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Adaptive Inquiry-Based Learning Applications for Enhancing Students' Critical Thinking Skills: An Innovative Approach

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ABSTRACT

Despite the urgency of fostering critical thinking in the Society 5.0 era, conventional digital learning often overlooks individual learner diversity, particularly in the post-pandemic educational landscape. This study addresses this gap by developing and validating a cloud-hosted learning application based on the Adaptive Inquiry Approach. Utilizing a Research and Development (R&D) methodology via the six-stage Luther-Sutopo model (concept, design, material collection, assembly, testing, and distribution), the platform dynamically tailored multi-modal content (text, audio, video, and simulations) to match diverse learning styles (visual, auditory, read/write, and kinesthetic) for elementary students (grades IV–VI). The findings indicated that validation by an interdisciplinary panel of experts established outstanding conceptual, pedagogical, and technical viability, with all composite evaluation scores exceeding the 80% threshold. Concurrently, empirical assessment instruments demonstrated optimal item difficulty and robust discriminatory power in tracing cognitive gains, while supplementary guidebooks achieved high institutional feasibility. By shifting from a static, uniform instructional delivery model to a dynamic, algorithmically tailored inquiry framework, this platform bridges the digital-pedagogical divide without diluting instructional substance. This study contributes to the educational technology literature by offering a powerful, scalable blueprint to systematically empower students' critical thinking skills in the post-pandemic era.

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1. INTRODUCTION

In the era of Society 5.0, critical thinking skills have transformed into a primary competency that students must possess to effectively navigate complex and dynamic global challenges (Yamada, 2023). Rather than being a mere conventional academic metric, these skills serve as a fundamental cornerstone for survival in a highly disruptive global landscape (Maftuhah, 2024). Comprehensively, this cognitive proficiency plays a pivotal role in shaping students' analytical, evaluative, and creative dimensions. Such attributes are highly indispensable for filtering massive influxes of digital information and facilitating rational, precise decision-making processes in real-world scenarios (Topali et al., 2023).

The urgency of reinforcing this competency aligns seamlessly with contemporary educational governance, particularly within the framework of Indonesia's *Merdeka Belajar* (Freedom to Learn) curriculum, which heavily mandates the integration of adaptive learning systems (Hunaepi & Suharta, 2024; Susilana et al., 2024). Instructional frameworks oriented toward fostering critical thinking are empirically proven to accelerate students' analytical capacities in absorbing complex knowledge while simultaneously sharpening their cognitive creativity in processing information. Consequently, restructuring contemporary instructional designs to bridge high-level cognitive demands with individual adaptability has become an urgent agenda in modern education.

However, empirical realities indicate that students' critical thinking capacities remain significantly compromised, particularly in the post-pandemic landscape that drastically altered school instructional patterns. Prolonged reliance on unoptimized online learning models has induced widespread student passivity, which consecutively hinders the holistic development of their cognitive, affective, and psychomotor domains (Hosen et al., 2021). This instructional setback is further exacerbated by online processes that lack participatory strategies, directly contributing to the systematic weakening of students' critical faculties (Akfal et al., 2025). This problematic state underscores that strategic interventions must transcend conventional pedagogical models, highlighting an immediate requirement for innovative and adaptive digital learning media capable of revitalizing students' core critical abilities (Muwafiq & Nugroho, 2025; Carniel et al., 2023).

Regrettably, the vast majority of current digital learning applications adopt a uniform, "one-size-fits-all" approach, delivering homogenized instructional treatments without accounting for the inherent diversity of individual learning styles (Narimo et al., 2025). In reality, every student possesses a unique cognitive modality—whether visual, auditory, reading/writing, or kinesthetic. Imposing rigid, uniform digital frameworks restricts students' natural expression in knowledge construction, thereby failing to optimize their critical thinking potential (El-Sabagh, 2021). Conversely, recent meta-analytic evidence consistently demonstrates that inquiry-based learning models are highly effective in fostering advanced critical thinking skills (Anugrah et al., 2025). This stark contrast exposes a critical research gap, demanding the development of adaptive applications that reconcile diverse learning modalities with autonomous, discovery-based frameworks.

