JOURNAL OF INNOVATION AND RESEARCH IN PRIMARY EDUCATION | ISSN 2829-775X
Vol. 4, No. 3, 2025, 673-683
https://doi.org/10.56916/jirpe.v4i3.1354

Development of Web-Based Learning Media with an Inquiry Model to Enhance Learning Outcomes and Student Independence in Elementary Schools

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Keywords
Elementary school
Interactive Web Media
Inquiry Learning
Learning Independence
Science Education (IPAS)

Article History
Received 2025-05-10
Accepted 2025-07-06

Abstract
This study aimed to develop a web-based learning medium utilizing an inquiry model to enhance primary school students' cognitive learning outcomes and learning independence. The development procedure followed the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The research subjects were 60 fifth-grade elementary school students, divided into experimental and control groups. Data collection techniques included observation, questionnaires, and learning achievement tests. Media validity assessments by material and media experts yielded an average score of 94% ("very valid" category), while practitioner teacher evaluations indicated 91% feasibility. Effectiveness tests revealed significant improvements in the experimental group: average cognitive learning outcomes increased from 68.4 to 87.2, whereas the control group only rose from 66.1 to 72.3. Similarly, the experimental group's learning independence questionnaire scores increased from 66.5 to 85.6, compared to the control group's increase from 67.2 to 70.8. T-tests confirmed the significance of these improvements ($p<0.05$) for both variables. The main innovation lies in integrating the inquiry model into an interactive web-based medium specifically designed for the IPAS topic "Earth Layer Structure." This medium empowers students to construct knowledge through self-exploration, visual interaction, and reflective, inquiry-based activities, addressing a gap in digital learning development at the primary school level. Practical implications suggest that this inquiry-based interactive web medium can serve as a strategic alternative for IPAS learning, emphasizing conceptual understanding and fostering learning independence. The medium's flexibility allows for broad integration into various learning scenarios, supporting both offline and online adaptive and personalized instruction.

INTRODUCTION

Education at the primary school level faces a significant challenge in cultivating student learning independence, a fundamental component of an effective learning process. Learning independence encompasses students' capacity to learn autonomously, manage their time effectively, and assume responsibility for their own learning, while exhibiting minimal reliance on teacher supervision (Zimmerman, 2017). Hattie (2017) posits that learning efficacy is contingent on students' ability to self-regulate their learning processes. In the contemporary educational landscape, learning models that foster independence, such as project-based learning, inquiry models, and the integration of educational technology, have gained significant prominence within the 21st-century learning paradigm.

The 21st-century learning paradigm places considerable emphasis on cultivating students' capacity for critical thinking, creative thinking, and autonomous learning. One method of facilitating independent learning is to provide media that enables active student engagement. Interactive web-based learning media constitutes a promising alternative with the potential to foster greater student

involvement in the learning process (Wang, 2020). The utilization of web-based media allows students to learn at their own pace, access diverse materials, and explore content with greater flexibility.

However, while the importance of independent learning is increasingly recognized, its application within the context of Natural and Social Sciences (IPAS) learning, particularly on more complex topics such as the structure of Earth's layers, remains limited. To facilitate effective IPAS learning, it is essential to adopt an approach that encourages active student participation and promotes independent understanding. The inquiry model, which grants students the autonomy to question, seek answers, and investigate information more thoroughly, has been identified as an effective solution (Gokhale, 2018).

Recent studies have demonstrated that integrating technology into learning can enhance student learning independence. Nugroho & Santoso (2021) suggest that utilizing interactive web-based media in educational settings has the potential to boost student engagement by providing readily accessible materials and enabling further exploration without the necessity for direct supervision. Furthermore, Sullivan & Schorr (2019) empirically substantiate the efficacy of technology-based learning models in enhancing students' cognitive achievement, particularly in scientific disciplines.

