiry model has advantages in developing critical thinking skills through scientific investigation activities. Meanwhile, the sports education approach has the advantage of providing an authentic learning context and increasing student motivation. However, most previous research has examined the two approaches separately. Therefore, there is still a research opportunity to integrate the guided inquiry model with the sports education approach in physics learning, particularly for parabolic motion.

Based on this gap, this study seeks to develop a parabolic motion learning tool using a sports education-based guided inquiry model to improve students' critical thinking skills. This study aims to describe the validity, practicality, and effectiveness of the developed learning tool in improving critical thinking skills in high school students.

The novelty of this research lies in the integration of the guided inquiry model with the sports education approach in developing a physics learning tool for parabolic motion. Furthermore, this research contributes to the development of learning tools that are not only oriented toward concept mastery but also toward developing critical thinking skills through contextual learning based on sports activities. This integration is expected to become an innovative alternative in physics learning that is more meaningful, contextual, and oriented toward the development of 21st-century skills.

RESEARCH METHOD

This research is a research and development (R&D) study aimed at producing a parabolic motion learning tool using a guided inquiry model based on sports education to improve students' critical thinking skills. The development model used is the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation (Aldoobie, 2020). The trial design used a one-group pre-test–post-test design to assess the effect of the treatment on improving critical thinking skills (Cohen et al., 2007).

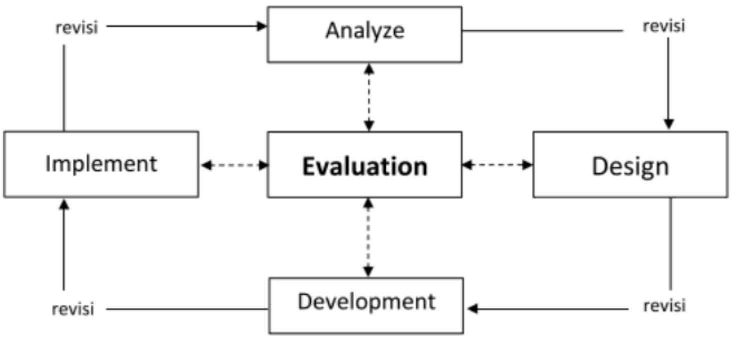

Figure 1. Research design
(Source: Hidayat, 2022)

Participants

The research subjects were 11th grade science students at SMAN 1 Kedunggalar in the 2025/2026 academic year. A limited trial was conducted in one class, while a broad trial was conducted in three classes consisting of one experimental class and two replication classes. The selection of research subjects aimed to determine the practicality and effectiveness of learning tools in improving students' critical thinking skills. The research variables consisted of the independent variable, namely guided inquiry learning based on sport education, the dependent variable, namely critical thinking skills, and the control variables in the form of learning time, teachers, and learning materials (Sanjaya, 2013; Sugiyono, 2015).

Table 1. Trial design

Class	Pre-test	Treatment	Post-test
Experiment	O_1	X	O_2
Replication-1	O_1	X	O_2
Replication-2	O_1	X	O_2

Instruments and Procedures

The research instruments included a learning device validation sheet, an observation sheet for learning implementation, a student response questionnaire, and a critical thinking skills test in the form of a pre-test and post-test. The learning devices developed included lesson plans, student worksheets, teaching materials, and assessment sheets (Kurniawan et al., 2020; Sari et al., 2020; Sari et al., 2021; Sutopo et al., 2021). Validation of the devices was conducted by three expert validators to ensure the appropriateness of the content, construction, and language of the learning devices. Observations were conducted by three observers to assess the implementation of the learning (Ciesielska et al., 2018).

The research procedure was carried out through five ADDIE stages: needs analysis, device design, device development and validation, learning implementation, and evaluation to determine the quality of the developed learning devices (Adeoye, 2024).

Data Analysis

Data analysis was conducted to determine the validity, practicality, and effectiveness of the learning tools. Validity was analyzed using the percentage of validation scores with specific interpretation criteria and reliability testing using Cronbach's Alpha (Arikunto, 2013; Arikunto, 2016; Riduwan & Akdon, 2013; Retnawati, 2020; Kurniawan et al., 2020).

Table 2. Validity percentage and interpretation criteria

Percentage (%)	Interpretation Criteria
0-20	Totally invalid
21-40	Less valid
41-60	Quite valid
61-80	Valid
81-100	Very valid

(Riduwan & Akdon, 2013; Kurniawan *et al.*, 2020)

Table 3. Reliability criteria

Reliability Result	Criteria
$0.80 < r_{11} \leq 1.00$	Very high
$0.60 < r_{11} \leq 0.80$	High
$0.40 < r_{11} \leq 0.60$	Enough
$0.20 < r_{11} \leq 0.40$	Low
$0.00 < r_{11} \leq 0.20$	Very low

(Arikunto, 2016)

Practicality was analyzed based on observational data on learning implementation using quantitative descriptive analysis with the mode technique (Purwanto, 2013; Sumintono & Widhiarso, 2014).