The capacity of inquiry-based models to stimulate higher-order reasoning has been extensively validated in prior literature. By positioning students as active agents who construct meaning through scientific investigation, reflection, and real-world problem-solving, inquiry models directly empower deep critical thinking (Alfroni et al., 2019;

Bhuttah et al., 2024; Uslan et al., 2025). Within scientific domains, frameworks such as Inquiry-Based Science Education (IBSE) have proven highly successful in facilitating independent conceptual discovery (Hasibuan et al., 2025). Furthermore, when inquiry models are integrated with adaptive systems—increasingly driven by Artificial Intelligence (AI) to establish personalized learning paths—they yield a profoundly positive impact on individual student engagement and overall learning outcomes (Chen & Chen, 2025; Penn et al., 2025).

Despite the recognized benefits of both inquiry paradigms and digital personalization, the current body of literature remains fragmented, largely examining traditional inquiry frameworks in isolation from digital adaptability. In the current landscape of digital transformation, the convergence of adaptive systems within inquiry-based architectures remains a largely uncharted territory (Yusra et al., 2022). To address this gap, the synthesis of these two domains into an Adaptive Inquiry Approach app is projected to facilitate deep conceptual or religious exploration while inclusively aligning with the unique cognitive needs of each student (Plooy et al., 2024). Moreover, incorporating adaptive supportive features, such as auto-prompting mechanisms, has been shown to successfully stimulate student curiosity and active engagement throughout the inquiry cycle (Tang, 2024). Through such responsive ecosystems, digital instruction bypasses superficial learning, comprehensively cultivating students' critical thinking competencies (Arifin et al., 2025).

Consequently, the absolute novelty of this study lies in the systematically designed development of a digital learning application anchored in the Adaptive Inquiry Approach. This research originally converges the methodological strengths of scientific inquiry with the algorithmic flexibility of an adaptive system calibrated to individual learning styles. Through this synergistic integration, the developed application is positioned as a pioneering instructional tool designed explicitly to bridge the digital-pedagogical divide, providing a measurable, scalable, and sustainable framework for empowering students' critical thinking skills in the modern era.

2. METHOD

This study employs a Research and Development (R&D) methodology designed to engineer, validate, and evaluate an educational product (Borg & Gall, 2003). Specifically, the development process is operationalized through the Luther-Sutopo multimedia development model, which systematically advances through six sequential phases: (1) concept formulation, (2) structural and instructional design, (3) material collection, (4) assembly and integration, (5) rigorous testing, and (6) final distribution (Sutopo, 2010). This iterative framework was strategically selected to ensure that the resulting learning application—anchored in the Adaptive Inquiry Approach—is pedagogically sound, technologically robust, and empirically proven to optimize students' critical thinking skills.

The target population for this development and evaluation phase comprises fourth-to-sixth-grade elementary students at Muhammadiyah Bantaeng Elementary School, Bantaeng Regency. The selection of these subjects was executed through purposive parameters based on institutional needs and developmental suitability. First, from a developmental psychology perspective, students at this educational tier are transitioning from the concrete operational stage to the formal operational phase, making it a critical window to cultivate higher-order cognitive proficiencies through structured adaptive inquiry strategies (Nhung et al., 2025). Second, empirical assessments within this locale indicated a post-pandemic decline in foundational critical thinking skills, a trend largely attributed to passive online learning modalities that lacked interactive engagement.

Furthermore, this specific elementary school environment provides an ideal empirical testing ground due to the high heterogeneity of student learning modalities—encompassing visual, auditory, reading/writing, and kinesthetic styles. This diverse classroom profile is highly relevant for evaluating the algorithmic responsiveness and personalization capabilities of the developed adaptive application (Liu et al., 2021). By embedding the study within this multi-modal learning environment, the research can rigorously observe how the application dynamically calibrates its inquiry paths to accommodate individual learning preferences, thereby establishing a scalable model for inclusive digital instruction.

