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Development Of The Smarty-Ai Model Within The Understanding By Design Framework To Enhance Students Critical Thinking Skills

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Abstrak. This study aims to develop and examine the effectiveness of the SMARTY-AI Model within the Understanding by Design (UbD) framework integrated with Artificial Intelligence (AI) in improving elementary school students critical thinking skills. The research employed a Research and Development (R&D) method consisting of model development stages, expert validation, and effectiveness testing through a quasi-experimental design involving experimental and control groups. The findings revealed that the SMARTY-AI Model achieved a very high level of feasibility based on expert validation results, with an average score of 92.6%. Furthermore, the effectiveness test indicated a more significant improvement in learning outcomes in the experimental class compared to the control class. The N-Gain score in the experimental class was 0.61 (moderate category), while the control class obtained 0.29 (low category).These findings indicate that the integration of the Understanding by Design approach with Artificial Intelligence support in the SMARTY-AI Model is effective in enhancing elementary school students' critical thinking skills. This model can serve as an innovative alternative for 21st century learning that emphasizes the development of higher-order thinking skills.

Kata Kunci: Model SMARTY-AI, Understanding by Design; Artificial Intelligence, Critical Thinking, Elementary School.

I. INTRODUCTION

Background of the Study

21st century education requires students not only to master knowledge but also to develop critical thinking, creativity, collaboration, and communication skills. Critical thinking skills are considered one of the essential competencies that should be cultivated from the elementary school level, as they help students analyze information, evaluate arguments, and make rational decisions [1]. However, various studies indicate that Indonesian students' critical thinking skills remain relatively low, particularly in learning environments that are still oriented toward memorization and provide limited opportunities for exploration [2].

Along with technological advancement, the utilization of Artificial Intelligence (AI) in education has demonstrated significant potential for improving learning quality. The implementation of AI in elementary school learning can also enhance students' digital literacy and thinking skills through more interactive and adaptive learning experiences [3]. AI can function as scaffolding that assists students in understanding concepts, providing immediate feedback, and facilitating more personalized learning experiences [4]. Furthermore, UNESCO [5] emphasized that the integration of AI into the elementary education curriculum is part of a global educational transformation aimed at developing digital literacy, computational thinking, creativity, and higher-order thinking skills. The use of AI in learning should therefore be pedagogically designed so that it not only serves as a supporting technology but also creates more personal, adaptive, and interactive learning experiences. The integration of digital technology into learning has been proven to increase student engagement and encourage the development of higher-order thinking skills [6]. Nevertheless, the use of AI in elementary school learning remains suboptimal and has not yet been systematically integrated into instructional design.

Problem of the Study

One approach that can be used to design meaningful learning is Understanding by Design (UbD). This approach emphasizes backward design, enabling the learning process to become more structured and focused on competency achievement [7]. UbD also promotes deep learning through the alignment between learning objectives, assessment, and instructional activities [8]. In the context of 21st-century learning, the integration of UbD with digital technology, including AI, can provide an innovative solution for improving learning quality [9].

In addition, technology-based and innovative learning approaches such as STEAM and AI have been shown to improve students' critical thinking skills through more contextual and interactive learning experiences [10]. The integration of AI in learning even enables the creation of adaptive and responsive learning environments that accommodate students' individual needs [11]. However, there are still limitations in the development of instructional models that specifically integrate the UbD approach with AI in the elementary school context.

Findings regarding the effectiveness of AI in learning are further supported by the study conducted by Zhang et al. [12], which revealed that AI-driven automated feedback can improve students' critical thinking skills through rapid, personalized, and continuous feedback. AI-based feedback systems help students evaluate mistakes, revise responses, and develop reflective thinking processes more independently [12]. In the context of elementary education, the use of AI as scaffolding and adaptive feedback is particularly important because it assists students in understanding concepts gradually according to their learning needs. Therefore, the integration of AI in the SMARTY-AI Model is designed not merely as a technological medium, but also as a learning facilitator that supports the optimal development of students' critical thinking skills.

Research Gap and Objective

Based on these issues, there is a need for an instructional model that systematically integrates strong pedagogical approaches with modern technology. Therefore, this study develops the SMARTY-AI Model within the Understanding by Design framework as a learning innovation aimed at improving elementary school students' critical thinking skills. This model is designed by integrating strategies, media, and learning activities supported by AI as a learning assistance tool.An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

II. METHODS

Research Design

This study employed a Research and Development (R&D) approach by adapting the Dick and Carey model, which emphasizes the integration of objectives, strategies, instructional materials, and learning evaluation [13]. The development process was conducted systematically, starting from needs analysis to the refinement of the final product.