Effectiveness was analyzed using the Shapiro–Wilk normality test and Levene's homogeneity test as prerequisite tests (Sudjana, 2005; Usmadi, 2020). Next, a paired sample t-test was conducted to determine differences before and after the treatment. Improvement in critical thinking skills was analyzed using the N-gain score (Hake, 1998; Bao, 2020; Adilla & Jatmiko, 2021). Furthermore, a one-way ANOVA test was used to determine the consistency of improvement across classes. Student responses were analyzed using Likert scale percentages to determine learning response categories (Riduwan, 2015).

Table 4. N-gain criterion

Nilai $\langle g \rangle$	Criteria	Level of effectiveness
$\langle g \rangle \geq 0.70$	High	Very Effective
$0.70 > \langle g \rangle \geq 0.30$	Moderately	Effective
$\langle g \rangle < 0.30$	Low	Less Effective

(Bao, 2020)

Table 5. Relationship between variables and data collection and analysis techniques

Variables	Indicators	Data Collection Techniques	Data Analysis Techniques
Validity	Learning device suitability	Validation sheet, by 3 expert validators	Validity analysis with statistics (percentage)
Practicality	Learning implementation	Learning observation sheet by 3 observers	Statistics with percentage scores
Effectiveness	Improvement of critical thinking skills	Tests (pretest and posttest) and student responses	Normality test (Shapiro-Wilk), homogeneity test (Levene), t-test or Wilcoxon, gain score (Hake), ANOVA or Kruskal-Wallis

Through these analysis stages, this research methodology is designed to ensure that the learning tools developed meet the criteria of being valid, practical, and effective in improving students' critical thinking skills.

RESULTS AND DISCUSSION

Results

Analysis

The analysis phase was conducted to identify the need for developing parabolic motion learning tools based on a guided inquiry model with a sports education approach. The analysis was conducted through a literature review, learning observations, and student needs analysis. The results of the literature review indicate that critical thinking skills are an essential 21st-century competency because they play a role in analysis, information evaluation, and problem-solving. Therefore, physics learning needs to be designed to systematically train critical thinking skills. Observations in grade 11 of SMA Negeri 1 Kedunggalar revealed a gap between the ideal and actual levels of students' critical thinking skills. Ideally, critical thinking skills are expected to reach over 80%. However, pre-study results indicated interpretation skills of 55.55%, analysis 47.22%, evaluation 36.11%, and inference 33.33%.

These low skills are due to learning that still focuses on mastering formulas and does not provide optimal opportunities for students to engage in inquiry activities such as analyzing problems, testing hypotheses, and drawing conclusions. Furthermore, students still experience difficulty conceptually understanding the concept of parabolic motion. Based on the needs analysis, the development of guided inquiry-based learning tools using a sports education approach is necessary to create more contextual learning and enhance students' critical thinking skills. This stage serves as the basis for designing learning tools in the next stage.

Design

The design phase was conducted based on the results of a needs analysis to develop parabolic motion learning tools based on a guided inquiry model with a sports education approach. The tools designed included Student Worksheets (LKM), teaching modules (RPP), teaching materials, and critical thinking skills assessment instruments. The LKM design was developed by integrating guided inquiry syntax with a sports education context through sports activities such as basketball throws and volleyball serves to help students understand the concept of parabolic motion contextually. The LKM was also designed to train critical thinking skills indicators, including interpretation, analysis, evaluation, and inference, through activities such as formulating problems, formulating hypotheses, conducting experiments, analyzing data, and drawing conclusions. Furthermore, the LKM was equipped with the use of technology such as QR codes, learning videos, and PhET simulations to support the learning process.

The teaching module (RPP) design was developed by integrating a sports education approach and a guided inquiry model to create more contextual and meaningful learning. The RPP was designed in four sessions, encompassing introductory, core, and closing activities. It also included prompt questions, collaborative activities, and learning reflections to support the development of students' critical thinking skills. The teaching materials are designed to support understanding of the concept of parabolic motion through examples of its application in sports activities, helping students connect physics concepts to real-world phenomena. The presentation of the material is complemented by illustrations, case studies, and analytical activities to systematically train students' critical thinking skills.

