

The Effectiveness of Guided Inquiry Through Flashcard Media on Force Material to Important Critical Thinking Skills of Elementary School Students

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Abstract: Critical thinking skills are essential 21st-century competencies that students must master. However, the results of PISA 2022 show that Indonesian students scored only 383 in science, far below the OECD average of 489, indicating weak analytical and problem-solving abilities. This study was motivated by persistent challenges in developing critical thinking skills among Indonesian elementary students, as indicated by consistently low PISA scores. It investigates the effectiveness of integrating the Guided Inquiry learning model with flashcards to enhance fourth-grade students' critical thinking skills, specifically regarding the abstract topic of force in science. Employing a pre-experimental design with a one-group pretest-posttest method, the research involved 30 purposively selected students from SD Negeri 3 Kalipucangkulon. Data were collected through critical thinking skill tests and analyzed using the Paired Samples T-Test, Cohen's *d* for effect size, and supported by the Shapiro-Wilk normality test. The results revealed a statistically significant and substantial improvement: the mean pretest score of 51.0 (SD=15.11) increased to 77.1 (SD=5.00) in the posttest, with a mean difference of 26.1 points. Statistical analysis confirmed a highly significant difference ($t(29) = -11.0, p < 0.001$) and a very large effect size (Cohen's $d = 2.01$). These findings demonstrate that the synergistic combination of Guided Inquiry's investigative framework and the concrete, engaging nature of flashcard media is highly effective in fostering students' analytical, evaluative, and inferential skills. The study concludes that this integrated strategy offers a practical and impactful approach to creating interactive, higher-order thinking-oriented science learning in elementary schools, addressing a crucial gap in 21st-century science education. The limitations of this study, particularly the lack of a control group, highlight the necessity for subsequent research employing more rigorous designs.

Keywords: Critical Thinking; Elementary School Science; Guided Inquiry; Flashcard; Force Material.

Introduction

The development of science and technology in the 21st century requires students to possess higher-order thinking skills (HOTS). Core 21st-century skills emphasized in education include critical thinking, communication, collaboration, and creativity, commonly known as the 4C skills. Twenty-first-century learning emphasizes creativity, critical thinking, collaboration, problem-solving, communication skills, social skills, and character development, where problem-solving ability is a key indicator of critical thinking skills [1]. The importance of these skills becomes evident in 21st-century education, which is not limited to traditional literacy, such as reading and memorization, but also includes critical and creative thinking as well as problem-solving abilities in daily life [2].

The OECD report, based on the Programme for International Student Assessment (PISA) in 2022, showed that Indonesian students' science scores were 383, far below the OECD average of 489. Similar findings were reported in TIMSS 2019, where Indonesian students achieved an average science score of 397, indicating weak analytical and problem-solving skills. Indonesian students' science achievement remains relatively low compared to other countries. These findings are supported by PISA 2015 results, which showed Indonesian students scored 403, still below the international average of 493, despite improvement

from previous years [3]. These data confirm that Indonesian students have not yet fully mastered 21st-century competencies, particularly critical thinking. Critical thinking skills constitute a fundamental basis for addressing global challenges, fostering students' ability to solve problems, make rational decisions, and engage in logical and systematic reasoning [4].

Critical thinking skills serve as a foundation for facing global challenges, as they encourage students to solve problems, make rational decisions, and think logically and systematically. Through critical thinking, students are trained to analyze, evaluate, and make decisions based on logical reasoning and accountable evidence [4]. Conceptually, critical thinking is the ability to make well-directed, consistent judgments about what actions to take, based on logical reasoning and valid evidence. It is a higher-level cognitive ability used to analyze, evaluate, and make decisions based on evidence and logical reasoning. Critical thinking is a process of purposeful, self-regulatory judgment that involves the interpretation, analysis, evaluation, and inference of obtained information [5]. Critical thinking is the ability to use reflective thinking processes to assess the accuracy and relevance of information in problem-solving [6].

In learning contexts, critical thinking helps students relate concepts to real-life experiences, evaluate evidence objectively, and draw logical and accountable conclusions

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[4]. Therefore, critical thinking skills are essential to develop from elementary school so that students can reason and make intelligent decisions in facing various life challenges. Based on Bloom's Taxonomy and HOTS learning, Anderson & Krathwohl state that HOTS includes analyzing, evaluating, and creating, which are the highest levels of the revised Bloom's Taxonomy [7]. Critical thinking is a cognitive process that involves the logical, systematic, and reflective evaluation of information. Thus, developing critical thinking skills in elementary school students is an important step toward improving learning quality. In the guided inquiry learning model, teachers guide students in formulating initial hypotheses (initial questions) and direct them to discuss ways to solve problems [8]. This is because IPAS learning trains students to understand natural phenomena through observing, reasoning, investigating, and drawing conclusions.