Despite numerous studies on technology use in learning, there remains a significant gap in research specifically examining the combination of inquiry models with web-based media, particularly within the context of IPAS learning in elementary schools. While research by Putri et al. (2022) indicates the inquiry model's capacity to enhance students' comprehension and critical thinking skills across various subjects, studies integrating this model with interactive web-based media for IPAS learning are still rare. Similarly, Rahman et al. (2020) demonstrated that implementing the inquiry model can improve students' understanding of complex subjects; however, its efficacy when combined with interactive web-based media, especially for IPAS topics requiring profound comprehension like Earth's layer composition, necessitates further investigation.

This gap is crucial given the challenges in fostering learning independence and deep understanding of complex IPAS topics. Existing research tends to examine inquiry models or web-based media separately, or within the context of other subject areas. Therefore, this study aims to address this gap by specifically integrating the inquiry model into interactive web-based learning media for the IPAS material "Earth Layer Structure." This integration is expected to create a learning environment that enables students to actively construct their knowledge through exploration, visual interaction, and reflection, consistent with the principles of constructivist learning theory (Piaget, 1972; Vygotsky, 1978). According to this theory, learning is an active process where students construct knowledge through experience and interaction with their environment. An interactive web-based medium designed with an inquiry model inherently supports this principle by facilitating self-directed exploration and problem-solving.

The significance and originality of this research lie in its systematic endeavor to develop and evaluate the effectiveness of an innovative learning medium that uniquely combines an inquiry model with an interactive web platform. This aims to enhance primary school students' learning independence and cognitive outcomes in complex IPAS subject matter. This combination, which is underrepresented in the existing literature, is expected to make a significant contribution to 21st-century educational practices. The main objectives of this research are: (1) to develop an interactive web-based learning media product incorporating an inquiry model for the IPAS material "Earth Layer Structure," and (2) to examine its impact on the cognitive learning outcomes and learning independence of fifth-grade elementary school students.

This study is anticipated to provide valuable insights into how technology and pedagogy can synergize to address learning challenges in primary education, particularly in developing crucial skills such as learning independence and deep conceptual understanding.

METHODS

This study employed a Research and Development (R&D) approach to develop and evaluate interactive web-based learning media integrating an inquiry learning model. The approach was selected for its ability to produce valid and effective learning products that improve cognitive outcomes and student autonomy (Borg & Gall, 2003). The development followed the ADDIE model—Analysis, Design, Development, Implementation, and Evaluation (Molenda, 2003).

The research was conducted at SD Kanisius Tlogosari Kulon, Semarang, during the first semester of the 2024/2025 academic year. Participants consisted of 60 fifth-grade students divided into two groups: an experimental group using the developed media (30 students) and a control group receiving conventional instruction (30 students). A purposive sampling method was applied based on equivalent academic ability and learning environment, determined through pretest scores and teacher input (Sugiyono, 2017).

The initial phase involved a needs analysis through teacher interviews and curriculum review to identify appropriate IPAS content aligned with student characteristics. The design stage included flowcharts, storyboards, and interface sketches based on the inquiry model. Media development was carried out using Unity WebGL, enabling browser access and incorporating interactive games and inquiry-driven tasks.

Expert validation followed the prototype's completion, involving material experts, media experts, and classroom teachers. Validation focused on content quality, interactivity, and instructional relevance, assessed using a 4-point Likert scale. Aiken's V was used to analyse item validity (Aiken, 1985), and expert feedback informed subsequent revisions. A readability test was then conducted in one class before implementation in the experimental group.

Three types of instruments were used. First, an expert validation questionnaire assessed media feasibility. Second, a 40-item multiple-choice test measured cognitive learning outcomes before and after implementation. Third, a student learning independence questionnaire—based on eight indicators from Ryan & Deci, Moos & Ringdal, Paris & Paris, Efklides, and Nicol & Macfarlane-Dick—measured: initiative, time discipline, autonomy, responsibility, self-confidence, perseverance, problem-solving, and self-evaluation. The instrument was validated through expert review and tested for reliability using Cronbach's Alpha ($\alpha = 0.86$), indicating high internal consistency (Fraenkel, Wallen, & Hyun, 2012).