The assessment instrument is designed in the form of descriptive questions that measure four indicators of critical thinking skills: interpretation, analysis, evaluation, and inference. This instrument is designed to measure students' ability to understand concepts, analyze variable relationships, use problem-solving strategies, and draw conclusions based on data. Evaluation of the design stage is conducted to ensure alignment between the learning tools and the learning objectives, guided inquiry syntax, and critical thinking skill indicators. The evaluation results indicate that the designed tools are appropriate for learning needs and ready for further development.

Development

The development stage was carried out through the preparation of draft learning devices that included teaching modules (RPP), LKM, teaching materials, and assessment instruments which were then validated by three expert validators to assess the content, construct, and linguistic aspects. The validation results showed that all learning devices had a very high level of validity with a percentage between 84%–98.8% and a reliability value above 0.60, so that all devices were declared very valid and reliable for use in research.

Table 6. Validation results of parabolic motion learning devices

No	Validation types	Average Percentage	Category	Reliability
1	Teaching Module/Lesson Plan	87.5 %	Very valid	0.883
2	Worksheets	90.63%	Very valid	0.677
3	Teaching Materials	84 %	Very valid	0.794
4	Test Instruments	86.6%	Very valid	0.883
5	Implementation Sheets	90.63%	Very valid	0.635
6	Student Response Questionnaires	98.8%	Very valid	0.778

Following the validation process, the learning tools were revised based on validator input, including refining the formulation of learning objectives, adding illustrations to the worksheets, improving the presentation of teaching materials, refining question indicators, and adjusting the observation sheets for greater consistency. These revisions were conducted to enhance the quality of the tools before the implementation phase.

As part of the development phase, a limited trial was conducted with 32 students to assess the initial feasibility of the learning tools. Observation results indicated that the learning tools were in the very good category, with teacher implementation rates of 88.54% in the first cycle and 86.98% in the second cycle, while student implementation rates were 86.98% and 85.93%.

Furthermore, student responses to the learning tools were also in the very good category, with an average percentage of 87.93%, indicating that the learning tools were easy to use and engaging for students.

Table 7. Limited trial student response analysis

No	Aspect	Percentage	Category
1	Language and Appearance	89.52 %	Very good
2	Sports Education Learning	87.60 %	Very good
3	Guided Inquiry Syntax	84.40 %	Very good
4	Critical Thinking Skills	90.20%	Very good
	Average	87.93 %	Very good

The results of the initial effectiveness test showed an increase in scores from pretest to posttest with an average score increasing from 34.75 to 74.91 with an N-gain value of 0.62 (moderate category). The results of the statistical test also showed a significant difference between the pretest and posttest scores (Sig. <0.05) which indicates that the learning device was able to improve students' critical thinking skills.

Table 8. Descriptive statistics of pretest and posttest scores

Variabel	N	Mean	Std. Deviation	N-Gain Value
Pre-test	32	34.75	8.74	0.62
Post-test	32	74.91	9.63	
		N-gain category		Moderate

Based on the results of validity, initial practicality, and initial effectiveness, the developed learning device was declared valid, practical, and effective so that it was worthy of being continued to a wider implementation stage.

Implementation

The implementation phase was conducted through extensive trials of the learning tools in one experimental class and two replication classes to assess the practicality and effectiveness of the parabolic motion learning tools based on the guided inquiry model with a sports education approach.

The results of the learning implementation showed that all learning activities were in the very good category, with an average teacher implementation of 87.13% in cycle 1 and 87.84% in cycle 2, while student implementation was 85.41% and 87.32%. These results indicate that the learning tools can be implemented effectively in the learning process.

Table 9. Summary of learning implementation

No	Class	Percentage of Teacher Implementation (%)		Percentage of Student Implementation (%)	
		Cycle 1	Cycle 2	Cycle 1	Cycle 2
1	Experiment	87.47	90.10	85.41	870.50
2	Replication 1	84.37	87.49	85.93	88.02
3	Replication 2	86.45	89.06	84.89	86.45
	Average	87.13	87.84	85.41	87.32

Student responses to learning also showed a very good category with an average of 86.85% in the experimental class, 88.20% in replication class 1, and 87.88% in replication class 2. This shows that sports education and guided inquiry-based learning is able to increase student involvement in learning.

Table 10. Student response analysis

No	Aspect	Percentage/Class			Category
		Experiment	Cycle 1	Cycle 2	
1	Language and Appearance	90.20 %	87.60 %	89.52 %	Very Good
2	Sports Education Learning	84.40 %	89.50 %	87.60 %	Very Good
3	Guided Inquiry Syntax	88.20 %	86.46 %	84.40 %	Very Good
4	Critical Thinking Skills	84.40 %	89.24 %	90.20%	Very Good
	Average	86.85 %	88.20%	87.88 %	Very Good

The results of the effectiveness analysis showed an increase in the average pretest to posttest scores across all classes with N-gain values of 0.59, 0.59, and 0.62, respectively, which are in the moderate category. These results indicate that the learning device is effective in improving students' critical thinking skills.

