Development of the Discovery Nano Learning (DNL) Model in Science Education to Enhance Students' Critical Thinking Skills in Elementary School

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Abstract
This study aimed to develop the Discovery Nano Learning (DNL) model in Science and Social Studies (IPAS) learning to improve elementary school students' critical thinking skills. The study was motivated by the low level of students' critical thinking skills, as indicated by low learning mastery achievement, the dominance of conventional teaching methods, limited exploratory learning activities, and the suboptimal use of digital technology in learning. The study employed a Research and Development (R&D) method comprising needs analysis, model design, product development, expert validation, formative evaluation, and effectiveness testing, using a quasi-experimental design. Formative evaluation was conducted through one-to-one and small-group evaluations and a field trial. The research subjects were fourth-grade students at Walantaka 1 Public Elementary School, Serang City, Banten Province. The research instruments included questionnaires, observation sheets, interviews, and tests of critical thinking skills. The findings revealed that the Discovery Nano Learning (DNL) model integrates discovery-based learning with the nano learning concept by presenting learning materials in small, simple, and structured units on social media platforms. Expert validation results indicated that the model was categorized as highly valid, with validation percentages of 91.67% for the learning model, 92.22% for instructional design, 96.92% for media, 86.67% for learning materials, and 93.33% for language aspects. The feasibility test results showed an average percentage of 96.9%, categorized as very good. Furthermore, the effectiveness test results showed that the experimental class's average posttest score was 96.67, higher than the control class's 66.79. The N-Gain score of 0.80 was categorized as high, while the effect size score of 6.48 indicated a very strong effect. Therefore, the Discovery Nano Learning (DNL) model was proven to be valid, feasible, and effective in improving elementary school students' critical thinking skills in Science and Social Studies (IPAS) learning.

Keywords: Discovery Nano Learning, Critical Thinking Skills, Elementary School Students.

A. INTRODUCTION

The Graduate Competency Standards (SKL) for elementary school (SD) or equivalent levels, as stipulated in Ministry of Education, Culture, Research, and Technology Regulation No. 5 of 2022 and Ministry of Education, Culture, Research, and Technology Regulation No. 7 of 2022, state that graduate competency standards are the minimum criteria for a combination of attitudes, skills, and knowledge that demonstrate students' achievement of competencies at the end of the level. These criteria encompass the scope of subject matter required to master scientific concepts, in line with advancements in science and

technological progress, and with the demands of 21st-century skills, particularly students' critical thinking skills (Ministry of Education, Culture, Research, and Technology, 2022).

These standards were developed by defining the scope of learning materials that must be appropriate (Audrin, 2022), aligned with students' learning progression at each level, and provide flexibility for teachers to facilitate the development of student competencies, while adopting the principles of 21st-century skills development (Thorndahl & Stentoft, 2020). Thus, ideally, graduate competency standards at the elementary education level emphasize the balanced development of students' knowledge and skills, with a primary focus on 21st-century skills such as critical thinking, which enable students to analyze information wisely and generate innovative solutions (Nogueira et al., 2022). Technological advancements need to be integrated as a vital component of learning to equip students to face life's challenges and contribute positively to society (Sanvi & Diana, 2022).

Critical thinking is one of the essential 21st-century competencies that must be developed early on, particularly at the elementary school level. Critical thinking encompasses the ability to observe, analyze information, evaluate arguments, identify problems, draw logical, rational conclusions, and make decisions. In the context of elementary school learning, these skills are highly relevant because they help students understand material more deeply—not merely by memorizing facts, but also by connecting concepts, making predictions, and solving problems based on evidence. Critical thinking skills can be applied from elementary through secondary and higher education (Schreglmann, 2018) and are an essential aspect that students need to face the challenges of life in an era of digital technological advancement (Warsah, 2021).

Teachers must pay close attention to students' critical thinking skills, as these have pedagogical implications for developing students' learning abilities (Soufi, 2019). Critical thinking is a skill that must be continuously developed and is a key component in the formation of students' knowledge (Zou'bi, 2021). According to Tseng (2020), the development of critical thinking skills is essential to learning objectives. The development of critical thinking skills is influenced by various factors, such as personality, culture, and social context (Shavkatovna, 2021). Learning that develops critical thinking skills is carried out by integrating students' abilities to analyze, evaluate, and synthesize information, which leads to increased knowledge; consequently, critical thinking skills have been incorporated into national education curricula in nearly all countries in the era of digital learning (Akbarilakeh, 2018).

In the teaching of natural and social sciences (IPAS), critical thinking skills are essential because students encounter a variety of phenomena that require conceptual understanding and in-depth analysis. Ideally, IPAS instruction should not only assess knowledge (cognitive aspects) but also measure critical thinking skills through exploratory tasks, case studies, mini-projects, or open-ended questions that challenge students' reasoning. Teachers need to provide constructive feedback and encourage students to reflect on their own thinking processes (metacognition). If these ideal conditions are consistently met, students will have a strong foundation in critical thinking to face learning challenges at the next educational level and in their daily lives.

Meanwhile, the reality on the ground presents a quite different picture. For instance, the results of the Program for International Student Assessment (PISA, 2025) show that Indonesian students' performance remains well below the OECD average. More than 60% of Indonesian students are only at Level 1 in reading, mathematics, and science, indicating basic abilities to understand and apply knowledge. In contrast, only a small number of Indonesian students reach Levels 5 or 6—levels that indicate high-level

critical thinking skills—compared to the average of other OECD countries. These results indicate that the development of critical thinking skills among Indonesian students has not yet been optimized.

Similar findings were revealed in the Progress in International Reading Literacy Study (PIRLS, 2011), which assessed students' critical thinking skills in Indonesia, ranking the country 45th out of 48 participating nations (IEA, 2012). This situation is further underscored by findings (Umbara, 2019) showing that teachers' knowledge of how to manage instruction to enhance critical thinking skills remains insufficient, the alignment of assessments with learning evaluation remains low, and the use of technology in classroom instruction models is not yet optimal. This indicates that teachers' activities in teaching and assessing students' functional and conceptual skills in critical thinking still need improvement.

Since 2021, the government has implemented the National Assessment (AN) as a replacement for the National Exam. One of its instruments, the Minimum Competency Assessment (AKM), measures students' literacy and numeracy skills, and its question formats are adapted from PISA questions that require higher-order thinking skills. This underscores that critical thinking skills are now the official focus of national educational evaluation. However, AKM results show that the literacy and numeracy skills of the majority of Indonesian students remain below the minimum competency threshold, with fewer than 50% having reached it (Ministry of Education, Culture, Research, and Technology, 2021). This situation aligns with Indonesia's PISA performance, which has consistently placed the country among the bottom ten groups. Numerous factors and indicators influence these low student competencies, necessitating more in-depth research and analysis.

Meanwhile, adapting to technological advancements—including the use of digital learning tools, access to learning resources, and platforms for sharing and collaboration—is essential for developing 21st-century skills (BSKAP, 2024). These skills must be relevant to real-life contexts, problem-solving-based, and integrated with current events (Burnett, 2015; Walker, 2020; Kim, 2019). There are six core competencies of 21st-century learning: critical thinking, creativity, collaboration, communication, citizenship, and character. These skills are crucial for students' success in navigating an uncertain future (Kafai, 2020; Kim, 2019; Ministry of Education and Culture, 2024).