Descriptive statistics were used to present validation outcomes and student responses. Inferential statistics were applied to determine media effectiveness. A paired sample t-test compared pretest and posttest results within groups, while an independent sample t-test compared outcomes between groups. N-Gain analysis assessed learning improvement (Hake, 1998). All analyses were performed using SPSS version 25.

RESULTS

The present study involved the development and evaluation of an interactive web-based learning medium named Geoland, designed with an inquiry model. The following sections detail the findings from the development and implementation phases.

1.Need Analysis

The needs analysis revealed that both students and teachers require learning media that are interactive, visually engaging, and capable of promoting active student participation. This finding aligns with Sadiman et al. (2016), who emphasized that instructional media play a crucial role in enhancing the effectiveness, efficiency, and attractiveness of the learning process. Moreover, the need for an inquiry-based model is consistent with Bruner's (1977) view that learning becomes more meaningful when students actively construct knowledge through questioning, exploration, and drawing their own conclusions. This need is further supported by Ayudia and Prasetya (2023), who highlighted the high demand for digital media in elementary science education due to its ability to visualize abstract concepts, increase engagement, and foster independent exploration. Their findings

also indicate that many teachers are still unfamiliar with interactive web-based tools, emphasizing the urgency of developing accessible and pedagogically relevant digital media.

2. Design and Development

The initial design of GeoLand was developed as a web-based medium incorporating an inquiry model approach, prioritizing active and reflective learning. Key characteristics of this medium include:

a. Interactive Materials with Triggering Questions.

Materials are designed to be interactive, featuring questions that prompt student engagement and critical thinking. Mayer (2020) posits that multimedia learning incorporating interactive components can significantly enhance students' cognitive engagement, a crucial element in inquiry-based education. This is in line with Hidayat (2024), who emphasized that "interactive web-based media should not only deliver content, but also actively engage students in exploration and critical reflection through thinking activities." Such design ensures that students are positioned as active constructors of knowledge, rather than passive recipients.

Figure 1 Design material interactive

b. Drag-and-Drop Games.

Interactive games utilizing drag-and-drop mechanics are employed for learning about the Earth's structural composition, atmosphere, and natural features. According to Piaget & Cook (2018), interactive games effectively reinforce knowledge construction through direct experience and reflection.

Figure 2 Design Games drag and drop

c. Digital Simulations

Simulations serve as an effective means of fostering experiential learning by enabling students to contextualize abstract scientific concepts through direct interaction. As emphasized by Gee (2017),

simulations act as cognitive bridges between theoretical understanding and real-world application. This notion is further substantiated by Lin and Lai (2020), who found that web-based interactive tools enable elementary students to autonomously explore and manipulate scientific representations across temporal and spatial dimensions, thereby promoting self-regulated learning processes.

d. Interactive Quizzes for Formative Assessment

Formative assessment plays a pivotal role in guiding students' learning trajectories through continuous feedback. According to Shute (2008), immediate feedback is critical for enhancing comprehension and supporting cognitive development. Building on this perspective, Lin and Lai (2020) assert that automated feedback mechanisms embedded in web-based quizzes facilitate students' self-monitoring skills and encourage independent learning behaviors, which are essential for fostering autonomy in primary-level education.

e. Product-Based Learning Outcomes

Learning outcomes that emphasize student-created products reflect a shift toward more constructivist, authentic educational experiences. Brophy (2013) argues that project-based tasks not only enhance learner motivation but also foster deeper application of knowledge in real-life contexts. Echoing this, Lin and Lai (2020) highlight that web-based learning environments which support creative output and reflective engagement contribute significantly to developing students' ownership of learning and their capacity for independent thought and action.

3. Expert Validation

Table 1. Media Expert Validation Results

No	Evaluation Aspect	Score
1	Content Expert	100%
2	Media Expert	92.5%
3	Education Practitioner	92.3%
	Overall Percentage	94.93%

The media feasibility testing through expert validation and limited trials indicates that *Geoland* has a very high feasibility level. This media is considered engaging, user-friendly, and well-suited to the characteristics of elementary school students. These findings align with Sadiman et al. (2019), who assert that effective learning media must meet the criteria of graphic quality, message clarity, interactivity, and meaningful content. Additionally, Wulandari and Hidayat (2021) emphasize the importance of aligning digital media with students' learning needs in the technological era.