Table 11. The average results of the post-test post-test scores and N-gain (Hake)

Class	Pretest Average	Post-Test Average	Average N-Gain
Experiment	33.25	72.17	0.59
Replication 1	31.64	71.19	0.59
Replication 2	34.03	74.47	0.62

The results of the statistical test showed that the data were normally distributed and homogeneous, and the t-test results showed a significant difference between the pretest and posttest scores (Sig. < 0.05). In addition, the ANOVA test results showed no significant difference in the increase in critical thinking skills between classes (Sig. > 0.05), which indicates that the learning tools had a consistent effect on all classes.

Table 12. Results of normality and homogeneity tests

Value	Class	Normality Test (Shapiro Wilk)	Homogeneity Test (Levene Statistic)
N-gain	Experiment	0.604	0.190
	Replication 1	0.808	
	Replication 2	0.287	

Table 13. Wilcoxon t-test results

Data Pair	Mean Difference	Std. Deviation	t	df	Sig.(2-tailed)
Experimental Class	-38.91 667	9.2	-25.379	35	0.000
Replication Class 1	-40.444	7.37	-32.893	35	0.000
Replication Class 2	-38.91	9.2	-25.379	35	0.000
Decision criteria		Sig. ≤ 0.05	Significant differences were found		

Table 14. ANOVA N-gain test results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0.00438	2	0.00219	0.876	0.419
Within Groups	1.34418	105	0.01280		
Total	1.34856	107			

In addition, improvements in critical thinking skills are also seen in all indicators, namely interpretation, analysis, evaluation, and inference, which show a moderate improvement category.

Table 15. N-gain value for each critical thinking skills indicator

No	Critical thinking skills indicators	Class N-gain Value		
		Experiment	Replication 1	Replication 2
1	Interpreting	0.58	0.57	0.57
2	Analyzing	0.51	0.50	0.49
3	Evaluating	0.61	0.62	0.63
4	Inferring	0.65	0.64	0.63

Evaluation

The evaluation phase was conducted to ensure that the developed learning tools met the criteria for validity, practicality, and effectiveness. The evaluation results indicated that the learning tools, including lesson plans (RPP), worksheets (LKM), teaching materials, and assessment instruments, were declared valid based on expert assessments of content, construction, language, and appropriateness of the learning model.

From a practical perspective, the learning tools demonstrated excellent learning implementation and received positive feedback from students, indicating that they were easy to use and capable of increasing student engagement in learning. From an effectiveness perspective, the increase in pretest-posttest scores and the moderate N-gain value indicated that the learning tools were effective in improving students' critical thinking skills. Overall, the evaluation results indicated that the parabolic motion learning tools based on a guided inquiry model with a sports education approach met the criteria for validity, practicality, and effectiveness, making them suitable for use in high school physics instruction.

Discussion

Validity

Validation results by three validators indicate that all developed learning tools, including the teaching module (RPP), worksheets (LKM), teaching materials, critical thinking skills test instruments, implementation observation sheets, and student response questionnaires, achieved a validity percentage of 84% to 98%, categorized as highly valid. This percentage exceeds the minimum eligibility threshold of 81%, thus declaring the learning tools suitable for use in learning.

The teaching module (RPP) achieved a validity percentage of 87.5%, indicating the suitability of the learning objectives, media selection, materials, and learning scenarios to the standards for developing learning tools (Ministry of Education and Culture, 2022). These results are consistent with Branch (2020), who stated that learning modules are considered appropriate when they include clear learning objectives, relevant materials, and systematic instructional procedures. Furthermore, the use of communicative and unambiguous language is also an important indicator in determining the readability and effectiveness of learning materials (Mayer, 2021).

The worksheet achieved a validity percentage of 90.6%, indicating its suitability to student needs and the stages of guided inquiry. This aligns with Hidayat et al. (2022), who stated that worksheets with a validity above 81% are considered highly valid. Furthermore, the structure of the worksheet, which includes inquiry stages and an attractive visual design, also aligns with the findings Mayer (2021), who stated that valid worksheets must have clear learning objectives, systematic inquiry stages, and a display that suits student characteristics.

The teaching materials achieved a validity percentage of 84%, indicating that the material was systematically structured using communicative language and supported by concept visualizations. This aligns with Kurniawan et al. (2020), who stated that teaching materials are considered valid if they are structured coherently, use easy-to-understand language, and are complemented by visualizations that support understanding of physics concepts.