This low level of critical thinking skills at the national level is also reflected in the results of an initial preliminary field study conducted by the researcher at Walantaka 1 Public Elementary School (SDN), Walantaka Subdistrict, Serang City, Banten, on September 11–13, 2024. Based on the researcher's observations and interviews, the school had implemented the Merdeka Curriculum. This curriculum serves as a refinement of the 2013 curriculum and a continuation of the emergency curriculum implemented during the COVID-19 pandemic; since the 2021–2022 school year, it has been piloted in approximately 2,500 pilot schools at the early childhood education (PAUD), elementary (SD), junior high (SMP), and senior high (SMA) levels across Indonesia (Sujadi, 2022).

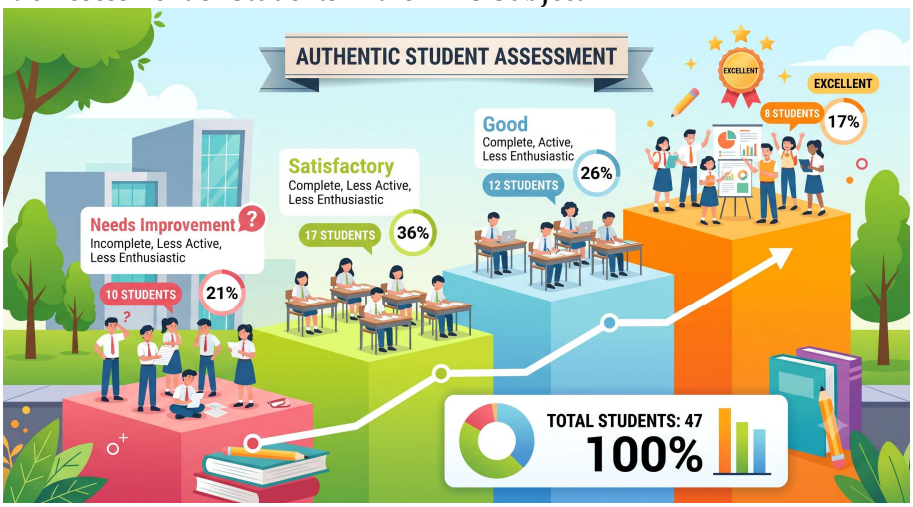
Observations based on educational report card data provided by teachers at SDN Walantaka 1 indicate that students' critical thinking skills remain in the yellow category (fairly low). Among fourth-grade students, only 25.8% demonstrated high critical thinking skills, while 29.1% were in the moderate category, and 45.1% were in the low category. Furthermore, only 57.6% of students demonstrated high-level abilities in identifying, analyzing, evaluating, and clarifying information. These findings suggest that although students can understand and articulate information clearly, they still struggle to develop problem-solving strategies and to provide logical reasoning when addressing problems.

Based on initial interviews conducted by the researcher with 47 fourth-grade students at SDN Walantaka 1 through direct questioning, it was found that 10 students stated that the IPAS subject was very difficult, 19 students stated it was difficult, 8 students stated it was easy, and 10 students stated they did not know or did not answer. Thus, 61.7% (29 students) reported that IPAS was very difficult or difficult; only 17% (8 students) reported it as easy; the remaining 21.3% (10 students) did not answer.

Data from the student evaluation results for the IPAS subject in the odd semester of the 2024/2025 academic year, as presented by the fourth-grade teacher at SDN Walantaka 1, further supports these findings. Of the 47 students who participated in the authentic assessment for IPAS, only 8 students were able to complete all tasks thoroughly, actively, and enthusiastically (very good);

12 students completed all tasks thoroughly and actively but lacked enthusiasm (good); 17 students completed all tasks thoroughly but were less active and less enthusiastic (fair); and 10 students completed the tasks incompletely, with low activity and low enthusiasm (poor). These results indicate that the learning model that fourth-grade teachers have been applying in the IPAS subject has not yet had an optimal impact on the achievement of learning objectives, as there are still 27 students in the "fair" and "poor" categories, as shown below:

Table 1.1 Authentic Assessment of Students in the IPAS Subject



Source: IPAS evaluation results for the odd semester of the 2024/2025 academic year

Based on the data from the students' authentic assessments, the teacher noted that the learning objectives had not been fully achieved, as 21% of students were still categorized as "below standard." Authentic assessment is a form of evaluation that involves various measures that reflect the application of attitudes, knowledge, and skills; therefore, the teacher needs to improve students' critical thinking skills in IPAS instruction (Sani, 2022). Authentic assessment is conducted comprehensively to evaluate the learning process and learning outcomes (outputs) (Diani & Sukartono, 2022). It requires students to demonstrate their abilities directly, either through their products or through their responses to traditional test questions (Pramana, 2019). Thus, authentic assessment involves direct observation of student performance through tasks that resemble real-life applications and must be conducted as objectively as possible, in accordance with students' grade-level developmental characteristics.

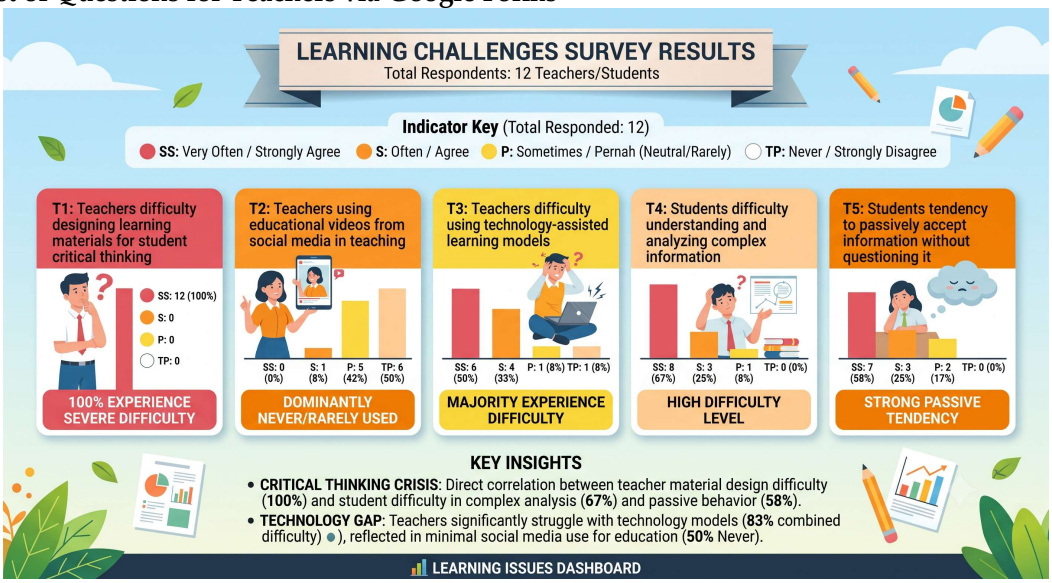
This situation was further reinforced by initial interviews with fourth-grade teachers and the principal of SDN Walantaka 1, who stated that teachers have not yet adequately addressed the understanding of

values and concepts in the IPAS curriculum—which is oriented toward critical thinking skills—due to several factors: limited access to technology-based learning resources, a heavy administrative burden, insufficient training, a tendency toward one-way instruction, and disparities in technological literacy. Students' average IPAS scores range from 65 to 73, still below the minimum proficiency threshold of 75. These results indicate the need for instructional interventions that can enhance students' abilities.