However, the ideal implementation of such learning is not always achieved in practice, particularly in building an understanding of abstract concepts [9]. Low student interest and focus are the main causes of difficulties in understanding material, in line with Piaget's theory that elementary school students are still in the concrete operational stage, making media-assisted science learning more effective [10]. Critical thinking indicators in the study of force encompass students' capacity to relate the concept of force to daily phenomena, articulate causal relationships in the motion of objects, and assess the reliability of observational data [11]. Thus, assessing critical thinking skills in science learning on force topics involves not only final answers but also students' scientific thinking processes during experiments. Elementary students' critical thinking skills remain low, as students tend to recall information without a deep understanding [12]. PISA 2022 data reported that Indonesian students' average critical thinking score reached only 379, far below the international average of 500 [13].

Observations and interviews conducted at SD Negeri 3 Kalipucangkulon revealed that the fourth-grade teacher is aware of using appropriate methods and simple practices in teaching Science and Social Studies (IPAS). Field facts also show that several innovative learning processes have been implemented, such as Project-Based Learning (PjBL) and Problem-Based Learning (PBL). However, about ten percent of students still struggle to understand the concept of force due to its abstract nature. The learning outcomes indicate that the topic of force has a lower average score (64.77) compared to other IPAS topics, with the highest score being 82 and the lowest being 36. This condition aligns with Slavin's theory, stating that science concept understanding remains low if students are not actively engaged in deep thinking processes [14]. Understanding science concepts requires concrete learning experiences to help students relate real phenomena to abstract concepts [15]. Additionally, low reading interest, self-confidence, and observational and reasoning skills contribute to weak critical thinking abilities.

These difficulties are consistent with findings showing that elementary students often experience misconceptions in force concepts due to abstract and memorization-focused learning. Without direct experience, students struggle to explain how forces affect motion or shape changes [16]. This indicates that IPAS learning at SD Negeri 3 Kalipucangkulon still needs improvement, particularly in conceptual understanding of force and critical

thinking skills. These issues demand learning innovations that foster critical thinking skills [17]. Students require learning approaches that enable them to observe, investigate, and discover concepts through direct experience. One approach with strong potential to enhance critical thinking is the guided inquiry learning model. Guided inquiry emphasizes scientific investigation activities with teacher guidance to discover concepts based on direct experience [12]. Students are trained to think logically and systematically through stages of observing, problem formulation, hypothesis generation, experimentation, data analysis, and conclusion drawing [18].

However, studies also reveal weaknesses in guided inquiry. Guided inquiry requires considerable time and students often lose focus without engaging learning media [19]. Furthermore, they emphasized that the effectiveness of the approach is highly contingent upon the teacher's facilitation skills. Its success depends heavily on teachers' facilitation skills [12]. found that without concrete media such as flashcards, inquiry-based learning is less effective in helping students understand abstract concepts like force and energy [20]. Therefore, learning media that facilitate exploration and increase engagement are needed. Flashcards are considered a solution to overcome these limitations. Flashcards are visual media that present images and brief information to help students understand concepts in an engaging, concrete way. This media not only increases learning interest but also supports inquiry activities involving exploration and independent concept discovery [19].

Several studies have demonstrated the effectiveness of using concrete media in inquiry-based learning. The implementation of a guided inquiry learning model assisted by flashcards had a more positive impact compared to conventional models on students' learning competence in the topic of matter and its changes, with an average N-Gain of 0.71 (high category) [21]. Furthermore, Minallahalibada and Nurhablum 2025 found that the inquiry model assisted by flashcards was more effective than the expository model in enhancing student activeness (84.30 vs 70.93) as well as learning outcomes (87.67 vs 80.67) [22]. These findings affirm that concrete learning media, such as flashcards, can strengthen the role of inquiry in helping students grasp abstract concepts while simultaneously increasing their engagement in the learning process. Even demonstrated that augmented reality-based flashcards significantly increased elementary students' science participation [23].

Based on the above literature review, this study offers a novelty that explicitly distinguishes it from previous research. First, although several studies have examined the integration of guided inquiry with flashcards [22], most have focused on improving general learning competence or on different topics such as matter and its changes, as well as non-science subjects. This study specifically targets the topic of force among fourth-grade students, an abstract concept that often leads to misconceptions. Second, previous research developed teaching materials to reduce misconceptions, whereas this study directly measures the impact on critical thinking skills using a rigorous pre-experimental design [20]. Third, unlike studies that employed advanced technologies such as Augmented Reality [23] this study utilizes simple and accessible flashcard media, making it more relevant to elementary

school contexts with limited technological resources. Fourth, and most crucially, no prior empirical study has integrated guided inquiry with flashcard media on the topic of force at the elementary level, and none has included an effect-size analysis using Cohen's *d* to statistically measure the magnitude of the intervention's impact. This study not only tests the significance of differences (*p*-value) but also quantifies the extent of the treatment effect ($d = 2.01$), which falls into the very large effect category, making a methodological contribution that strengthens the validity and interpretation of the findings.