Development Procedures

At the initial stage, a needs analysis was carried out through observations and interviews to identify learning conditions and students' needs. Subsequently, the researcher designed the SMARTY-AI Model based on the Understanding by Design (UbD) framework, integrating AI technology as instructional scaffolding. The use of AI as scaffolding in learning is also supported by the findings of Sun et al. [14], which demonstrated that prompt-based support and digital discussions can help students develop critical thinking skills through deeper reflection and analytical processes. This finding indicates that technology can be effectively utilized to support students' active engagement in learning.

The developed product was then validated by material experts, media experts, and language experts to evaluate content feasibility, visual appearance, and readability. After undergoing revisions, the model was tested on a limited scale before being implemented in a field trial using a quasi-experimental design involving an experimental group and a control group.

Research Subjects

The research subjects consisted of 10 elementary school students divided into two groups: 5 students in the experimental group and 5 students in the control group. The experimental group used the SMARTY-AI Model, while the control group received conventional learning instruction.

Data Collection and Analysis

Data collection was conducted through pretests and posttests to measure students' critical thinking skills. Data analysis was performed using the N-gain test to determine improvements in learning outcomes, as well as descriptive analysis to evaluate the feasibility of the model.

I. RESULT AND DISCUSSION

A. Product Design and Development

The SMARTY-AI Model was developed based on the Understanding by Design (UbD) framework, which emphasizes the backward design approach, where instructional planning begins with determining learning objectives, followed by assessment design, and ends with the development of learning activities. This model also integrates the use of Artificial Intelligence (AI) as scaffolding to support students' critical thinking processes. The use of technology in UbD-based instructional design can support the creation of deeper learning through structured and meaningful learning activities [15]. The development of the SMARTY-AI Model adapted the principles of backward design within the UbD framework so that learning activities, media, and assessments were systematically integrated to support students' critical thinking skills [16].

The design and development process was conducted systematically by considering the interrelationship among instructional strategies, media, and learning activities. At this stage, the researcher designed UbD-based learning scenarios integrated with AI through the components of strategy, media, and activity, ensuring that learning was not only oriented toward content delivery but also toward students' thinking processes. UbD-based learning helps students understand concepts more deeply through the alignment between learning objectives, assessments, and instructional activities [17].

Furthermore, the development stage focused on creating the SMARTY-AI Model prototype along with digital instructional materials that support the implementation of learning. The resulting products included interactive digital modules, instructional videos, and AI-STEM-based quizzes designed to increase student engagement and critical thinking skills. The integration of Artificial Intelligence (AI) in STEAM learning can create more personalized and adaptive learning experiences according to students' needs [18].

The development of instructional materials considered the characteristics of elementary school students, who tend to prefer visual and interactive learning experiences. Therefore, the media integrated text, images, videos, and interactive features that enabled students to learn independently as well as through guided instruction.

In addition, the model development process involved collaboration with educational teams and partners to ensure that the resulting product was not only theoretically valid but also applicable within classroom learning contexts. This, the developed SMARTY-AI Model possesses adaptive, contextual, and critical thinking-oriented characteristics. The following is the SMARTY-AI design framework based on Understanding by Design to enhance students' critical thinking.

Figure 1. Research Framework

Source: Developed by the researcher, 2026.

B. ***Expert Validation Result***

The validation stage was conducted to ensure the feasibility of the SMARTY-AI Model before its implementation in learning activities. The validation process involved media experts, material experts, and language experts to evaluate the quality of the product from various aspects. The validation results indicated that the SMARTY-AI Model was categorized as highly feasible for use.

Table I. Model Validation Results

Aspect	Percentage	Category
Media	91%	Highly Feasible
Material	93%	Highly Feasible
Language	94%	Highly Feasible
Average	92.6%	Highly Feasible

Source: Processed Data, 2026

Based on Table 1, the language aspect obtained the highest score, indicating that the presentation of the material was communicative and appropriate for the characteristics of elementary school students. Meanwhile, the material and media aspects also achieved the “highly feasible” category, meaning that the learning content was relevant and supported by an attractive and user-friendly design.

These results indicate that the SMARTY-AI Model has met the feasibility standards in terms of content, design, and language. Therefore, the model could proceed to the effectiveness testing stage with minor revisions based on the validators suggestions.

C. ***Effectiveness Test Result (Pretest-Posttest)***

The effectiveness test was conducted to determine the effect of the SMARTY-AI Model on students’ critical thinking skills. The measurement was carried out through pretests and posttests administered to both the experimental and control groups.

Table 2. Pretest And Posttest Data

Class	Pretest	Posttest
Experimental	55	82
Control	54	65

Source: Processed Data, 2026

Based on Table 2, the average pretest scores of both groups were relatively similar, indicating that the students’ initial abilities were at a comparable level. However, after the treatment was administered, the experimental group showed a more significant improvement compared to the control group. This improvement indicates that the use of the SMARTY-AI Model contributed positively to students learning outcomes, particularly in enhancing critical thinking skills. This result was supported by the integration of AI as scaffolding and the UbD based instructional design, which encouraged students to think more deeply and systematically.