Findings from an interview with a fourth-grade teacher, identified only by the initial T, reinforce these findings, noting that many students still do not fully understand how to apply critical thinking skills due to a lack of practice problems. Field data show that approximately 80% of students still have a limited understanding of critical thinking, while only 20% have mastered problem-solving strategies through critical thinking.

Meanwhile, based on an initial survey of teachers conducted via a Google Forms questionnaire—completed by 12 (twelve) teachers at SDN Walantaka 1 in Serang City—the following information was obtained:

Table 1.2 List of Questions for Teachers via Google Forms



Based on the table above, 12 teachers—or all of them—had difficulty designing lesson materials to improve students' critical thinking skills; 6 teachers never used educational videos from social media when delivering lesson content; and 6 teachers had difficulty using technology-assisted learning models. Additionally, 8 teachers reported that students struggled to understand and analyze complex information, and 7 teachers noted that students tended to accept information passively without questioning or further analysis.

The preliminary data and information above indicate a significant gap between ideal and actual field conditions. On the one hand, the 21st-century curriculum and learning requirements mandate that elementary school students develop strong critical thinking skills; on the other hand, the reality on the ground, as seen at Walantaka 1 Public Elementary School, shows that fourth-grade students still exhibit low levels of critical thinking. Many students consider IPAS to be a difficult subject. This gap is strongly suspected to stem from a learning process that remains teacher-centered and relies on conventional teaching models, thereby failing to provide sufficient opportunities for students to develop their critical thinking skills optimally. Therefore, a transformation in learning is needed to support the development of

more innovative instructional models, the utilization of technology, and the gradual strengthening of students' critical thinking skills (Pratiwi, 2019; Vieira, 2018).

A review of previous research also indicates a learning gap. This aligns with a study (Kintoko et al., 2024) that found that although teachers recognize the importance of critical thinking skills for students as essential 21st-century competencies, they still struggle to implement them in the classroom. Practices such as group discussions and active learning are considered effective but remain limited to cognitive skills and require further support to enhance students' critical thinking abilities (Alida, 2022). The prevailing culture of rote memorization and exam-oriented education remains a major challenge (Ruminten et al., 2022). Although the Merdeka Curriculum was designed to develop 21st-century skills, its implementation has not yet been fully effective in practice (Sherly et al., 2020). Errors in managing and analyzing learning materials affect the future development of students' critical thinking skills (Hwang et al., 2023). In contrast, critical thinking is an essential intellectual ability for effective decision-making, problem-solving, and social interaction (Winarni et al., 2020).

Various previous studies have sought to enhance elementary school students' critical thinking skills through diverse instructional models. For example, a study by Prasanti (2023) demonstrated that the discovery learning model significantly improved fifth-grade students' critical thinking skills, with an N-gain score in the moderate range. Furthermore, a study (Fauziah, 2023) developed digital video-based instructional materials for IPAS (Integrated Science, Technology, and Mathematics) instruction. It improved critical thinking skills, with an N-gain of 0.64 (moderate). A study (Utomo, 2019) found that the CTL model significantly improved critical thinking (sig. < 0.05), with approximately 80.95% of students meeting the mastery criteria. Furthermore, a study (Mustadi, 2023) demonstrated that a video-based discovery learning model significantly improved critical thinking skills compared to the expository method ($p = 0.004$ and $p = 0.005$). These findings confirm that active and innovative learning models can effectively enhance students' critical thinking skills; however, most have not yet optimized the integration of digital technology to align with the characteristics of elementary school students.

Thus, one model with the potential to develop critical thinking skills is discovery learning. This model encourages students to discover concepts on their own through active learning experiences such as observation, experimentation, problem-solving, and discussion, positioning them as active participants in the learning process rather than passive recipients of information. According to Azainil (2019), discovery learning is part of a broader category of active learning models—such as cooperative learning, problem-based learning, and project-based learning—that place students in an active role in constructing knowledge and developing critical thinking skills. Advances in information and communication technology can enhance discovery learning (Thongkhotr, 2022) by enabling students to access a wider variety of learning resources and interact with the material independently, thereby creating new opportunities for exploration and discovery in technology-enhanced learning (Barlian et al., 2022). Nevertheless, at the elementary school level, this model is considered too complex and requires significant time and resources to be implemented effectively (Wang, 2023).

With current advancements in information and communication technology, innovative digital-based learning models are becoming increasingly relevant for elementary education. One promising model is nano-learning, a digital-based approach that presents content in small, concise, focused, efficient, and easy-to-understand units (micro-content). Nano-learning describes the process of delivering learning content in small units lasting approximately 1–5 minutes (Aburizaizah & Albaiz, 2021), aimed at helping students acquire new knowledge quickly and effectively without spending excessive time (Wibowo et al.,

2023), typically through electronic devices (Xin, 2022). Since mastery of technology in learning is a key factor influencing the improvement of teachers' and students' abilities to address issues related to critical thinking skills (Bryant, 2019), and such mastery is not merely technical but must also encompass cognitive aspects that comprehensively develop critical thinking skills (Cladis, 2020; Wiratsiwi, 2020).

Although there have been many previous studies on discovery learning and nano-learning models—such as Winarni's (2020) study, which focused on language and science literacy through discovery learning integrated with ICT-based media—the variables examined were language and science literacy, not critical thinking skills. Similarly, the study by Hariyanto et al. (2022) analyzed the contribution of critical thinking and social skills in the discovery learning model to student character, without developing a learning model. Furthermore, the study by Khlaif & Salha (2021) was purely descriptive and exploratory, examining only the use of social media for nano-learning, without developing a new model. Furthermore, the study by Vivekananth (2022) was purely conceptual and theoretical; it did not test the application of nano-learning at specific educational levels or in specific subjects, nor did it directly integrate it with discovery learning in the classroom.

It appears that previous studies employed the discovery learning and nano-learning models separately and have not yet fully leveraged the interactive visual capabilities of digital technology. Most of these studies still treat critical thinking skills as supporting variables rather than primary objectives, as they are linked to character, attitudes, or social skills. Consequently, no learning model has been developed that systematically integrates the strengths of discovery learning and nano learning to enhance students' critical thinking skills in elementary school jointly. Thus, this study can serve as a novel foundation to address the existing research gap. By combining these two models, it is hoped that the limitations of discovery learning—which are considered to overburden the cognitive capacity of elementary school students, as highlighted in cognitive load theory—can be addressed through the use of nano-learning's characteristics, specifically the presentation of brief and focused material that aligns with the cognitive developmental stage of elementary school students.

Based on this explanation, this study proposes the development of a new learning model that combines discovery learning and nano learning, hereinafter referred to as the discovery nano learning model (DNL). The DNL model is designed to provide an intensive and efficient learning experience through short modules focused on understanding specific concepts or skills (Alsubaie, 2022), while simultaneously engaging students in actively discovering concepts on their own. The DNL model can combine students' exploratory engagement with the presentation of content that is concise, brief, and easily accessible through digital media such as short videos; thus, it is expected to address the challenges of IPAS learning, which demands interdisciplinary conceptual understanding, active engagement, and the strengthening of students' critical thinking skills within a limited learning timeframe. This is because the development of technology-based learning models aims not only to improve learning quality but also to equip students with the 21st-century skills needed in a world increasingly rich in digital information (Rodríguez et al., 2018).