To ensure theoretical rigorousness prior to field implementation, the initial product draft undergoes a structured expert validation process. This phase serves as a rational, construct-oriented evaluation to assess whether the architectural and pedagogical components of the application align with established instructional design theories. The evaluation utilizes an expert judgment protocol where content specialists, instructional technologists, and linguists appraise the product against standardized metrics. The quantitative feedback and qualitative interpretations derived from this expert panel are systematically classified using the multi-tier Likert scale detailed in Table 1, establishing a baseline for iterative refinement before empirical deployment.

Table 1. Product draft validation assessment categories

Percentage	Category
0% - 20%	Very inadequate
21% - 40%	Unadequate
41% - 60%	Fairly adequate
61% - 80%	Adequate
81% - 100%	Very adequate

3. RESULTS AND DISCUSSION

Results

Media Product Validation

To optimize the instructional framework, this study developed a web-based learning application anchored in the Adaptive Inquiry Approach, specifically designed to cultivate and evaluate students' critical thinking skills. Architecturally, the media platform leverages cloud hosting to ensure ubiquitous accessibility, allowing users to engage with instructional contents seamlessly across any internet-enabled device. The system's core algorithmic feature lies in its ability to dynamically identify and categorize individual learning styles into visual, auditory, reading/writing, and kinesthetic modalities. Upon diagnostic profiling, the application populates user registration metrics alongside visual analytics dashboards depicting the user's specific cognitive profile. This data-driven personalization dictates the deployment of an adaptive four-tier instructional module, which delivers tailored learning content in the form of integrated text, high-fidelity audio, educational video, and interactive simulations aligned with the student's unique learning preferences.

Complementing its adaptive delivery system, the application incorporates a robust evaluation infrastructure designed to measure cognitive gains through pre-test and post-test assessments, supporting both multiple-choice and essay-based formats. To ensure pedagogical flexibility, the platform features a comprehensive backend question bank that grants administrative privileges to teachers, allowing them to dynamically edit, configure, and specify the volume of diagnostic instruments deployed to student users. Post-assessment, the media engine automatically processes and visualizes individual diagnostic reports for both preliminary and summative outcomes, while providing automated functionality to generate comprehensive, printable final learning outcome reports for institutional accountability. Following the completion of the systematic design, development, and expert validation phases, the finalized interface of the Adaptive Inquiry application is presented in Figure 1.