Regarding content feasibility, *Geoland* adheres to principles of accuracy, relevance, and curriculum alignment. The material presented is scientifically accurate, in line with the Learning Outcomes (LO) of the Merdeka Curriculum, and supports educational objectives. These findings reinforce Sanjaya's (2017) theory, which highlights that learning content must be accurate, systematic, and suitable for students' developmental stages. Trianto (2018) further explains that in inquiry-based learning, content should encourage students to actively explore and independently discover concepts. The design and presentation of *Geoland* are highly attractive, communicative, and structured, in accordance with Arsyad's (2019) theory, which states that good visual design can enhance appeal and clarify messages. Mayer (2014) also asserts that the combination of text, images, and interaction in digital media can enhance student retention and conceptual understanding.

The interactivity aspect of *Geoland* supports inquiry-based learning, with features such as quizzes, drag-and-drop activities, and simulations of Earth's structure. Sadiman et al. (2018) explain that interactive media encourages active student participation and enhances learning effectiveness. Media feasibility analysis refers to five evaluation aspects from Suryani et al. (2019): (1) Media Accessibility, (2) Language Use, (3) Presentation, (4) Media Effects on Learning Strategies, and (5) Overall Appearance. All these aspects are well-achieved in *Geoland*. This media also supports all stages of inquiry-based learning, as outlined in Trianto's (2018) theory.

The evaluation from practitioners (teachers) shows that *Geoland* enhances student motivation, reduces dependency on the teacher, and encourages independent learning. This supports Prastowo's (2017) view that learning media should be designed to foster student independence through engaging information and exploratory tasks.

The evaluation from practitioners (teachers) shows that Geoland enhances student motivation, reduces dependency on the teacher, and encourages independent learning. This supports Prastowo's (2017) view that learning media should be designed to foster student independence through engaging information and exploratory tasks. Overall, Geoland is highly suitable as a learning medium for fifth-grade IPAS students, as it meets both technical and pedagogical standards and supports learning objectives focused on strengthening cognitive skills and student independence.

4. Implementation and Evaluation

a. Pretest and Posttest Results Description

This study measures the effectiveness of the interactive web-based learning media with an inquiry model by testing students' cognitive abilities before (pretest) and after (posttest) the use of the *Geoland* media. The average pretest and posttest scores in the experimental class are shown below.

Table 2. Average Pretest and Posttest Scores in the Experimental Class

Test Type	Average Score
Pretest	73.33
Posttest	93.67

The significant improvement in scores (from 73.33 to 93.67) indicates that Geoland media supports a more effective learning process. According to Mayer (2017), interactive digital learning media designed according to cognitive principles can enhance knowledge retention and transfer by involving processes of visualization, elaboration, and meaningful integration of concepts.

b. Cognitive Improvement Analysis (N-Gain Score)

The effectiveness of the media was analyzed using the Normalized Gain (N-Gain) score, calculated using Hake's (1999) formula. With a maximum score of 100, the average N-Gain score in the experimental class was 0.76, which falls into the high category (N-Gain ≥ 0.7). According to Hake (1999) and reinforced by recent research (Zhou et al., 2021), a high N-Gain score indicates that the learning intervention has a significant positive impact on students' cognitive achievement. This finding is consistent with constructivist theory (Richardson, 2017), which emphasizes the importance of active student involvement in learning. Through an inquiry-based interactive web model, students are encouraged to explore and build knowledge independently, leading to significant improvements in conceptual understanding.

c. Statistical Testing

Normality tests for the pretest and posttest data were conducted using the Shapiro-Wilk test. The results showed that all data were not normally distributed ($p<0.05$). As the data did not follow a normal distribution, a non-parametric test, specifically the Mann-Whitney U test, was used to compare the posttest results between the experimental and control groups.