The DNL model to be developed is not intended to replace existing learning models but rather to refine and improve them by offering learning that is more innovative, simple, technology-based, and tailored to students' specific needs and characteristics. The DNL model is expected to provide sufficient space for students to develop their interests, talents, creativity, and independence in accordance with their cognitive, physical, and psychological development during their learning phase, thereby ultimately supporting the development of students' critical thinking skills. This study aims to design, develop, and

test the effectiveness of the DNL model in enhancing students' critical thinking skills in IPAS learning. Through the DNL model, students are expected not only to understand concepts cognitively but also to develop skills in problem-solving, analytical thinking, and decision-making based on data and facts throughout the learning process.

Thus, this study is expected to make a tangible contribution, both theoretically through the examination of innovative learning models and practically through the DNL model, which teachers can easily implement in the classroom.

Based on the findings and discussion above, the researcher is interested in conducting a study titled "Development of the Discovery Nano Learning (DNL) Model in IPAS Instruction to Enhance the Critical Thinking Skills of Fourth-Grade Elementary School Students." Through the development of the DNL model, the researcher aims to bridge the limitations of conventional learning models with a more innovative and interactive model tailored to the learning needs of elementary school students, thereby developing students' critical thinking skills to help them face future life challenges.

METHOD

The research used in this study is quantitative, employing the Research and Development (R&D) method. R&D is a design method in learning research that involves steps such as investigation, design, testing, and implementation to develop effective learning practices (Gustiani, 2019). Research and development aim to produce new products or processes and to improve existing ones through a series of systematic, organized processes (Sugiono, 2021). This enables researchers to explicitly test and verify the effectiveness of the developed learning models, thereby providing innovative and practical solutions to learning problems.

The objective of the R&D model in product development begins with needs assessment. It continues with development to produce a tested product encompassing various elements such as media, materials, models, and learning systems (Sugiyono, 2022). This study aims to develop a DNL learning model for the IPAS subject to enhance critical thinking skills among elementary school students.

The Research and Development (R&D) in this study employs a development model following the steps outlined by Dick and Carey, combined with the Borg and Gall model during the product development phase. The strength of the Dick and Carey model (1985) lies in its detailed task analysis and hierarchically structured specific learning objectives (Dick et al., 2005), as well as the inclusion of repeated trials, which ensures that the results obtained through this systematic approach are reliable (Ganda Hutabarat, 2015). Developmental research involves seeking innovation and excellence to enhance effectiveness, efficiency, and productivity. It is oriented toward developing and validating instructional products (Gall et al., 2003).

The DNL model was developed using the Dick and Carey model, recommended by Borg and Gall as the "Step-by-Step System Approach Model of Educational Research and Development." This model is schematic and procedural, proposing the application of instructional design principles in a sequential, step-by-step manner. Several researchers have successfully developed products using the Dick and Carey model by combining it with the Borg and Gall model (Almazyad & Alqarawy, 2020), both generally and contextually, as it is structured based on an analysis of learning objectives linked to the development of innovative models. This model consists of ten planning stages, including: (1) analysis of learning needs

and objectives, (2) learning analysis, (3) identification of students' characteristics and prior knowledge, (4) formulation of learning indicators, (5) development of assessment instruments, (6) development of learning strategies, (7) development and selection of learning materials, (8) design and implementation of formative evaluation, (9) revision of learning materials, and (10) design and implementation of summative evaluation.

The development model follows the general stages of instructional systems development (ISD), including analysis, design, development, implementation, and evaluation. This research was conducted to develop a DNL model product that supports the improvement of critical thinking skills in Natural and Social Sciences (IPAS) learning for fourth-grade elementary school students, specifically on the "Bhinneka Tunggal Ika" element for the topic "What was the area where I used to live like?" The development process included validation by subject-matter experts, validation by teachers, and pilot testing by students.

The research site is Walantaka 1 Public Elementary School (SDN), Jln. Raya Ciruas-Petir KM 4, RT. 01 RW.01, Walantaka Village, Walantaka Subdistrict, Serang City, Banten Province 42183. The researcher conducted preliminary research in September 2024. The research will be conducted over one year, beginning in the odd semester of the 2024–2025 academic year and continuing through the even semester of the 2025–2026 academic year.

Participants in the study consist of teachers and students. The researcher collaborated with fourth-grade teachers to develop, provide suggestions, and jointly implement the DNL model, which supports the improvement of critical thinking skills in the Natural and Social Sciences (IPAS) curriculum. The study's respondents included 58 students: 30 from Class IV-A and 28 from Class IV-B at Walantaka 1 Public Elementary School (SDN) in Serang City, Banten.

RESULTS AND DISCUSSION

Based on the instructional analysis conducted, several fundamental problems were identified regarding students' low critical thinking skills. Most students still struggle to analyze phenomena in their surroundings, evaluate information, and make decisions based on data. Students tend to memorize concepts without connecting them to real-life contexts. At the same time, classroom instruction remains predominantly teacher-centered, relying on conventional teaching models and written assignments that do little to encourage active student engagement. This situation has prevented discussion, exploration, and problem-solving activities—which should form the foundation of critical thinking—from functioning optimally. Consequently, students lack practice in asking questions, processing information, and reasoning and drawing logical conclusions.

The analysis also found that students find IPAS lessons unengaging because the material presented is often abstract and not connected to real-life contexts. Learning that remains teacher-dominated and relies on less-than-interactive PowerPoint presentations further underscores the urgent need for a change in the learning model. Teachers also acknowledge their limitations in providing a variety of engaging digital strategies and media due to time constraints and limited access to learning resources. Consequently, both teachers and students expressed a need for a learning model that fosters active engagement, challenges thinking, integrates video, audio, and contextual exploration activities, and is easily accessible across various devices without requiring significant data usage. These findings confirm that a learning model

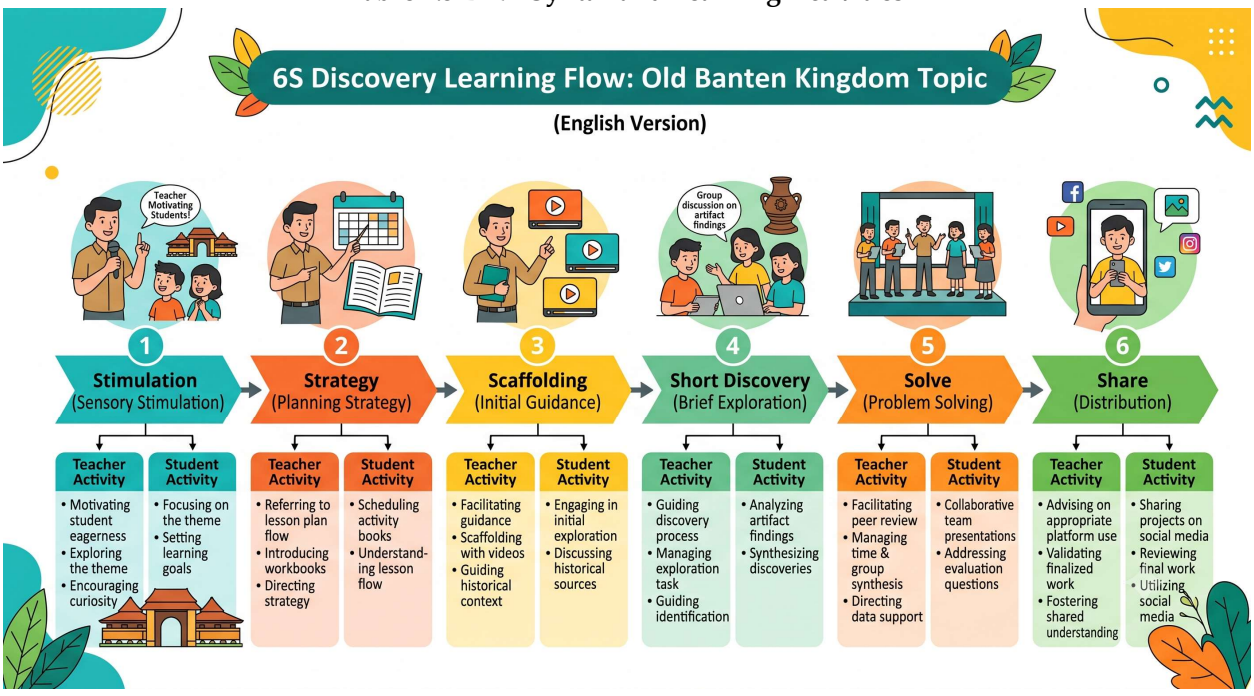
that solely emphasizes the memorization of concepts has proven inadequate for developing critical thinking skills among fourth-grade elementary school students.