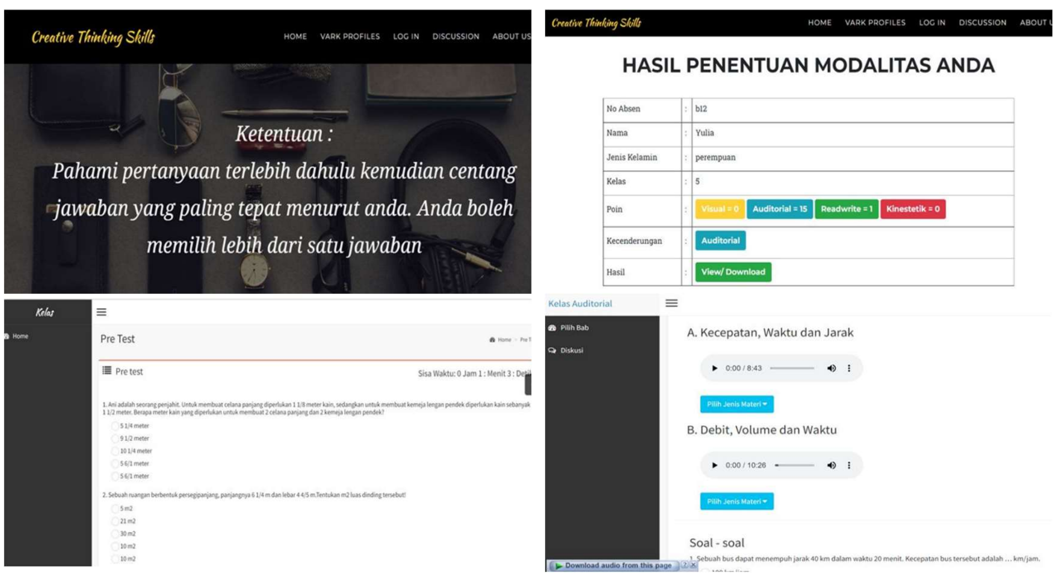

Figure 1. Display of the results of the learning application product

The application's display, it appears that the learning media application has a home page containing operating instructions for determining learning styles. When accessing the learning style determination menu, students are presented with 16 questions to answer based on their personality or character tendencies. The top right image will appear after the application identifies a specific learning style. Students will then be taken to the classroom, preceded by an initial test. The learning process is fully tailored to the learning style identified by the learning media application: visual, auditory, read/write, or kinesthetic.

During the application development process, a feasibility test is also conducted to assess user acceptance of the application being developed and designed. The product draft, consisting of the learning application media and model guide, is then validated by experts. The experts who validated the media application are a number of experts, with the division of validation areas shown in Table 2 below and a summary of expert validation of the learning concepts is shown in Table 3 below.

Table 2. List of validation fields in the application

No	Validation Fields	Number of Validators
1	Learning model concept	2 Validators
2	Learning technology	2 Validators
3	Application design and graphics	2 Validators
4	Determining learning style preferences	2 Validators
5	Model guidelines	2 Validators
6	Implementation of the adaptive inquiry learning concept	2 Validators

Table 3. List of validation fields in the application

No	Aspect	Interpretation Index (%)
1	Syntax	87.50
2	Social system	87.50
3	Reaction principle	75.50
4	Support system	75.50
5	Learning impact	87.50
	Mean Interpretation Index	82.50

The expert validation results yielded an average interpretation score of 82.50%, indicating that the learning model concept is highly feasible. The syntax model assessed has clear, systematic, and logical stages, and can be used to measure critical thinking skills. Students assessed were able to formulate answers in their own words, enthusiastically ask questions, and actively participate in debates when applying the model. The model assessed provides opportunities for students to be proactive, responsive, innovative, communicative, and respectful. The model is complemented by learning tools in the form of modules and worksheets, which were deemed satisfactory by the experts. Students, targeted by the implementation model, were able to understand the material, work cooperatively, and develop critical thinking skills as an instructional impact of the implementation model. The experts assessed that this learning model can have a complementary impact, namely accustoming students to active problem-solving and fostering effective communication between students, ultimately fostering critical thinking. The experts' recommendations included a slightly more detailed support system. A summary of the expert or learning technology expert validation of the learning application can be seen in Table 4 below.

Table 4. Summary of validation results by learning technology experts

No	Aspect	Number of Indicator	Interpretation Index (%)
1	Teaching Materials	4 indicators	81.25

No	Aspect	Number of Indicator	Interpretation Index (%)
2	Learning Process	3 indicators	91.67
3	Assessment	4 indicators	81.25
4	Activities Supporting Learning	3 indicators	91.67
5	Materials to Improve Student Competence	5 indicators	85.00
6	Critical Thinking Aspects	6 indicators	87.50
	Average Interpretation Index		86.00

The empirical validation of the developed learning application draft commenced with a structured appraisal by two instructional technology experts, as synthesized in Table 4. The expert review yielded a highly favorable mean interpretation index of 86.00%, which, according to the standardized evaluation rubric, establishes the product draft as exceptionally viable for field testing. Despite this strong quantitative consensus, the evaluators provided critical qualitative feedback to optimize the platform's pedagogical rigor. Their formative recommendations primarily focused on refining the instructional framework, specifically advising a deeper and broader elaboration of the learning materials. Furthermore, the experts underscored the necessity of distributing assessment materials more uniformly, clarifying the descriptive indicators for learning competencies, expanding the designated time allocations, and ensuring precise alignment between the test instruments and their targeted problem-solving dimensions.