The critical thinking skills test instrument achieved a validity of 86.6%, while the implementation observation sheet achieved a validity of 90.6%, indicating the indicators' suitability to the syntax of guided inquiry. These findings align with those of Retnawati (2020), who stated that an observation sheet is valid if its indicators objectively represent the learning stages. The student response questionnaire achieved the highest percentage, at 98.8%, indicating its suitability for measuring student perceptions and engagement in learning. This aligns with Taherdoost (2021), who stated that a questionnaire response is considered valid if it accurately reflects student interest and engagement in the learning model. Overall, the validation results indicate that the learning tool aligns with learning outcomes, guided inquiry syntax, sports education principles, and critical thinking skill indicators, making it suitable for use in physics learning.

Practicality

The practicality of the learning tools was assessed based on their implementation and student responses. Observations showed that all aspects of learning, including introductory, core, and closing activities, time management, and classroom atmosphere, were in the very good category, with percentages exceeding 61% in all three classes. In the limited trial, the teacher's implementation of the learning tools averaged 88.54% and the students' 86.98%. In the extensive trial, the teacher's implementation of the learning tools in the experimental class reached 87.49% in cycle 1 and 90.10% in cycle 2, in replication class 1 at 84.37% and 87.49%, and in replication class 2 at 86.45% and 89.06%. These results demonstrate that the learning tools can be implemented consistently in accordance with the lesson plan design and guided inquiry syntax.

The implementation of the learning tools also demonstrated that student activities followed the inquiry stages, from formulating problems, developing hypotheses, designing and implementing experiments, analyzing data, and drawing conclusions. This indicates that the learning device demonstrates clear steps, integrated activities, and conforms to the characteristics of process-based science learning (Pedaste et al., 2015). Furthermore, the results of the student response questionnaire showed a very good rating with an average percentage of 87.88%. Students assessed that the worksheet design was engaging, the learning steps were systematic, and the sports education-based learning facilitated understanding of the concept of parabolic motion. This learning also trained students in identifying problems, analyzing data, and drawing conclusions independently, thereby increasing active engagement in learning.

The positive student responses indicated that the learning device was easy to use and capable of creating an active, collaborative, and conducive learning atmosphere. This finding aligns with research by Sari et al. (2021), which stated that a collaborative learning environment based on real-life activities can improve the quality of learning interactions and the effectiveness of implementing the inquiry model in science learning. Based on the results of the learning implementation and student responses, it can be concluded that the developed learning device meets practical criteria because it is easy to use, can be implemented according to plan, and receives positive responses from students.

Effectiveness

The effectiveness of the learning device was assessed based on improvements in critical thinking skills based on pre-test and post-test results, the N-gain value, and the fulfillment of statistical assumptions. The results showed an N-gain value in the limited trial of 0.62 (moderate category). In the extensive trial, the average N-gain for the experimental class was 0.59, replication class 1 was 0.59, and replication class 2 was 0.62, all of which were in the moderate category.

The results of normality and homogeneity tests showed a significance value >0.05, indicating normally distributed and homogeneous data. The paired t-test showed a significant increase between pre-test and post-test scores, while the ANOVA test showed a significance value of 0.419 >0.05, indicating no significant differences between classes. This indicates that the learning device was consistently effective across student groups. These findings align with the principle of learning device effectiveness, which states that a device is considered effective if it has a relatively uniform impact on various target groups.

Improvements also occurred across all critical thinking skill indicators: interpretation, analysis, evaluation, and inference, with moderate gains. The inference and evaluation indicators showed higher increases than the analysis indicator, indicating that the learning tools were more effective in developing inference and evaluation skills than analytical skills. The effectiveness of these learning tools can also be explained through constructivism theory, which emphasizes that knowledge is built through meaningful learning experiences. Sports education-based learning allows students to construct an understanding of the concept of parabolic motion through direct experience, while the guided inquiry syntax supports the scientific reasoning process through the stages of formulating problems, formulating hypotheses, making observations, analyzing data, and drawing conclusions.

The results of this study are also supported by research by Sutopo et al. (2021), which showed that a guided inquiry model based on performance assessment effectively improves students' critical thinking skills through active engagement in the inquiry process. However, this study did not integrate a sports education approach. In this study, this approach was enhanced through teamwork, student role allocation, and sports-based contextual learning activities, providing a more comprehensive learning experience. These findings align with research by Mardiyanti and Jatmiko (2022), which demonstrated that a guided inquiry model assisted by PhET effectively improves students' critical thinking skills. However, that study focused on digital simulations, while this study integrates real-world contexts through a sports education approach, making learning more contextual and collaborative.