Based on these findings, the instructional strategy development phase focused on implementing the DNL model using social media videos as a systematic approach to deliver IPAS content. This is because the DNL model positions students as active participants, encouraging them to discover knowledge independently through short, contextually relevant video content relevant to their daily lives. The DNL model is also supported by four key elements: a learning system that encourages interaction and discussion among students; the principle of response, which positions the teacher as a facilitator of discovery; a support system consisting of diverse and easily accessible video media; and learning outcomes aimed at measurably improving students' critical thinking skills. Thus, the development of the DNL model is highly relevant and urgently needed for implementation in IPAS instruction in elementary schools to address students' and teachers' needs for learning that is more interactive, contextual, collaborative, and effective in comprehensively fostering students' critical thinking skills.

The DNL model is a learning model that aims to encourage students' active engagement through independent or group discovery activities to understand learning material through very small (nano) units focused on a single learning objective, using digital learning in the form of very short videos (1–5 minutes) via social media platforms such as YouTube, Instagram, TikTok, or similar applications. Meanwhile, the syntax serves as a general guide outlining the sequence or structure of the learning process.

The DNL model syntax developed consists of six steps (S6): stimulation, strategy, scaffolding (providing initial guidance), short discovery, solve, and share. As explained in the following table:

Table 4.5 DNL Syntax and Learning Activities



In the learning process, the social system encompasses the roles, relationships, and dynamics of interaction among teachers, students, and the learning environment, which together form a meaningful

learning ecosystem. This system not only governs how students interact with one another but also how teachers facilitate the learning process and how the classroom environment—both physical and virtual (digital)—is managed to ensure it is conducive to and supports the achievement of learning objectives. In the context of implementing the DNL model, the social system is developed to be more adaptive, collaborative, and exploratory. Student-centered learning is the defining characteristic, where students are encouraged to actively construct knowledge through the discovery phase by using short videos on social media platforms such as TikTok, YouTube, Instagram, etc., within short learning units (nano-learning) that are more structured and contextual for elementary school students.

Interaction among students becomes more prominent through collaborative activities, discussions, and problem-solving in a more active and engaging environment, thereby strengthening critical thinking, communication, and collaboration skills. Meanwhile, the teacher's role shifts to that of a facilitator, mediator, and learning designer who not only guides but also designs meaningful, adaptive, and student-centered learning experiences. Teachers provide scaffolding (support) when students encounter difficulties, while simultaneously monitoring learning progress through various activities. The use of interactive social media allows students to explore, experiment, and interact in real time and flexibly, thereby creating a more authentic and contextual learning experience. Thus, the social system in the DNL model not only emphasizes interaction but also fosters a learning culture that is participatory, reflective, active, engaging, and oriented toward independent knowledge discovery.

The principle of responsiveness in the DNL model refers to how teachers respond to students' actions, thought processes, and learning outcomes as they engage in discovery-based learning experiences within small units (nano-learning). This principle is crucial because it determines the quality of pedagogical interactions between teachers and students, particularly in ensuring that the discovery process does not proceed "freely without direction," but remains structured, reflective, and meaningful in line with learning objectives.

In the context of the DNL model, the principle of reaction is no longer one-directional—such as merely assessing right or wrong—but places greater emphasis on adaptive scaffolding. This means that teachers provide feedback tailored to students' cognitive needs as learning activities unfold, whether students successfully discover a concept or encounter confusion during the exploration process. Teacher feedback is aimed at reinforcing students' thinking processes, rather than directly providing the final answer. Furthermore, the feedback principle in DNL emphasizes immediate feedback because the short and focused structure of nano-learning demands rapid correction or reinforcement. This helps students immediately reflect on their discoveries and refine their understanding without having to wait until the end of the learning activity.

The next principle involves reflective and metacognitive responses, where teachers not only assess outcomes but also encourage students to explain how they arrived at a conclusion. Thus, teachers' responses serve to activate students' awareness of their own thinking (thinking about thinking), which is at the core of discovery-based learning. In the implementation of digital-based learning within the DNL model, the principle of feedback also includes data-driven responses, whereby teachers utilize the digital traces of students' activities to provide more targeted interventions. For example, when the system indicates that a student repeatedly fails at a certain stage, the teacher provides specific assistance on that concept.

Thus, the principle of response in the DNL model functions not only as a form of assessment but as an active pedagogical mechanism that maintains a balance between students' freedom to explore and the teacher's guidance. This principle ensures that the discovery process remains focused, efficient on a nano-scale, and sufficiently in-depth in fostering conceptual understanding—all tailored to the learning needs and characteristics of elementary school students.

In the context of implementation in elementary schools, the support system for the DNL model is determined not only by the readiness of teachers, students, and learning facilities but also by the integration of digital media relevant to students' learning habits in the current era. Based on field findings, the use of short-form video-based learning media from social media platforms such as YouTube, TikTok, Instagram, and similar platforms has become a highly significant supporting element in strengthening the DNL model. These short videos serve as an initial stimulus in the discovery process, as they present learning concepts in a concise, engaging, and visually accessible format that is easy for elementary school students—who have a relatively short attention span—to understand.

The positive impact of implementing the DNL model is evident in the aspects of learning effectiveness, efficiency, and flexibility. In terms of effectiveness, the use of short videos as a catalyst for discovery enhances students' attention and engagement in understanding initial concepts, thereby making the learning process more meaningful. Students do not merely receive information passively but are encouraged to observe, interpret, and discover concepts independently through structured "nano tasks." The availability of tools such as smart TVs, laptops, smartphones, projectors, speakers, and internet access is crucial to ensuring this model functions effectively. However, the DNL model can still be adapted in settings with limited technology by utilizing simple media combined with offline learning methods. This demonstrates that the DNL support system is flexible and does not rely entirely on advanced devices, but rather on teachers' creativity in managing the learning resources available at school.

In terms of efficiency, the DNL model allows for the delivery of material in a shorter timeframe while still focusing on core concepts, so that learning time can be utilized optimally without compromising the depth of understanding. This is highly relevant to the characteristics of learning in elementary school, which requires a variety of activities to prevent lessons from becoming monotonous and boring. Meanwhile, in terms of flexibility, DNL provides ample room for adaptation for both teachers and students. Teachers can select and customize instructional videos according to the context of the material, while students can independently revisit the material outside of class hours. This flexibility also supports differentiated instruction, as students with varying abilities can learn at their own pace.