Thus, this study fills a specific gap in the literature by providing empirical evidence on the effectiveness of combining guided inquiry and flashcards on the topic of force, with a robust effect-size analysis. Based on this discussion, combining guided inquiry with flashcard media is expected to improve fourth-grade students' critical thinking skills and understanding of force concepts at SD Negeri 3 Kalipucangkulon, addressing the school's need to enhance HOTS-based learning and strengthen modern competencies in Indonesian elementary education.

Research Methods

This study employed a quantitative, pre-experimental design to examine the effect of guided inquiry supported by flashcard media on elementary students' critical thinking skills. This method is suitable for educational research focusing on measuring learning outcome changes before and after treatment [24]. The selection of a pre-experimental design was based on practical considerations and the exploratory nature of this study, which aimed to examine the effectiveness of an intervention in real classroom settings without disrupting ongoing learning processes. Although this design has limitations in terms of internal validity due to the absence of a control group, it is considered appropriate for the initial purpose of a proof-of-concept before conducting further research with more rigorous designs.

Although the pre-experimental design has limitations in terms of internal validity due to the absence of a control group, it was chosen for critical and contextual considerations. First, this is an initial pilot study aimed at exploring the effectiveness of integrating the guided inquiry model with flashcard media in a specific context: fourth-grade students at SD Negeri 3 Kalipucangkulon. Pre-experimental designs are often employed in early-stage educational research to obtain initial estimates of an intervention's effects before conducting more rigorous trials with pure experimental designs [25]. Second, practical constraints related to population size and resources (time, effort, and cost) were taken into account. The school where the study was conducted only had one fourth-grade class with a limited number of students (30), making it impossible to form an equivalent control group without disrupting the natural learning process. Third, this design allowed the researcher to conduct in-depth observations of the changes within a single group, aligning with the objective of understanding the dynamics of critical thinking skill development more holistically before broader generalization. Thus, although the findings cannot be widely generalized without replication, this design still provides valuable empirical contributions as a foundation for subsequent experimental research.

The study was conducted at SD Negeri 3 Kalipucangkulon, Jepara Regency, during the even semester of the 2025/2026 academic year. The sample consisted of 30 fourth-grade students selected purposively based on low critical thinking engagement in science learning. The research population consisted of all fourth-grade students. The sampling technique used in this study was saturated sampling. In this technique, all members of the population, totalling 30 fourth-grade students, were included as research samples. The choice of this method was based on the relatively small, homogeneous population, which enabled the researcher to obtain more complete and representative data. By employing saturated sampling, the study was able to portray the actual condition of the entire class without the need to select specific samples. This approach is consistent with the research objective, which aims to comprehensively examine the effectiveness of the Guided Inquiry model, supported by flashcards, on students' critical thinking skills.

The research instrument was a critical thinking skills test consisting of 25 multiple-choice items developed based on Facione's critical thinking indicators (interpretation, analysis, evaluation, inference). The research procedure consisted of three stages: preparation: developing learning tools (teaching modules, student worksheets, flashcard media) and test instruments; implementation: administering a pretest, applying guided inquiry learning assisted by flashcards over four sessions, and administering a posttest; analysis: processing and analyzing the data.

Data quality testing included instrument validity testing using Pearson Product-Moment and reliability testing using Cronbach's Alpha. Statistical assumption tests included normality (Shapiro-Wilk) and homogeneity of variances (Levene's Test). Since the data were normally distributed, a paired-samples *t*-test was used to compare the pretest and posttest mean scores. To determine the magnitude of the treatment effect, Cohen's *d* was used to calculate the effect size, with the following interpretations: small ($d = 0.2$), medium ($d = 0.5$), large ($d = 0.8$), and very large ($d > 0.8$).

Results and Discussion

This research is a quantitative study using a pre-experimental, one-group pretest-posttest design. This design was chosen to measure the effect of the treatment, namely the implementation of a guided inquiry learning model assisted by flashcard media, on improving students' critical thinking skills in the material on force. Quantitative data were obtained from a comparison of pretest and posttest scores, which were then analyzed statistically to test the significance and magnitude of the treatment effect.

Instrument Validity and Reliability Test Result

The initial stage of this research involved preparing the data collection instrument. The researcher tested the validity and reliability of 25 designed question items. These items were piloted with fifth-grade students on relevant subjects, as they had an understanding of the IPAS material on force and the environment. A good instrument must be valid, practical, and reliable. The following table shows the validity test results.

Table 1. Validity Test Result

No	1	2
Parameter	Valid	Tidak Valid
Nomor	3,4,5,8,9,10,11,12,13,14	1,2,6,7,17,22
Soal	,15,16,18,19,20,21,23,24,25	
Total	19	6

Table 2. Reliability Test Result

	Cronbach's α
scale	0.805

Instrument validity and reliability tests were conducted on 25 test items administered to fifth-grade students. Results showed 19 valid items and 6 invalid items. The analysis results indicate that the correlation matrix shows several significant relationships, including between items 10 and 4 ($r = 0.510, p = 0.003$) and between items 11 and 8 ($r = 0.647, p < 0.001$). The reliability of the scale is categorized as good, with a Cronbach's α value of 0.805. Items 25, 11, and 23 contributed most to the scale's internal consistency. If an instrument lacks sufficient validity, it will not produce accurate data, which may affect the accuracy of

the research results [26]. In line with Anwar's criteria, an alpha value above 0.70 indicates that the instrument is reliable and suitable for use in research.