Table 3 Mann-Whitney U Test

Test Statistic	Value
U calculated	679.5
p-value	0.0000057
α	0.05
Conclusion	Significant

The results show a p-value <0.05, indicating a significant difference between the two groups. Therefore, Geoland media has been statistically proven to be effective in improving students' cognitive learning outcomes. This is supported by Aljohani (2017), who states that interactive technology-based learning enhances student engagement and understanding, especially in science education at the elementary school level.

d. Homogeneity Test

Table 4 Homogeneity Test Results (Levene's Test)

Test Statistic	Value
Levene's F	0.097
p-value	0.757
α	0.05
Conclusion	Homogeneous

With a p-value > 0.05, the variances between groups are considered homogeneous. Thus, the data meet the requirements for further group comparison tests.

e. Paired Sample t-Test

A paired t-test was conducted to determine the significant difference between the pretest and posttest results in the experimental class.

Table 5 Paired Sample t-Test Results for Experimental Class

Test Statistic	Value
t	16.57
df	29
p-value	< 0.001
Conclusion	Significant

The significant improvement in scores confirms the effectiveness of the media. According to Permana et al. (2022), the significant increase between pretest and posttest scores indicates that interactive digital-based learning provides a stronger learning stimulus than conventional methods.

f. Independent Sample t-Test

Additionally, an independent sample t-test was conducted to observe the posttest score differences between the experimental and control classes.

Table 6 Independent Sample t-Test Results

Test Statistic	Value
t	4.83
df	55
p-value	< 0.001
Conclusion	Significant

The results of this test support previous findings that *Geoland* media significantly improves students' cognitive achievement. This is in line with the view of Dwijayanti et al. (2023), who state that interactive and engaging web-based media enhances the effectiveness of IPAS learning at the elementary school level.

g. Results of Learning Independence

The measurement of learning independence was conducted using a questionnaire based on eight aspects (initiative, time discipline, independence, responsibility, self-confidence, perseverance, problem-solving, and self-evaluation). The analysis results revealed that the average scores for all aspects of learning independence were higher in the experimental class compared to the control class. The greatest improvements were observed in the self-evaluation aspect (+0.59), self-confidence

(+0.41), and initiative (+0.35), indicating a positive impact of the *Geoland* media on students' self-reflection and learning motivation.

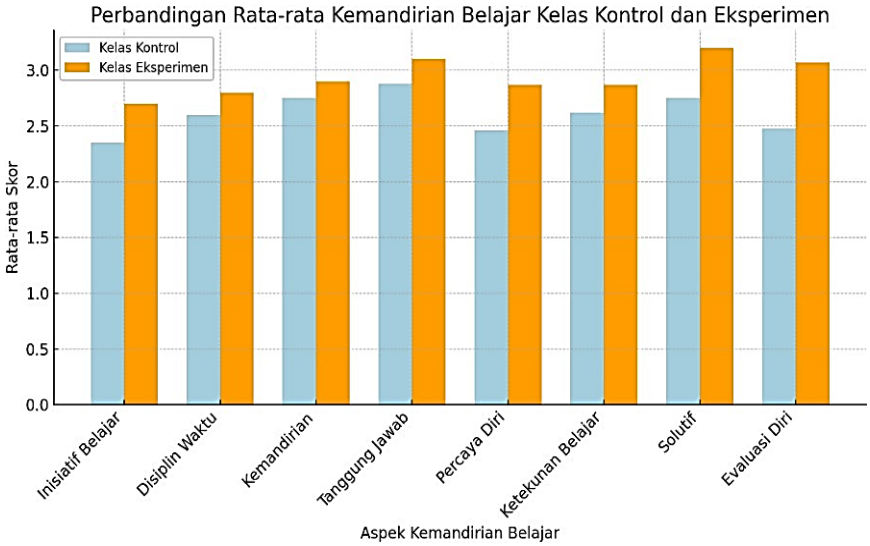

Figure 2 Graph learning independence

Table 7 Comparison of N-Gain Scores for Learning Independence

Class	Average N-Gain
Experimental	0.14
Control	0.04

The average N-Gain score for learning independence in the experimental class was 0.14 (low-positive category), which was higher than the control class, which only reached 0.04. This indicates an improvement in learning independence after the use of interactive web-based media with an inquiry model.