Additionally, the DNL model includes the learning environment, instructional modules, student activity sheets, and a user guide, which serves as a technical reference during the learning process. All of these components serve not only as tools but also as pedagogical resources, creating interactive and meaningful learning experiences. In developing students' critical thinking skills, the DNL model provides contextual experiences through short videos, allowing students to observe, analyze, and evaluate phenomena directly in a digital environment. Meanwhile, the modules and student activity sheets guide the thinking process through problem-based tasks and prompt questions that encourage students to reason and make decisions independently.

Furthermore, the learning environment is an integral part of the support system that cannot be overlooked. Field findings indicate that flexible, interactive classrooms that facilitate student

collaboration improve the effectiveness of DNL. Classroom arrangements that allow for small-group discussions, access to learning resources, and a safe and open learning atmosphere encourage students to be more active in exploring information. In this context, teachers act as facilitators of the learning environment, ensuring that every activity within the framework aligns with learning objectives.

Thus, a DNL support system integrated with short video content from digital platforms not only strengthens the learning process in elementary schools but also effectively stimulates students' critical thinking skills through exploratory, analytical, and reflective activities, resulting in a more active, contextual, efficient, and flexible learning experience. Ultimately, the DNL model drives the transformation of learning from a conventional approach to one that is more adaptive to technological advancements and the characteristics of elementary school students—a generation growing and developing in a digital environment.

The use of the DNL model in fourth-grade IPAS instruction in elementary school, incorporating the "Bhinneka Tunggal Ika" principle—particularly in the topic "What Was My Hometown Like in the Past?" through the history of the Banten Kingdom—is expected to have a significant impact on learning by fostering historical understanding while simultaneously strengthening students' character. Through a discovery-based learning model in small units (nano-learning), students are guided to actively explore the origins of their local area, local figures who played a role in the region's development, and historical artifacts still found today. This process makes learning more contextual because students connect historical material to the real-world environment close to their daily lives.

The impact of this learning is also expected to be evident in students' ability to retell the history of their region in simple terms, name important figures, and identify exemplary traits in those figures. Additionally, students will be able to compare the past and present conditions of their region, enabling them to understand the social, historical, cultural, and environmental changes that have occurred over time. In the context of the Banten Kingdom, students not only learn about the kingdom that once flourished in their region but also begin to understand history's role in shaping the region's current identity, as well as the importance of upholding exemplary values and preserving historical relics as part of their cultural heritage.

Furthermore, implementing the DNL model aims to improve students' critical thinking skills. Through a structured, systematic discovery process on a small (nano) scale and in stages, students are trained to observe, categorize information, compare facts, and draw simple conclusions from various learning sources. These activities encourage students not only to receive information passively but also to question, analyze, and reflect on the relationship between the past and the present. Thus, IPAS learning based on the DNL model not only strengthens students' conceptual understanding of IPAS but also fosters critical thinking skills appropriate for elementary school students' developmental stage.

An analysis of the audience (students) and the context in the research on developing the DNL model to enhance fourth-grade students' critical thinking skills in IPAS at the elementary school level reveals a learning environment that is contextual, diverse, and shaped by learning habits in the digital technology era. Based on an analysis of 58 fourth-grade students, the data revealed that students expressed greater interest in learning presented in the form of short videos, images, or interactive simulations than in explanations delivered through conventional methods. Additionally, students reported finding it easier to understand the material when presented through video platforms such as YouTube, Instagram, and

TikTok in short durations, indicating that visual and audiovisual elements play a dominant role in supporting student comprehension.

In terms of access to and use of technology, many students reported being accustomed to using mobile devices or smartphones at home—though most are still under parental supervision—and admitted to accessing videos on social media platforms such as YouTube, Instagram, and TikTok for both learning and entertainment. This situation indicates significant potential for the DNL model, which leverages short videos as an initial stimulus for the discovery process in learning.

Regarding critical thinking skills, the findings show that students can identify simple information from learning materials; however, they also struggle to compare information or draw independent conclusions. Students' advanced evaluation and reasoning skills remain in the low-to-moderate range, as evidenced by their inability to provide reasons for their selected answers. These findings indicate that students' critical thinking skills still need improvement through a more structured, context-based, step-by-step discovery-based learning model.

Challenges encountered in the classroom include students' low level of independent learning; most students still require teacher guidance in discovering concepts within the material. Furthermore, although students are accustomed to using mobile devices, smartphones, and social media platforms, their use is not yet fully directed toward learning, as these devices are still predominantly used for entertainment. Meanwhile, students' critical thinking skills remain limited, particularly in analyzing, comparing, and drawing independent conclusions.

Differences in access to and guidance on technology use at home mean that digital technology-based learning has not yet been implemented evenly; consequently, teachers still need to play an active role as facilitators who guide the use of media to ensure it is more focused, structured, and supports both conceptual understanding of the material and the optimal development of students' critical thinking skills. Overall, the analysis of audience (student) characteristics and context indicates that students exhibit characteristics of visual and digital learners with sufficient initial potential for critical thinking; they also require active, context-specific learning tailored to the needs of the digital generation.

The study utilized a primary instrument—a test—designed to measure students' critical thinking skills in fourth-grade IPAS (Integrated Science, Art, and Social Studies) lessons on the topic "What Was My Hometown Like in the Past?" covering the Banten Kingdom, using the DNL model. The instrument was used to assess cognitive learning outcomes following the instructional process based on four key aspects of critical thinking: clarification, evaluation, inference, and strategy. The test instrument consisted of 10 items organized according to five learning achievement indicators: the ability to describe the origins of the region and local figures; to identify exemplary attitudes of historical figures; to compare the region's past and present conditions; to identify kingdoms that once flourished in the region; and to explain the importance of preserving historical heritage. Each indicator has two test items designed to measure students' understanding and thinking skills in a simple yet targeted manner. Scoring on the test instrument is based on the accuracy and completeness of students' answers.

The presentation of the results is integrated. Test results are presented as percentages of mastery or as average student achievement scores for each indicator. Furthermore, these results are analyzed comparatively and descriptively to examine the relationship between the learning process and learning outcomes (tests), thereby providing a comprehensive picture of the effectiveness of applying the DNL

model in the IPAS subject in enhancing the critical thinking skills of fourth-grade elementary school students.

The development and selection of instructional materials in this study focused on supporting the implementation of the DNL model in fourth-grade IPAS instruction at the elementary school level, specifically for the topic "What Was the Area Where I Used to Live Like?" covering the Banten Kingdom, to develop students' critical thinking skills through the learning process. The instructional materials were not only designed based on the Merdeka Curriculum—which includes learning outcomes and learning objectives—but were also adapted to students' needs, cognitive developmental characteristics, and learning styles, which are more responsive to brief, engaging audiovisual media. In line with the implementation of the DNL model, the materials are designed as learning activities focused on a single core concept (one learning objective) in each learning activity, so that students can gradually engage in a discovery process through observing, identifying, comparing, and drawing conclusions about information related to the material.

In selecting instructional materials, emphasis is placed on using short instructional videos (1–5 minutes) sourced from social media platforms such as YouTube, TikTok, and Instagram—platforms that are already familiar to students in their daily lives. These videos are selectively chosen and adapted to ensure they are relevant to the learning objectives, easy to understand, and capable of serving as an initial stimulus for learning. Instructional materials must also be flexible and easily accessible via Android devices, smartphones, or smart TVs, thereby supporting learning that is not limited by time or place. In addition to videos, the materials include enrichment content, thought-provoking questions, and simple inquiry-based tasks designed to develop students' critical thinking skills gradually.