Normality Test Result

Table 3. Normality Test (Shapiro-Wilk)

Variabel	W	P
Pretes-Postes	0.946	0.133

The Shapiro-Wilk normality test yielded a p-value of 0.133 ($p > 0.05$). This indicates that the data are normally distributed, thus meeting the t-test assumption.

Descriptive Statistics Of Pretest and Posttest

Table 4. Descriptiv Statistic

	N	Mean	Median	SD	SE
Pretes	30	51.0	53.0	15.11	2.758
Postes	30	77.1	76.5	5.00	0.913

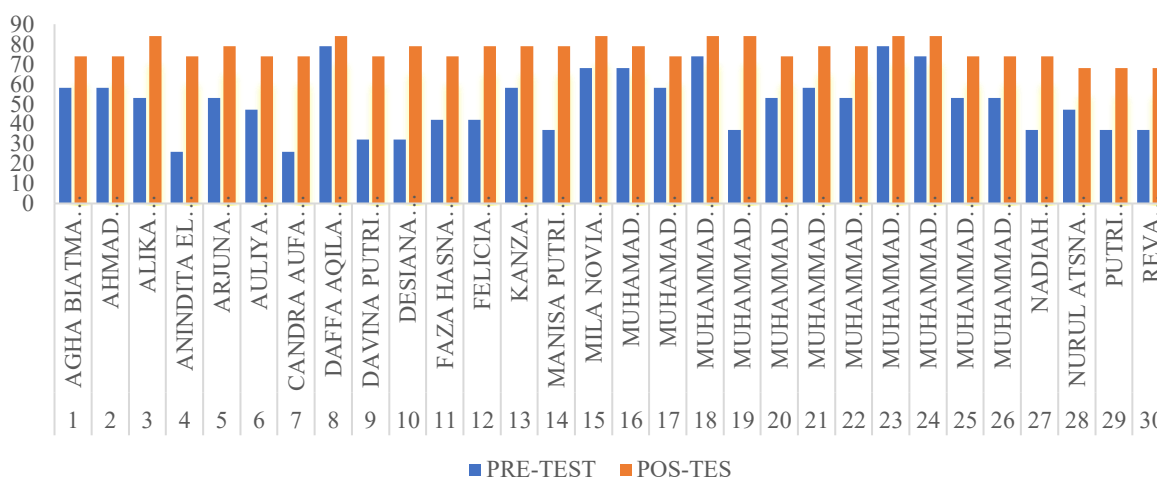


Figure 1. Pretest and Posttest Results of Students' Critical Thinking Skills

The mean pretest score was 51.0 with a standard deviation of 15.11. The wide variation in students' initial abilities was evident. After receiving the intervention, a guided inquiry learning model supported by flashcards, the mean posttest score increased significantly to 77.1, with a smaller standard deviation (5.00). Students' critical thinking skills improved significantly, with an average increase of 26.1 points. This average gain of 26.1 points indicates a strong positive effect of the learning intervention. The reduced standard deviation in the posttest suggests that, following the intervention, students' critical thinking abilities became more uniform. The statistical significance of this improvement was tested using a paired samples t-test. The hypothesis test results showed $t(29) = -11.0, p < 0.001$. The p-value, well below 0.05, confirms that the improvement in students' critical thinking skills was not due to chance but a direct result of the intervention. Furthermore, to determine the magnitude of the treatment effect, Cohen's d was calculated, yielding a value of 2.01. According to Cohen's (1988) benchmarks, a value of $d > 0.8$ is categorized as a very large effect. Thus, it can be concluded that the

combination of guided inquiry learning and flashcard media had a highly substantial impact on improving the critical thinking skills of fourth-grade students in the topic of force.. This indicates that guided inquiry, when paired with flashcards, substantially improved elementary school students' critical thinking skills.

The main findings of this study empirically demonstrate that integrating the Guided Inquiry learning model with flashcard media is highly effective in enhancing students' critical thinking skills in the topic of force. This success cannot be separated from the synergy between the pedagogical strength of the inquiry model and the cognitive function of concrete visual media. The Cohen's d value of 2.01 indicates not only statistical significance but also extraordinary practical significance. In other words, this intervention is not merely "successful" in statistical terms, but it has a highly meaningful impact in the real classroom learning context. The magnitude of this effect can be interpreted through the cognitive synergy between the learning process and the media. First, the Guided Inquiry model serves as a framework for scientific thinking.