Concurrently, the architectural and aesthetic dimensions of the application interface were rigorously vetted by two software design and computer graphics specialists, whose quantitative metrics are detailed in Table 5. This technical validation generated a robust mean interpretation index of 83.13%, confirming that the user interface (UI) and user experience (UX) layout are highly appropriate for empirical deployment. To maximize visual ergonomics and cognitive accessibility, the design experts outlined several technical adjustments. These included the systematic reorganization of textual and illustrative components to facilitate easier comprehension, the strategic preservation of active "white space" to prevent cognitive overload, and the enforcement of absolute consistency in typographic fonts and sizing across all pages. Additionally, the experts recommended streamlining the linguistic structure for enhanced textual flexibility and optimizing the spatial layout of each screen to ensure an intuitive, balanced digital environment, as summarized in Table 5.

Table 5. Summary of validation results by design and graphic experts for software applications

No	Aspect	Number of Indicator	Interpretation Index (%)
1	Organization	4 indicators	87.50
2	Attractiveness	2 indicators	87.5
3	Font Size and Shape	3 indicators	91.67
4	Space (white space)	1 indicator	100
5	Consistency	3 indicators	79.17
6	Presentation of Images/Videos/Text	5 indicators	92.50
7	Language	2 indicators	81.25
	Average Interpretation Index		83.13

The following is a summary of the validation results by learning style preference experts. Table 6 provides information on the assessment results from two learning style experts, with an average interpretation index of 81.82%.

Table 6. Summary of validation results by learning style experts

No	Aspect	Number of Indicator	Interpretation Index (%)
1	Linguist	3 indicators	87.50
2	Sentence Accuracy	4 indicators	84.37
3	Perception	4 indicators	75.00
	Average Interpretation Index		81.82

The assessment scale category, it shows that both learning style experts assess the draft of the developed learning application as very suitable for testing. Some suggestions for improvement from the learning style experts are: 1) more appropriate word choice; 2) improvement of sentence writing according to the meaning and significance of the sentence; 3) improvement of writing so as not to cause double meaning; 4) in terms of learning style determination, it needs to be emphasized more; 5) broader perspective. After validation of the learning application that will be used in learning, the next step is to conduct a construct validation test to measure the suitability between the indicators and items that have been formulated according to the material and in accordance with the theory. Before conducting a construct analysis, an analysis is carried out on the level of difficulty, discriminatory power and reliability of the instrument to determine the rules that apply in the development instrument that is suitable for use in Mathematics learning in empowering the critical thinking skills of students participating in the lesson. The results of the discriminatory power analysis can be seen in Table 7.

Table 7. Results of the Analysis of the Discriminatory Power of Mathematics Questions (Pre-test)

Item	Biserial coefficient	Category
1	0.350	Good
2	0.300	Good
3	0.330	Good
4	0.340	Good
5	0.430	Good
6	0.350	Good
7	0.420	Good
8	0.420	Good
9	0.310	Good
10	0.430	Good

In the Mathematics questions (pre-test questions), the discriminatory power of the items was categorized as good, namely that if $D \geq 0.3$, the items are considered to have good discriminatory power (Cahyaningsih et al., 2024). Furthermore, in the mathematics questions for the post-test, the discriminatory power of the items was also measured. The results of the analysis can be seen in Table 8. In the Mathematics questions (post-test questions), the discriminatory power of the items was categorized as good, namely that if $D \geq 0.3$, the items are considered to have good discriminatory power.