D. ***N-Gain Analysis***

To determine the level of improvement in students’ critical thinking skills more specifically, an N-Gain analysis was conducted.

Table 3. N-Gain Result

Class	N-Gain	Kategori
Experimental	0.61	Moderate
Control	0.29	Low

Source: Processed Data, 2026

Based on Table 3, the N-Gain score of the experimental group was categorized as moderate, while the control group was categorized as low. This indicates that the improvement in critical thinking skills among students who used the SMARTY-AI Model was higher than that of students who experienced conventional learning. More specifically, these findings indicate that the integration of AI technology in learning can provide effective cognitive support for students in understanding concepts and solving problems. In addition, the UbD approach, which focuses on learning objectives and assessment, helps students build more meaningful understanding. Therefore, it can be concluded that the SMARTY-AI Model is effective in improving elementary school students' critical thinking skills, although the improvement remains within the moderate category. This finding provides opportunities for further development so that future studies may achieve higher improvement categories.

E. ***Discussion***

The findings of this study indicate that the SMARTY-AI Model based on Understanding by Design (UbD) integrated with Artificial Intelligence (AI) demonstrates strong feasibility and effectiveness in improving elementary school students' critical thinking skills. This was evidenced by the expert validation results, which fell into the highly feasible category, as well as the greater improvement in learning outcomes shown by the experimental group compared to the control group.

From the validation aspect, the average score of 92.6% indicates that the developed model met quality standards in terms of content, media, and language. The high score in the language aspect demonstrates that the presented material was communicative and appropriate for elementary school students' characteristics, while the media and material aspects indicate that the instructional design was engaging, relevant, and supportive of the learning process. These findings strengthen the view that UbD-based design can produce structured instructional materials oriented toward clear learning objectives.

Furthermore, the effectiveness test results revealed a significant improvement in the experimental group compared to the control group. Although the initial pretest scores of both groups were relatively similar, the posttest improvement in the experimental group was substantially higher. This finding suggests that the SMARTY-AI Model provided more meaningful learning experiences than conventional learning approaches. The integration of AI in the SMARTY-AI Model was designed as instructional scaffolding that assisted students in understanding concepts and gradually developing critical thinking skills. This finding is consistent with the perspective of Luckin and Cukurova [19], who argued that AI-based educational technology should be designed to support adaptive and meaningful learning processes. The improvement achieved was closely related to the role of AI as scaffolding that helped students understand concepts, receive feedback, and develop thinking processes gradually.

The N-Gain analysis further strengthened these findings, where the experimental group achieved a moderate category (0.61), while the control group remained in the low category (0.29). This difference indicates that the integration of the UbD approach with AI technology can enhance learning effectiveness, particularly in developing critical thinking skills. Learning designed through backward design enables students to understand learning objectives more clearly, while AI provides adaptive support according to students' learning needs.

From a pedagogical perspective, these findings align with constructivist theory, which emphasizes that learning becomes more effective when students actively construct their own knowledge. In the SMARTY-AI Model, students not only received information but were also involved in interactive activities, problem-solving, and reflection processes that encouraged higher-order thinking. Moreover, the use of interactive digital media is compatible with the characteristics of the current generation, who tend to respond more positively to technology-based learning.

Nevertheless, the N-Gain results, which remained within the moderate category, indicate that there is still room for further improvement. Several possible influencing factors include the limited duration of implementation, students' adaptation to new technologies, and variations in students' initial abilities. Therefore, future research may further develop this model through longer implementation periods, more adaptive AI features, and application in broader contexts and educational levels.

Overall, the findings of this study demonstrate that the UbD-based SMARTY-AI Model integrated with AI is not only feasible for use but also effective in improving students' critical thinking skills. This model can serve as an innovative alternative for 21st-century learning that demands the integration of pedagogy, technology, and higher-order thinking skill development.

II. CONCLUSIONS

This study aimed to develop and examine the effectiveness of the SMARTY-AI Model based on Understanding by Design (UbD) in improving elementary school students' critical thinking skills. The findings revealed that the developed model achieved a very high level of feasibility based on expert validation results, with an average score of 92.6%. In addition, the effectiveness test demonstrated a more significant improvement in learning outcomes in the experimental group compared to the control group, supported by an N-Gain score of 0.61 (moderate category) in the experimental group and 0.29 (low category) in the control group. These findings indicate that the integration of the UbD approach with the use of Artificial Intelligence (AI) can positively contribute to the development of students' critical thinking skills. he SMARTY-AI Model contributes to creating learning environments that are more structured, adaptive, and goal-oriented. The backward design approach helps teachers systematically design instruction, while AI integration functions as scaffolding that supports students' individual learning processes. Nevertheless, the findings indicate that the improvement achieved remained within the moderate category, suggesting the need for further development, such as enhancing AI adaptivity features, extending the implementation duration, and conducting studies with broader contexts and larger sample sizes to obtain more optimal results.

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