The development process is carried out systematically, beginning with an analysis of student and teacher needs, the "Merdeka" curriculum, and the critical thinking indicators to be achieved. Next, during the design phase, a nano-based content structure is developed that aligns with the IPAS learning objectives: understanding the region's historical development through historical figures and artifacts, and their relevance to contemporary life. During the development stage, the materials were also organized into a discovery-based sequence that begins with a stimulus in the form of a short video, followed by information exploration, discussion, and simple reflection, encouraging students to build their understanding independently. The selection of instructional materials in the DNL model emphasizes ease of access and relevance to students' lives, without compromising the depth of learning.

In this study, the researcher has also developed an instructional design blueprint that serves as the foundation for the DNL model. Theoretically, an instructional design blueprint is a systematically organized framework for learning planning that outlines how the learning process is designed, developed, and implemented in its entirety before being applied in the classroom. This blueprint encompasses the interrelationships between learning objectives, content, strategies, media, student activities, and learning assessment, ensuring that all these components are logically and purposefully interconnected. In the literature on instructional design, Reigeluth (1983) asserts that instructional design is "a set of prescriptive strategies for facilitating learning," suggesting that it serves as a strategic guide to facilitate the learning process effectively.

The pedagogical design serves not only as a conceptual framework but also as a systematic guide that describes how the learning process is designed, organized, and implemented. The results of this design were realized in two main products: an academic book and an implementation guidebook. The academic

book presents the theoretical foundations, basic concepts, and scientific development of the DNL model. In contrast, the model implementation guidebook provides operational instructions for the practical, structured application of the model in classroom learning activities.

Thus, the instructional design blueprint developed in this study serves as a bridge between theory and practice, ensuring that the DNL model can be comprehensively understood while remaining easy for teachers to apply and use in classroom learning contexts. The following is the instructional design blueprint developed in this study:

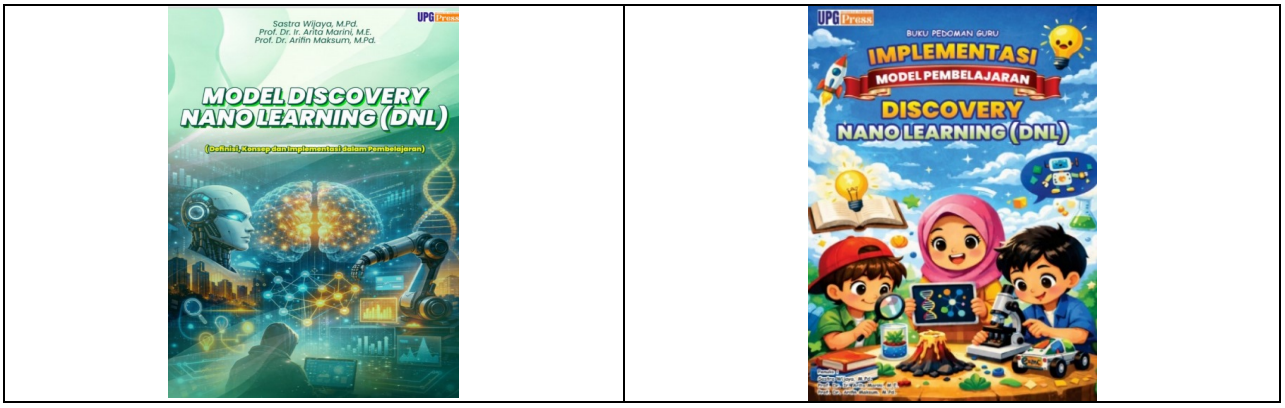


Figure 4.6 Pedagogical Design (Instructional Design Blueprint)

Overall, a comparison of the two classes shows that the experimental class achieved a much greater improvement than the control class, both in average and maximum scores. This indicates that the DNL model is more effective in improving students' critical thinking skills than conventional instruction. In addition to significantly improving learning outcomes, this model also produces a more even distribution of scores at high achievement levels, suggesting that it offers advantages in both the quantity and quality of learning outcomes. An N-Gain test was then used to determine the extent of improvement in students' critical thinking skills following the intervention. The results of the N-Gain test are presented in the following table:

Table 4.36 Results of the N-Gain Score Test

Class	N	Mean N-Gain	Category
Experimental	30	0,80	High
Control	28	0,25	Low

The n-gain score test results above show the level of improvement in students' critical thinking skills following instruction in both classes. In the experimental class, the average n-gain score was 0.80, placing it in the high category, with 30 students. This indicates that implementing the DNL model produced a highly significant improvement in students' critical thinking skills. An n-gain score close to 1 indicates that most students experienced optimal improvement from their initial level to the final results, meaning that the instruction was not only effective but also maximized students' overall learning potential.

In contrast, in the control class, the average n-gain value was 0.25 for 28 students, which falls into the low category. This suggests that the improvement in students' critical thinking skills in the class using conventional instruction was relatively limited. Although an improvement occurred, its magnitude was not significant and did not yet lead to optimal learning outcomes.

The striking difference between these two classes demonstrates that the DNL model is far more effective than conventional instruction in enhancing students' critical thinking skills. Constructively, these findings reinforce the notion that instructional models emphasizing active student engagement, exploration, and independent concept discovery—such as the DNL model—are better at fostering improvements in critical thinking skills than passive instructional models. Thus, the DNL model can be recommended as an effective alternative learning strategy to improve the quality of students' learning processes and outcomes. Subsequently, a prerequisite test was conducted to ensure that the data met the assumptions of parametric analysis. To determine whether the difference in means was statistically significant, an independent-samples t-test was performed. Hypothesis testing in this study used an independent-samples t-test to determine whether there was a difference in improvement in students' critical thinking skills between the experimental class using the DNL model and the control class using conventional instruction. This test focused on gain data (n-gain) because it better represents changes in students' abilities after the intervention was administered.

Two hypotheses were established for this test: the null hypothesis (H_0), which states that there is no difference in the improvement in critical thinking skills between the two classes, and the alternative hypothesis (H_1), which states that there is a difference in the improvement in critical thinking skills between the experimental class and the control class. Through this test, the researcher can determine whether the implemented learning model has a significant effect on students' critical thinking skills.

Table 4.39 Results of the Independent Sample T-Test

Description	Value
Experimental Group	30
Control Group	28
Total	58
Calculated t-value	10,21
df	56
Table t-value	2,00
Sig (2-tailed)	0,000

The results of the independent-samples t-test indicate a highly significant difference in the improvement in critical thinking skills between students in the experimental and control classes. Based on the data, the sample sizes for the experimental and control classes were 30 and 28 students, respectively, for a total of 58 students. The calculated t-value was 10.21 with 56 degrees of freedom (df). When compared to the critical t-value of 2.00 at a significance level of 0.05, it is evident that the calculated t-value is much larger than the critical t-value (10.21 > 2.00). Additionally, the significance value (Sig., 2-tailed) is 0.000, which is less than 0.05.