Table 8. Results of the Analysis of the Discriminatory Power of Mathematics Questions (Post-test)

Item	Biserial Coefficient	Category
1	0.300	Good
2	0.300	Good
3	0.340	Good
4	0.360	Good
5	0.300	Good
6	0.300	Good
7	0.340	Good
8	0.320	Good
9	0.300	Good
10	0.350	Good

To ensure the suitability of this instrument for use, an analysis of the difficulty level of each item was conducted. The results of the difficulty analysis for the pre-test items in Mathematics are shown in Table 9.

Table 9. Results of the Difficulty Analysis for Mathematics Items (Pre-test Items)

Item	Biserial Coefficient	Category
1	0.565	Good
2	0.440	Good
3	0.525	Good
4	0.570	Good
5	0.475	Good
6	0.505	Good
7	0.530	Good
8	0.530	Good
9	0.585	Good
10	0.535	Good

Table 9 shows that the scores for all items range from 0.3 to 0.7. This indicates that all items fall within the criteria for a good level of difficulty. This aligns which states that a good difficulty level for descriptive items is $0.3 \leq P \leq 0.7$ (Cahyaningsih et al., 2024). The analysis of the difficulty level for the post-test items in Mathematics is then continued, as shown in Table 10.

Table 10. Results of the Difficulty Analysis for Mathematics Items (Post-test Items)

Item	Biserial coefficient	Category
1	0.700	Good
2	0.690	Good
3	0.690	Good
4	0.700	Good
5	0.700	Good
6	0.690	Good
7	0.700	Good
8	0.700	Good
9	0.680	Good
10	0.695	Good

Table 10 shows that the scores for all items fall within the criteria for a good level of difficulty. The summary of the validation results for the learning model's feasibility is presented in Table 4.10 below. Table 11 provides information on the assessment results from two experts, with an average interpretation index of 81.82%. Based on the assessment scale categories, both learning style experts rated the developed draft learning application as highly feasible for pilot testing.

Table 11. Learning Feasibility Validation Results

No	Learning Stage	Number of Indicator item	Interpretation Index (%)
1	Ask a question	2	87.50
2	Formulate an answer	2	75.00
3	Apply the case study	3	81.25
4	Motivate questions	1	75.00
5	Enable debate	2	87.50
6	Provide	1	75.00
	Average Interpretation Index		81.82

Some suggestions for improvement from the validators include: 1) shorter and more open-ended questions; 2) simpler case studies; 3) improved methods for motivating students to ask questions; 4) improvements to the PUEBI (Information and Training for Mathematics). For the development of the selected Mathematics material, a learning guide module was subsequently developed containing core material, instructions for use and implementation. The learning model guidebook was validated by Mathematics material experts before being used in the learning process. The validation results can be seen in Table 12.

Table 12. Results of Expert Validation for Model Guide Material

No	Learning Stage	Number of Indicator item	Interpretation Index (%)
1	Completeness of Material	2	87.50
2	Accuracy of Material	1	75.00
3	Up-to-date Material	1	75.00
4	Material develops thinking skills	2	93.75
5	Material follows a scientific system	2	81.25
6	Basic concepts of material	1	87.50
7	Sub-topic concepts	1	87.50
8	Image concepts	1	75.00
9	Material delivery techniques	1	87.50
10	Material can empower critical thinking skills	1	87.50
11	Relevance to everyday life	1	87.50
	Average Interpretation Index		84.82

The expert validation results for the learning model guidebook material obtained a score of 84.82%, indicating it is highly feasible/relevant and therefore suitable for use in Mathematics teaching. Suggestions from the experts included: 1) more straightforward sentence writing; 2) more systematic presentation; 3) better alignment of images with concepts.

After being deemed highly suitable for use in learning, the next step was to validate the learning model guidebook with a linguist to assess its suitability for proper and correct use of Indonesian. The results of the linguist validation are shown in Table 13.