Grounded in constructivist theory, this model positions students as active subjects in the construction of their own knowledge. Through systematic stages such as observation, problem formulation, hypothesis generation, experimentation/exploration, data analysis, and conclusion drawing, students are trained not only to receive ready-made information but to discover concepts independently. This discovery process intrinsically cultivates higher-order thinking skills (HOTS), such as the ability to analyze cause-and-effect relationships (for example, why rough surfaces produce greater frictional force), evaluate evidence from simple experiments, and make inferences based on the data they collect.

These results are consistent with previous studies, emphasized that guided inquiry encourages students to think logically and connect concepts with real-life experiences [15]. The guided inquiry model is a learning model based on investigation that provides students with opportunities to discover concepts independently while remaining under the teacher's guidance. The guided inquiry model is a learning model that guides students in conducting scientific investigations under teacher guidance. According to the guided inquiry model, it emphasizes independent yet guided activities of observation, information gathering, exploration, experimentation, and conclusion drawing. The guided inquiry model is based on constructivist theory, which positions students as active subjects in the construction of knowledge. Its main principles include independent learning activities, concept exploration, and direct student involvement in the process of discovering facts. States that the inquiry model requires students to think critically and process information deeply by utilizing direct experience [27]. The goals of the guided inquiry model are to develop higher-order thinking skills (HOTS), enhance conceptual understanding, train problem-solving abilities, and foster students' scientific attitudes such as curiosity, objectivity, and thoroughness.

Found that the integration of inquiry learning with picture card media significantly enhanced students' science process skills and critical thinking abilities [28]. However, the effectiveness of the inquiry model alone, particularly for elementary school students at the concrete operational stage (Piaget), may be constrained by the abstract nature of science content, such as the concept of force. This is where the crucial role of flashcard media as a bridge to understanding becomes evident. The flashcards used in this study (as shown in Figure 2) were specifically designed to concretize these abstract concepts. The use of flashcards also helped students transform abstract force concepts into concrete, engaging learning experiences. Moreover, the integration of flashcards into guided inquiry provided students with visual anchors that reduced cognitive load, enabling them to focus more on reasoning, analyzing, and evaluating scientific phenomena.

Figure 2 displays several examples of the flashcards used. The "Friction Force" flashcard not only defines friction but also illustrates a cyclist braking, visually showing how friction slows motion. The "Magnetic Force" and "Gravitational Force" flashcards clearly distinguish non-contact forces with concrete examples, such as a magnet attracting metal and a parachutist falling. These media serve as visual advance organizers that help students connect everyday phenomena with scientific concepts. Previous studies such as emphasized that flashcards enhance the

understanding of science concepts and knowledge retention due to their visual and memorable nature [19]. In line with this highlighted that flashcards help students develop ideas from images relevant to daily activities [29]. In this study, during the inquiry exploration stage, students could observe the flashcards to trigger questions ("Why is it difficult to push a box on a rough floor?"), formulate hypotheses and then conduct further investigations. Flashcards transformed abstract concepts into concrete and engaging starting points for inquiry.



Figure 2. Flashcard

Flashcards are a media consisting of small cards containing pictures, short text, numbers, or other symbols, designed to aid memory or guide students in developing ideas from the images presented. Flashcards are one of the tools in picture reading, in the form of cards, to help develop ideas or vocabulary using pictures relevant to students' daily activities [29]. In science instruction, flashcards help students identify scientific phenomena through concrete images. The advantages of flashcards include ease of use, their ability to attract attention, and their effectiveness in clarifying abstract concepts. Their disadvantages are that they are limited to visual materials and can be easily damaged if not cared for [30]. Flashcards are highly relevant for teaching the topic of force, as the concept of force is often abstract for elementary school students. Pictures depicting push, pull, friction, and gravity forces will help students understand the relationship between force and changes in an object's motion.

The effectiveness of learning through the guided inquiry model is influenced by students' active involvement in independently discovering concepts and by the interaction between their learning experiences and the teacher's guidance. When combined with flashcards, visual media enhances learning by facilitating students' understanding of abstract concepts, such as force. Furthermore, demonstrated that flashcards improve students' understanding of science concepts and knowledge retention [19]. Similarly, found that the combination of guided inquiry and augmented reality flashcards improved students' critical thinking skills and scientific literacy through interactive visual exploration [23]. These findings align with the theoretical framework underpinning the research. The Guided Inquiry model, grounded in constructivism, positions students as active subjects who construct their own knowledge through a series of scientific inquiry stages (observation, formulating problems, hypothesizing, experimenting, analyzing data, and concluding). This process intrinsically trains analytical,

evaluative, and inferential skills, which are the core of critical thinking. However, the effectiveness of Guided Inquiry for elementary school students who, according to Piaget, are still in the concrete operational stage is often hindered by the abstract nature of science concepts, such as force.