Furthermore, research by Rizki et al. (2021) demonstrated that a guided inquiry-based student worksheet (LKM) on parabolic motion has high validity and supports students' cognitive engagement. Unlike that study, this study developed a learning tool with a sports education approach that emphasizes not only concept exploration but also social interaction and collaboration, thus potentially enhancing critical thinking skills more comprehensively. Overall, the results of this study indicate that a parabolic motion learning tool based on a guided inquiry model with a sports education approach is effective in improving students' critical thinking skills.

CONCLUSION

Fundamental Findings: This research produced a parabolic motion learning tool based on a guided inquiry model with a sports education approach that met the criteria for validity, practicality, and effectiveness in improving high school students' critical thinking skills. The tool's validity was demonstrated by expert assessment results with a very valid category. Practicality was demonstrated by excellent learning implementation and positive student responses. Effectiveness was demonstrated by consistent increases in pretest-posttest scores and moderate N-gain across all classes. These findings demonstrate that integrating a guided inquiry model with a sports education context can create more contextual and meaningful physics learning. **Implications:** The results of this study imply that a guided inquiry-based learning tool with a contextual approach, such as sports education, can be an innovative alternative in physics learning to train students' critical thinking skills. Furthermore, this study also demonstrates the importance of linking physics concepts to real-world phenomena to make learning more relevant, increase student engagement, and support 21st-century learning oriented toward higher-order thinking skills. **Limitations:** This study is limited by the sample size, which is limited to one school, and the material focused on parabolic motion. Furthermore, effectiveness measurements are still limited to improving critical thinking skills, thus not fully examining the device's influence on other 21st-century skills such as creativity or collaboration. **Future Research:** Further research is recommended to develop similar learning devices for other physics topics and involve a wider sample to test the consistency of the device's effectiveness. Furthermore, future research could also examine the integration of sports education approaches with digital technology or other innovative learning models to more comprehensively enhance various 21st-century skills.

AUTHOR CONTRIBUTIONS

Widi Astutik: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing – original draft. **Wasis:** Supervision, Validation,

Methodology, Writing – review & editing. **Budi Jatmiko:** Supervision, Validation, Project administration. **Noer Risky Ramadhani:** Writing – review & editing.

CONFLICT OF INTEREST STATEMENT

The authors confirm that there are no conflicts of interest, either financial or personal, that may have influenced the content or outcome of this study.

ETHICAL COMPLIANCE STATEMENT

This manuscript complies with research and publication ethics. The authors affirm that the work is original, conducted with academic integrity, and free from any unethical practices, including plagiarism.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors acknowledge the use of digital tools, including AI-based technologies, to support the research and writing processes of this article. Specifically, Mendeley was utilized for reference management and citation formatting, SPSS was used to conduct statistical analysis of the research data, and ChatGPT (OpenAI) was employed as a writing assistant to help refine language and organize the structure of the manuscript. All content generated with digital assistance was critically reviewed, validated, and revised by the authors to ensure academic integrity and ethical standards were maintained. The final responsibility for the content of this manuscript rests entirely with the authors.

REFERENCES

Adair, R. K. (2021). *The physics of sports*. HarperCollins. https://www.harpercollins.com/products/the-physics-of-sports-robert-k-adair

Adeoye, M. A. (2024). Unleashing the power of the ADDIE model for effective teaching and learning. *Jurnal Pendidikan Indonesia*, 13(2), 150–162. https://doi.org/10.23887/jpiundiksha.v13i1.68624

Adilla, I. N., & Jatmiko, B. (2021). Keefektifan pembelajaran daring fisika SMA berbasis probing prompting untuk meningkatkan keterampilan berpikir kritis peserta didik. *PENDIPA Journal of Science Education*, 5(3), 426–435. https://doi.org/10.33369/pendipa.5.3.426-435

Aldoobie, N. (2020). ADDIE model. *American International Journal of Contemporary Research*, 10(2), 1–7. http://www.aijcrnet.com/journals/Vol_5_No_6_December_2015/10.pdf

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2020). Does discovery-based instruction enhance learning? *Journal of Educational Psychology*, 112(1), 1–18. https://doi.org/10.1037/a0021017

Amijaya, L. S., dkk. (2018). Pengaruh model pembelajaran inkuiri terbimbing terhadap hasil belajar dan kemampuan berpikir kritis murid. *Jurnal Pijar MIPA*, 13(2), 94 – 99. https://doi.org/10.23887/jlls.v2i1.17322

Arikunto, S. (2013). Prosedur *penelitian suatu pendekatan praktik (edisi revisi)*. Rineka Cipta.