DISCUSSION

These findings support Zimmerman's (2002) self-regulated learning theory, which emphasizes the importance of reflection and self-control in independent learning. Further research by Zhao et al. (2022) underscores that interactive digital learning platforms can enhance metacognition and learner autonomy through responsive, student-centered learning experiences. Empirical support is also provided by Kuo & Yang (2023), who found that inquiry-based digital media significantly promotes active engagement and learning decision-making in elementary school students.

Thus, *Geoland* not only supports cognitive learning achievement but also proves effective in fostering students' learning independence through the reinforcement of reflective, motivational, and problem-solving aspects. The study results indicate that *Geoland*, as an inquiry-based media, can enhance learning outcomes and facilitate students' independence. The improvement in learning outcomes aligns with the constructivist theory, which emphasizes active and exploratory engagement. This finding is consistent with research by Nugroho & Santoso (2021) and Putri et al. (2022), which demonstrated the effectiveness of interactive digital media in IPAS learning. The increase in learning independence occurs because the media allows students to learn according to their own pace and interests, in line with the self-regulated learning theory from Bandura and Zimmerman.

However, the limitations of this study include the short duration of media use and the absence of analysis based on student characteristics. Future research is recommended to examine the long-term effects and develop similar media for other IPAS topics. In line with these findings, Fadilah et al. (2025) demonstrated that the use of interactive media such as Wordwall led to significantly higher student learning outcomes compared to conventional instruction (83.77 vs. 70.61). They concluded

that interactive educational games not only support better academic performance but also make learning more enjoyable and exploratory, allowing students to "learn while playing."

This study has practical implications for the development of web-based learning media in elementary schools. Teachers can use GeoLand as an alternative enrichment tool that encourages student independence and exploration. Theoretically, these results reinforce the importance of inquiry-based learning and educational technology in promoting meaningful and autonomous learning experiences in the digital age.

CONCLUSION

his study successfully developed and validated Geoland, an interactive web-based learning medium designed with an inquiry model for elementary Natural and Social Sciences (IPAS) education, specifically focusing on Earth's layer structure. Expert validation and feasibility tests confirmed the medium's high quality, aligning its design with established pedagogical theories of multimedia learning (Mayer, 2020) and constructivism (Piaget & Cook, 2018; Jonassen, 2014).

Empirical results demonstrate that Geoland significantly enhances both students' cognitive learning outcomes and learning independence. The experimental group showed a substantial improvement in cognitive scores (N-Gain = 0.76, high category) and a discernible increase in learning independence (N-Gain = 0.14), both statistically significant ($p<0.05$). These findings are consistent with prior research on technology-enhanced learning (Aljohani, 2017; Dwijayanti et al., 2023) and self-regulated learning theories (Zimmerman, 2002; Zhao et al., 2022).

This research makes a novel theoretical contribution by demonstrating the synergistic effectiveness of integrating an inquiry model within an interactive web-based learning environment for a complex science topic at the primary school level. While individual components (inquiry learning or web-based media) have been widely studied, this study specifically addresses a documented research gap by providing empirical evidence for their combined power in fostering both cognitive gains and learning independence in elementary IPAS education. It supports and extends constructivist principles by illustrating how a structured, inquiry-based digital environment can actively facilitate students' knowledge construction and metacognitive development, moving beyond passive information reception.

Practically, Geoland offers a viable and effective alternative for IPAS instruction, empowering teachers with a tool to promote student-centered, exploratory learning. Its design can serve as a blueprint for developing similar interactive digital media for other complex subjects, supporting adaptive and personalized hybrid learning environments in elementary schools. This study's limitations include the relatively short intervention duration and the absence of analysis based on specific student characteristics. Future research should investigate the long-term impacts of such media and explore its effectiveness across diverse student profiles and other IPAS topics.

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