The finding of a significant improvement with a very large effect size confirms the theoretical proposition that Guided Inquiry is effective for training critical thinking skills. However, this research provides a more specific contribution by empirically demonstrating that this effectiveness can be dramatically optimized when integrated with concrete visual media like flashcards, particularly for teaching abstract concepts like force to elementary school students. This directly addresses the challenge highlighted in previous studies: the limitations of Guided Inquiry in presenting abstract concepts and the need for appropriate supporting media. This is where the role of flashcards becomes catalytic. Flashcards successfully bridge the gap between abstract concepts and students' concrete understanding. The images on the flashcards, depicting various types of forces (push, pull, friction, gravity) in everyday contexts, provide clear visual representations and guide students in conducting observations and connecting phenomena with concepts. This media not only captures attention and increases engagement but also functions as a concrete tool during the exploration and investigation stages of the Guided Inquiry model.

The synergy between these two components creates an interactive and meaningful learning environment. The teacher's guidance in Guided Inquiry ensures that student investigations remain focused and in-depth, while flashcards facilitate independent concept discovery. This combination allows students not merely to memorize facts, but to genuinely experience the process of "discovering" knowledge, analyzing cause-and-effect relationships from observed images, and drawing conclusions based on visual evidence. It is this type of learning experience that effectively sharpens higher-order thinking skills (HOTS) while simultaneously strengthening conceptual understanding. Beyond merely proving a method's effectiveness, this research offers a tested, concrete, and directly adaptable learning solution package for similar contexts. The tested combination of Guided Inquiry and flashcards has proven capable of transforming science learning from rote, abstract instruction into a visual, interactive, and analytical inquiry experience. This is a crucial practical contribution, given the gap between the demands of the HOTS-oriented Merdeka Curriculum and the availability of feasible, proven-effective teaching strategies in the field, particularly in elementary schools with limited resources.

This study confirms those findings, but with tighter methodological control through effect-size analysis (Cohen's d), which was not conducted in Wardani et al.'s study. Thus, this research provides stronger quantitative evidence of the intervention's impact. Sari and Haryanto emphasized that flashcards enhance the understanding of science concepts and knowledge retention [19]. This study goes further by demonstrating that improving conceptual understanding through flashcards, when integrated into an inquiry framework, directly enhances critical thinking skills rather than merely conceptual comprehension. This shows a

positive chain effect of using appropriate media within a suitable pedagogical model. In the context of more advanced technology, Chakim, Widiyono, and Muzakki. found that guided inquiry with Augmented Reality (AR) flashcards improved scientific literacy and critical thinking [23]. This study demonstrates that the fundamental principle of combining inquiry and concrete visual media remains relevant and effective even with simple (non-AR) media. This is an important finding for schools with limited technological resources, demonstrating that educational innovation does not always rely on advanced technology.

Theoretically, this study strengthens constructivist theory and cognitive load theory. The integration of concrete visual media (flashcards) into inquiry-based learning effectively reduced the intrinsic cognitive load associated with understanding abstract concepts, enabling students to allocate their cognitive resources to critical thinking. This supports the proposition that effective instructional design must consider students' cognitive characteristics and the nature of the subject matter. Practically, this study offers a learning solution that is affordable, easy to implement, and proven effective in improving critical thinking skills in the topic of force at the elementary level. Teachers can adopt the combination of guided inquiry and flashcards as an alternative innovative teaching method. Flashcards can be developed independently by utilizing images from open sources or self-created illustrations, thus requiring no high cost. Teacher training on how to effectively facilitate guided inquiry is also an important recommendation for successful implementation.

Therefore, the effectiveness of this learning approach is not solely due to the model or the media, but rather to their synergistic integration. The inquiry model provides cognitive challenges that encourage students to think critically, while flashcards offer concrete support that makes these challenges manageable for elementary students. This combination successfully creates an interactive, meaningful, and student-centered learning environment, ultimately resulting in a significant leap in their critical thinking skills, as evidenced by the very large effect size ($d = 2.01$). These findings offer a practical and powerful solution to address the challenges of science learning in elementary schools, particularly in instilling abstract concepts and fostering 21st-century skills.

Conclusion

This study concludes that the guided inquiry learning model supported by flashcard media has been proven effective and exerts a strong influence on improving fourth-grade students' critical thinking skills on the topic of force. The guided inquiry learning model, supported by flashcard media, has been proven effective in improving elementary school students' critical thinking skills when learning IPAS force material. The paired-samples t-test results indicate a significant difference between pretest and posttest scores, with a substantial improvement effect. The statistical results show $t(29) = -11.0$, $p < 0.001$, with Cohen's $d = 2.01$, indicating a very large effect size. This demonstrates that combining concrete visual media with scientific inquiry can encourage students to think logically and analytically while developing a deep understanding of force concepts. To improve the quality of HOTS-based learning and strengthen

21st-century skills in elementary schools, guided inquiry learning assisted by flashcards can serve as an effective and engaging alternative instructional approach. This study has several limitations, including a small sample size (30 students) and the absence of a control group, both of which weaken internal validity and limit the generalizability of the findings. For future research, it is recommended to employ a quasi-experimental design with a control group, apply the intervention to other abstract science topics (e.g., energy or sound), and develop digital or augmented reality-based flashcards to enhance interactivity. Further studies may also examine the impact of this combination on other dependent variables such as creativity or collaboration.