Arikunto, S. (2016). Dasar-dasar evaluasi pendidikan (edisi ke-2). Bumi Aksara.

Bao, L. (2020). Theoretical comparisons of average normalized gain calculations. *American Journal of Physics*, 88(7), 1–8. https://doi.org/10.1119/10.0001599

Branch, R. M. (2020). *Instructional design: The ADDIE approach*. Springer. https://doi.org/10.1007/978-0-387-09506-6

Budiarti, I. S. (2023). *Indra penglihatan*; Mata. Bumi Aksara.

Ciesielska, M., Boström, D., & Öhlander, M. (2018). Observation methods in qualitative research: A review. *The Qualitative Report*, 23(11), 2603–2612. https://doi.org/10.46743/2160-3715/2018.3340

Cohen, L. (2007). *Research methods in education (6th ed*). Routledge. https://doi.org/10.4324/9780203029053

Facione, P. A. (2011). *Critical thinking: what it is and why it counts*. Measured Reasons and The California Academic Press. https://www.insightassessment.com/article/critical-thinking-what-it-is-and-why-it-counts

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. (2021). Experimental studies of inquiry-based science teaching. *Review of Educational Research*, 91(3), 410–460. https://doi.org/10.3102/0034654312457206

Giancoli, D. C. (2021). *Physics: Principles with applications* (8th ed.). Pearson. https://www.pearson.com

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64–74. https://doi.org/10.1119/1.18809

Hattie, J. A., & Donoghue, G. M. (2016). Learning strategies: A synthesis and conceptual model. *npj Science of Learning*, 1(1), 1-13. https://doi.org/10.1038/npjscilearn.2016.13

Hayati, N., & Setiawan D. (2022). dampak rendahnya kemampuan berbahasa dan bernalar terhadap kemampuan berfikir kritis murid sekolah dasar. *Jurnal Basicedu* 6(1), 8517-8528. https://doi.org/10.31004/basicedu.v6i5.3790

Hidayat, R., Festiyed, F., & Asrizal, A. (2022). Desain LKPD berorientasi pembelajaran terpadu tipe jaring laba-laba untuk pembelajaran ipa kelas viii SMPN 1 Painan. *Pillar of Physics Education*, 8(1), 12-23. http://dx.doi.org/10.24036/2471171074

Johnson, E. B. (2020). *Contextual teaching and learning: What it is and why it's here to stay*. Corwin Press. https://us.corwin.com

Khoirunnisa, J. P. N., & Dwikoranto, D. (2021). Profil keterampilan berpikir kritis murid dalam penyelesaian masalah materi hukum Newton. *Edukatif: Jurnal Ilmu Pendidikan*, 3(3), 806–816. https://doi.org/10.31004/edukatif.v3i3.384

Kurniawan, D. A., Astalini, A., & Darmaji, D. (2020). Evaluation of students' critical thinking skills using performance assessment in science learning. *International Journal of Evaluation and Research in Education,* 9(4), 1030–1038. https://doi.org/10.11591/ijere.v9i4.20481

Mardiyanti, N. E. A., & Jatmiko, B. (2022). Keefektifan pembelajaran fisika dengan model inkuiri terbimbing berbantuan simulasi PhET untuk meningkatkan kemampuan berpikir kritis murid. *Jurnal Inovasi Pendidikan Fisika*, 11(3), 455–463. https://doi.org/10.20527/jipf.v6i2.5281

Mayer, R. E. (2021). *Multimedia learning* (3rd ed.). Cambridge University Press. https://doi.org/10.1017/9781316941355

Ministry of Education, Culture, Research, and Technology. (2022). *Guidelines for curriculum implementation*. Kemendikbudristek.

Nathan, A. M., & Sawyer, R. K. (2022). *Learning through physical activity and sport*. Routledge.

OECD. (2021). *21st century readers: Developing literacy skills in a digital world*. OECD Publishing. https://doi.org/10.1787/a83d84cb-en

OECD. (2023). *PISA 2022 results*. OECD Publishing. https://doi.org/10.1787/53f23881-en

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A., Kamp, E. T., Manoli, C. C., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, 14, 47–61. https://doi.org/10.1016/j.edurev.2015.02.003

Purwanto. (2013). *Evaluasi Hasil Belajar*. Pustaka Pelajar.

Retnawati, H. (2020). Validity and reliability of assessment instruments for measuring students' higher order thinking skills. *International Journal of Instruction*, 13(2), 355–370. https://doi.org/10.29333/iji.2020.13224a

Riduwan, & Akdon. (2013). *Rumus dan data dalam analisis statistik (Edisi Kedua)*. Alfabeta.