Statistically, these results indicate that the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted; thus, it can be concluded that there is a significant difference in the improvement of critical thinking skills between the two groups. In other words, the treatment administered to the experimental class has a significant effect on learning compared to the control class. Substantively, the very high calculated t-value indicates that the observed difference is not merely statistically significant but also reflects a strong effect size. This means that the DNL model makes a significant contribution to improving students' critical thinking skills compared to conventional teaching methods. This difference is also consistent with previous analysis results, such as the higher n-gain scores in the experimental class. From a constructive perspective, these results provide a strong foundation for recommending the

implementation of innovative learning models like DNL in the learning process, particularly for developing students' critical thinking skills. Thus, these findings not only have theoretical implications but also offer practical contributions to the development of more effective learning strategies in the classroom.

Furthermore, an effect size calculation (Cohen's d) was performed to determine the practical magnitude of a treatment's influence—beyond mere statistical significance. In other words, although the t-test results indicated a difference, the effect size helps explain how strong or substantial that difference is in a real-world context. The primary purpose of using Cohen's d is to provide a measure of the strength of an effect from a learning model, thereby making research results more meaningful and easier to interpret. Mathematically, Cohen's d is calculated by comparing the difference in means between two groups with the pooled standard deviation. The formula used is: $d = (M_1 - M_2) / SD_{pooled}$, where M_1 is the mean of the experimental group, M_2 is the mean of the control group, and SD_{pooled} is the pooled standard deviation of both groups. The resulting value is then interpreted to determine whether the effect is small, moderate, or large. The results of the effect size calculation (Cohen's d) are shown in the following table:

Table 4.40 Results of the Effect Size (Cohen's d) Calculation

Comparison	***Cohen's d***	Category
Experimental vs. Control	6,48	Very High

The results of the effect size calculation (Cohen's d) above indicate that the learning model implemented had a very strong effect on improving students' critical thinking skills. Based on the data, the mean score in the experimental class was 96.67, while that in the control class was 66.79, with a pooled standard deviation (SDpooled) of 4.61. From these calculations, a Cohen's d value of 6.48 was obtained, which falls into the "very high" category. Substantively, an effect size of 6.48 indicates that the difference between the two groups is not only statistically significant but also very strong in practical terms. This means that the improvement in students' critical thinking skills in the experimental class using the DNL model was far greater than that in the control class, with a very large and consistent difference. In the context of Cohen's interpretation, a value above 0.8 is already considered large; thus, a value of 6.48 indicates an exceptionally strong effect.

From a constructive perspective, these findings indicate that the DNL model is highly effective in enhancing students' critical thinking skills. This model is capable of producing tangible and significant impacts on learning outcomes, making it not only theoretically relevant but also highly recommended for implementation in educational practice. Thus, these effect size results reinforce all previous research findings and confirm that the use of the DNL model is a highly effective strategy compared to conventional instruction.

Consequently, to provide a comprehensive explanation, the researchers have summarized the analysis results to offer a complete picture of the differences in learning outcomes and improvements in students' critical thinking skills between the experimental and control classes. This data is a synthesis of various tests that have been conducted, including descriptive statistics, the N-Gain test, hypothesis testing, and effect size calculations, so that it can be used as a basis for drawing comprehensive research conclusions. The summary of the analysis results is presented in the following table

Table 4.41 Summary of Analysis Results

Analysis	**Results**

Mean Posttest (Experimental Group)	96.67
Mean Posttest (Control Group)	66.79
N-Gain (Experimental Group)	0.80 (High)
N-Gain (Control Group)	0.25 (Low)
T-Test Significance	0.000
Cohen's d	6.48 (Very High)

Based on the summary of the analysis results above, it can be seen that the average posttest score for the experimental class was 96.67, significantly higher than that of the control class, which was only 66.79. This indicates a significant difference in learning outcomes. Furthermore, the N-Gain score for the experimental class was 0.80, which falls into the high category, while the control class scored only 0.25—a low category—indicating that the improvement in critical thinking skills among students in the experimental class was far more optimal. The results of the hypothesis test also showed a significance value of 0.000 (< 0.05), meaning there was a significant difference between the two groups.

This finding is further reinforced by a Cohen's d value of 6.48, which falls into the very high category; thus, it can be concluded that the DNL model not only has a statistically significant effect but also exerts a very strong influence on improving students' critical thinking skills compared to learning using conventional models.

The results of the student tests reinforce the finding that the DNL model has been proven to enhance students' thinking skills, particularly as measured by the indicators of clarification, assessment, inference, and strategy. The test results were summarized to provide a more objective and contextual overview of students' engagement and the development of their critical thinking skills during the implementation of the DNL model. Thus, the results demonstrate that the use of the DNL model has proven to be highly effective in improving students' critical thinking skills in elementary school.

CONCLUSION

The DNL model was developed using a research and development (R&D) approach based on the Dick and Carey model. The DNL model was developed in response to empirical needs in the field, which revealed low student learning achievement—with only 36.21% of students meeting proficiency standards—as well as a high demand among students and teachers for digital technology-based learning. As a result, the DNL model integrates the principles of discovery learning and nano-learning, embodied in the S6 framework—namely, stimulation, strategy, scaffolding, short discovery, solve, and share—each of which is structured to progressively develop students' critical thinking skills.

Based on research on the development of the DNL model in IPAS instruction to enhance elementary school students' critical thinking skills, several key findings can be summarized to reflect the entire research process and outcomes comprehensively. First, the development of the DNL model was driven by real-world needs in the field, namely students' low critical thinking skills—evidenced by suboptimal learning outcomes—and the limitations of the instructional models currently used by teachers. Instruction that remains conventional, teacher-centered, and fails to engage students actively is one of the main factors hindering the development of critical thinking skills. Furthermore, the characteristics of elementary school students—who require concrete, visual, and step-by-step learning—have not been

fully accommodated in current instructional practices. Therefore, the DNL model was developed as an innovative solution tailored to the characteristics and learning needs of elementary school students.

Second, the DNL model and its implementation guidebook were deemed highly suitable for instructional use. The suitability of the DNL model was confirmed by validation from instructional model experts (91.67%) and instructional design experts (92.22%), with an average of 91.94% in the "highly suitable" category. Meanwhile, the suitability of the guidebook was determined by validation from media experts (96.92%), content experts (86.67%), and language experts (93.33%), with an average of 92.31% in the "highly suitable" category. This level of suitability is further reinforced by user response test results: a 94.44% response rate from teachers and a 95.00% response rate from students, which confirm that the DNL model and its supporting handbook are not only theoretically valid but also practical and well-received in real-world classroom use.

Third, the DNL model has proven effective in enhancing elementary school students' critical thinking skills. This was demonstrated through a series of phased trials, ranging from one-on-one trials with an average score of 73.33 to small-group trials with an average of 81.11, culminating in a field trial that yielded the most convincing results. In the field trial, the experimental class using the DNL model achieved a posttest average of 96.67 with an N-Gain of 0.80 in the high category, far surpassing the control class, which only achieved a posttest average of 66.79 with an N-Gain of 0.25 in the low category. The results of the independent-samples t-test yielded a p-value of 0.000, which is less than 0.05, thus confirming a significant difference between the two classes, while the effect size (Cohen's d) of 6.48—classified as "very high"—indicates an exceptionally strong effect.

Thus, it can be concluded that the development of the DNL model, aimed at improving elementary school students' critical thinking skills in the IPAS subject, has been successfully implemented systematically and has met the criteria for a valid, feasible, and effective learning model. Consequently, the DNL model is highly recommended as an alternative to enhance elementary school students' critical thinking skills in the IPAS subject in the era of digital technological advancement.

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