Author's Contribution

A. Suyani: primarily responsible for the research conceptualization, methodology design, field investigation, formal data analysis, data curation, and original draft preparation. A. Widiyono: contributed to methodology refinement, resource provision, and academic supervision, and conducted a critical review and substantive editing of the manuscript. All authors have read and approved the final version of the manuscript.

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References

- [1] A. Jufriadi, C. Huda, S. D. Aji, H. Y. Pratiwi, and H. D. Ayu, "Analisis Keterampilan Abad 21 melalui Implementasi Kurikulum Merdeka Belajar Kampus Merdeka 21 st Century Skills Analysis through The Implementation of Merdeka Belajar Kampus Merdeka Curriculum," vol. 7, pp. 39–53, 2022, doi: 10.24832/jpnk.v7i1.2482.
- [2] L. Maulidia, T. Nafaridah, M. Fraick, N. Gillian, E. Maya, and K. Sari, "Analisis Keterampilan Abad Ke 21 Melalui Implementasi Kurikulum Merdeka Belajar di SMA Negeri 2 Banjarmasin," no. Prospek Ii, 2023.
- [3] OECD, "oecd 2016," pp. 1–8, 2016.
- [4] C. B. Nurnaningsih, Hanum, W. Sopandi, and A. Sujana, "Keterampilan Berpikir Kritis dan Berpikir Kreatif Siswa Sekolah Dasar dalam Pembelajaran Berbasis RADEC," *J. BASICEDU*, vol. 7, no. 1, pp. 872–879, 2023.
- [5] P. . Facione, *Critical thinking: What it is and why it counts*. California Academic Press, 2015.
- [6] S. Z. Mardiyah, A. P. Salsabilla, N. Luthfi, and R. Herianingtyas, "STRATEGI PENINGKATAN KEMAMPUAN BERPIKIR KRITIS," *Awwaliyah J. PGMI*, vol. 6, 2023.
- [7] Y. Adhikari and E. R. Office, "A Review Of Revised Bloom's Taxonomy Of Educational Objectives," *Educ. Rev. J.*, vol. 1, no. July, pp. 115–126, 2024.
- [8] E. M. dan R. S. H. Yulaidi, "komparasi model pembelajaran inquiry learning dan guided inquiry learning terhadap hasil belajar peserta didik dalam pembelajaran," *J. Rev. Pendidik. Dasar J. Kaji. Pendidik. dan Has. Penelit.*, vol. 9, no. 1, pp. 61–66, 2023.
- [9] M. Isro and K. Listya Widhyastuti, "Efektifitas Penggunaan Model Pembelajaran Inquiry dalam Pembelajaran IPA di Sekolah Dasar Literature Review: Effectiveness of Using Inquiry Learning Model in Science Learning in Elementary Schools," *IJoEd Indones. J. Educ.*, vol. 1, no. 3, pp. 228–234, 2025, [Online]. Available: <https://doi.org/10.70437/zdyk6g05>
- [10] T. D. Utama *et al.*, "Kesulitan Belajar Peserta Didik pada Mata Pelajaran IPAS Kurikulum Merdeka Kelas IV," *J. Educ. Instr.*, vol. 8, no. 1, pp. 58–68, 2025, doi: 10.31539/joeai.v8i1.13375.
- [11] C. H. Eli Handayanti, Ferina Agustini, "Efektivitas Pembelajaran Inquiry Terhadap Keterampilan Berpikir Kritis IPA Siswa Kelas V Sonpandanlamper 05 Semarang," *Didakt. J. Ilm. PGSD FKIP Univ. Mandiri*, vol. 09, no. 04, 2023, doi: <https://doi.org/10.36989/didaktik.v9i04.1522>.
- [12] N. Pratiwi, S. N., & Suryani, "Guided Inquiry Learning Model: Its Effectiveness in Improving Critical Thinking Skills of Elementary Students," *J. Prim. Educ.*, vol. 13, no. 1, 2024, doi: <https://doi.org/10.15294/jpe.v13i1.59872>.
- [13] Kemdikbudristek, *Laporan Hasil PISA Indonesia 2022*. Jakarta: Pusat Asesmen Pendidikan, 2023. doi: <https://doi.org/10.31004/pisa.v2i3.500>.
- [14] A. Aminuddin, "Efektivitas penerapan teori belajar Robert E Slavin pada materi logika matematika," *Tautologi J. Math. Educ.*, vol. 3, no. 1, 2025.
- [15] D. M. Maya Anggraini, Sri Mulyani, "Meningkatkan Keaktifan Belajar Siswa Melalui Penggunaan Media Konkret Pada Mata Pelajaran Ilmu Pengetahuan Alam dan Sosial," *J. Genta Mulia*, vol. 16, no. 1, pp. 141–151, 2025.
- [16] S. Febrianti, R., & Zubaidah, "Analisis Kesulitan Belajar IPA pada Materi Gaya di Sekolah Dasar," *J. Ilm. Pendidik. Dasar*, vol. 82, 2023, doi: <https://doi.org/10.30659/jipda.8.2.234-245>.
- [17] S. dan R. Rofi'ah, "Analisis Kemampuan Berpikir Kritis Siswa dalam Memecahkan Masalah pada Mata Pelajaran IPAS kelas V Sekolah Dasar," *Soc. Humanit. Educ. Stud.*, vol. 7, no. 3, pp. 1–23, 2024, [Online]. Available: <https://doi.org/10.20961/shes.v7i3.92274>
- [18] I. Wulandari and A. Widiyono, "The Influence of Problem-Based Learning Model on the Improvement of Students' Critical Thinking Skills in IPAS Learning," *BASICA J. Prim. Educ.*, vol. 5, no. 1, pp. 15–30, 2025, doi: 10.37680/basicav5i1.6792.
- [19] H. Sari, D. P., & Haryanto, "Pengembangan Media Flashcard untuk Meningkatkan Pemahaman Konsep IPA Siswa Sekolah Dasar," *J. Pendidik. Sains Indones.*, vol. 11, no. 1, 2023, doi: <https://doi.org/10.24815/jpsi.v11i1.28765>.