Rizki, I. A., Widodo, W.. (2021). Eksperimen dan respon mahasiswa terhadap praktikum fisika non-laboratorium menggunakan aplikasi Tracker video analysis untuk percobaan kinematika gerak. *Journal of Teaching and Learning Physics*, 6(2), 77–89. http://dx.doi.org/10.15575/jotalp.v6i2.12640

Saavedra, A. R., & Opfer, V. D. (2012). Learning 21st-century skills requires 21st-century teaching. *Phi Delta Kappan*, 94(2), 8-13. https://doi.org/10.1177/003172171209400203

Handayani, N., Aw, S., Zamroni, M. I., Setiawan, J., & Fadli, M. R. (2024). Development of higher order thinking skill assessment instruments in social studies learning. *International Journal of Evaluation and Research in Education (IJERE)*, 13(2), 923-933. http://doi.org/10.11591/ijere.v13i2.26448

Sanjaya, W. (2013). Penelitian Pendidikan: Jenis, Metode, dan Prosedur. Kencana Prenada Media Group.

Sari, D. P., Widodo, A., & Wiyanto. (2021). Development of physics teaching materials based on contextual learning to improve students' critical thinking skills. *Journal of Physics: Conference Series*, 1806(1), 012123. https://doi.org/10.1088/1742-6596/1806/1/012123

Sari, R. P., Supahar, & Kuswanto, H. (2020). Development of student worksheets based on scientific inquiry to improve physics learning outcomes. *Journal of Physics: Conference Series*, 1440(1), 012061. https://doi.org/10.1088/1742-6596/1440/1/012061

Sari, Ratna. (2016). Kemampuan berfikir kritis dan pemahaman konsep fisika murid sma pada materi hukum newton. Pascasarjana Universitas Negeri Malang.

Serway, R. A., & Jewett, J. W. (2020). *Physics for scientists and engineers* (10th ed.). Cengage Learning. https://www.cengage.com

Kurniawan, D. A., Astalini, A., & Darmaji. (2020). Evaluation of students' critical thinking skills using performance assessment. *International Journal of Evaluation and Research in Education, 9*(4), 1030–1038. https://doi.org/10.11591/ijere.v9i4.20481

Sudjana. (2005). *Metode Statistika*. Tarsito.

Sugiyono. (2015). *Metode penelitian pendidikan: pendekatan kuantitatif, kualitatif, dan R&D*. Alfabeta.

Sumintono, B., & Widhiarso, W. (2014). *Aplikasi model rasch untuk penelitian ilmu-ilmu sosial*. Bumi Aksara.

Sutopo, S., Wartono, W., & Diantoro, M. (2021). Guided inquiry learning in physics education: Its impact on students' conceptual understanding and critical thinking skills. *Jurnal Pendidikan IPA Indonesia*, 10(3), 368–378. https://doi.org/10.15294/jpii.v10i3.30409

Taherdoost, H. (2021). Data collection methods and tools for research: A step-by-step guide to choose data collection technique. *International Journal of Academic Research in Management*, 10(1), 10–38. https://hal.science/Hal-03741847/

Usmadi. (2020). *Pengujian hipotesis: analisis data statistik parametrik dan non-parametrik*. Prenada Media. https://prenadamedia.com

Wicaksono, A. G., & Madlazim. (2020). Penerapan pembelajaran berbasis aktivitas kontekstual untuk meningkatkan keterampilan berpikir kritis murid. *Jurnal Inovasi Pendidikan IPA*, 6(1), 12–21. https://doi.org/10.21831/jipi.v6i1.28461

World Economic Forum. (2020). *The future of jobs report*. WEF. https://www.weforum.org/publications/the-future-of-jobs-report-2020/

Zion, M., & Mendelovici, R. (2021). Moving from structured to open inquiry. *Science Education International*, 32(1), 1–10. https://files.eric.ed.gov/fulltext/EJ997103.pdf

***Widi Astutik (Corresponding Author)**
Physics Education, Universitas Negeri Surabaya
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: 24031635002@mhs.unesa.ac.id

Wasis
Physics Education, Universitas Negeri Surabaya
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: wasis@unesa.ac.id

Budi Jatmiko
Physics Education, Universitas Negeri Surabaya
Jl. Ketintang, Ketintang, Kec. Gayungan, Surabaya, Jawa Timur 60231
Email: budijatmiko@unesa.ac.id

Noer Risky Ramadhani
Mae Fah Luang University
333 Moo 1, Tha Sut, Muang, Chiang Rai 57100, Thailand
Email: ramadhanirisky52@gmail.com