- [20] I. Ika, A. Mimanah, and N. Suprpto, "Development of an Inquiry-Based Science Learning Material Using Flash Card to Reduce Misconception of Elementary School Students," *IJORER Int. J. Recent Educ. Educ.*, vol. 1, no. 2, pp. 178–190, 2020, doi: <https://doi.org/10.46245/ijorer.v1i2.35>.
- [21] R. A. Putri, M. P. Sari, F. Yanto, and T. Lestari, "Pengaruh Penerapan Model Pembelajaran Inkuiri Terbimbing Berbantuan Flash Card Untuk Meningkatkan Kompetensi Belajar Siswa Pada Materi Zat Dan Perubahannya," vol. 8, pp. 41645–41654, 2024.
- [22] N. Minallahalibada, I. Zukdi, and G. Kenedi, "Pengaruh Model Pembelajaran Inkuiri Berbantuan Media Pembelajaran Flashcard terhadap Peningkatan Keaktifan dan Hasil Belajar Peserta Didik Pada Mata Pelajaran Al- Qur ' an Hadis," vol. 9, pp. 7254–7261, 2025.
- [23] M. J. Chakim, A. Widiyono, and M. A. Muzakki, "Pengaruh Inquiry Terbimbing Berbantuan Augmented Reality Flashcards pada Peningkatan Literasi Sains Siswa Sekolah Dasar dalam Materi Tata Surya," vol. 5, no. 3, pp. 672–682, 2025, [Online]. Available: <https://doi.org/10.58218/lambda.v5i3.1617>
- [24] M. Waruwu, S. N. Pu'at, P. R. Utami, E. Yanti, and M. Rusydiana, "Metode Penelitian Kuantitatif: Konsep, Jenis, Tahapan dan Kelebihan," *J. Ilm. Profesi Pendidik.*, vol. 10, no. 1, pp. 917–932, 2025, doi: [10.29303/jipp.v10i1.3057](https://doi.org/10.29303/jipp.v10i1.3057).
- [25] J. D. Creswell, J. W., & Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (6th ed.)*. SAGE Publications, 2023.
- [26] A. Syafitri, A., Simorangkir, M., & Sudrajat, "Validity and Reliability Analysis of HOTS Multiple Choice Questions in a Chemistry Course at a Senior High School," *KnE Soc. Sci.*, 2024, doi: <https://doi.org/10.18502/kss.v9i8.15568>.
- [27] E. Joyce, B., Weil, M., & Calhoun, *Models of teaching (9th ed.)*. Pearson Education., 2018.
- [28] A. Wardani, R., Setyosari, P., & Husna, "Pengaruh Inkuiri Terbimbing Berbantuan Media Kartu Bergambar terhadap Keterampilan Proses Sains dan Berpikir Kritis," *J. Pendidik. Teor. Penelitian, dan Pengemb.*, vol. 7, no. 6, 2022, doi: <https://doi.org/10.17977/jptpp.v7i6.15234>(<https://doi.org/10.17977/jptpp.v7i6.15234>).
- [29] C. Aziza, O. M., & Yulia, "Efektifitas Media Flashcard untuk Meningkatkan Pemahaman Kemandirian Belajar Peserta Didik.," *Edukatif J. Ilmu Pendidik.*, vol. 4, no. 4, 2022, doi: <https://doi.org/10.31004/edukatif.v4i4.3635>.
- [30] C. dan helma T. A. Mutia, "Perbaikan Pembelajaran Siswa di SD Tentang Konsep IPA Gaya Magnet Melalui Eksperimen dan Metode Belajar Kelompok," 2025.