Table 13. Results of the linguist validation of the model guidebook

No	Aspect	Number of Indicator	Interpretation Index (%)
1	Good and correct Indonesian Language	2	87.50
2	Application presentation	1	75.00
3	Language clarity	1	75.00
4	Language appropriateness	2	87.50
	Average Interpretation Index		83.33

The validation results for the model guidebook by language experts obtained a score of 83.33%, indicating it is very relevant/good, and therefore suitable for use in Mathematics teaching. Recommendations from the language expert validator were: 1) simplify the language for ease of understanding; 2) avoid ambiguous sentences and make them more standard. After the model guidebook was deemed very suitable for use in teaching, the next step was to validate the teacher's guidebook with a graphic design expert to determine its appeal and suitability for the images to the material. The results of the graphic design expert validation for the teacher's guidebook are shown in Table 14. The expert validation results for the graphic design of the mathematics teacher's guidebook obtained a score of 81.44%, indicating it is very suitable/good, and therefore suitable for use in Mathematics teaching. Comments were given that the module book met the standards for composition and its appearance was quite good.

Table 14. Results of the graphic design expert validation for the teacher's guidebook

No	Aspect	Number of Indicator	Interpretation Index (%)
1	Module Physical Size	2	87.50
2	Module Cover Layout	4	87.50
3	Module Typography	4	81.25
4	Module Illustrations	2	81.25
5	Module Content Layout	9	79.17
6	Module Content Typography	8	69.69
7	Module Content Illustrations	4	81.25
	Average Interpretation Index		81.44

After the graphic validation of the teacher's guidebook, the next step was to validate the teacher's guidebook. A summary of the validation results is shown in Table 15.

Table 15. Teacher's Guide Validation Results

No	Aspect	Number of Indicator	Interpretation Index (%)
1	Module Content	3	83.33
2	Material	4	81.25
3	Evaluation	4	81.25
4	Presentation	7	82.14
5	Language/Readability	5	77.50
6	Module Display	1	87.50
	Average Interpretation Index		82.16

The teacher's guide validation result obtained a score of 82.16%, indicating it is very suitable/good, and therefore suitable for use in the mathematics learning module. Comments from the validators included: 1) the language used has been simplified to make it easier for students to understand; 2) the font size has been adjusted.

Product Draft Revision

The results of the learning application validation test indicated that the learning application is generally suitable and good, according to learning technology experts, design and graphics experts, learning style experts, and language experts. Therefore, the developed product has the validity to be tested in Mathematics learning, but with several revisions.

The revision of the application's media design will refer to the suggestions and recommendations from the experts. Several aspects of the content need to be improved as suggested, including the addition of adequate and engaging illustrations, the presentation of video material to avoid boredom or monotony, and several sections of the application pages will be made more attractive with attractive colour schemes. Improvements to the use of spelling, use of capital letters, word order and punctuation also need to be considered for revision.

Discussion

The primary objective of this study was to engineer, validate, and evaluate an innovative, cloud-hosted learning application based on the Adaptive Inquiry Approach, specifically calibrated to cultivate students' higher-order cognitive faculties, precisely their critical thinking skills. The cumulative validation data from various independent expert domains confirm that the developed platform successfully bridges the long-standing digital-pedagogical divide. By achieving a robust conceptual model index of 82.50%, an instructional technology coefficient of 86.00%, and a graphic/UI design score of 83.13%, the application demonstrates exceptional cross-disciplinary structural viability for empirical pilot deployment. These indices indicate that the transition from a traditional classroom setting to an adaptive digital architecture does not dilute pedagogical substance, provided the system is governed by a rigorous interplay between diagnostic personalization and systematic scientific exploration. This empirical alignment directly corroborates the Technological Pedagogical Content Knowledge (TPACK) framework, which posits that true educational innovation occurs only when technological tools are seamlessly interwoven with solid pedagogical strategies and subject-matter content (Ait Ali et al., 2023; Jibril & Adedokun-Shittu, 2024). Furthermore, these high validation scores echo the findings of contemporary digital learning research, which demonstrates that structured digital interventions, when mapped tightly to explicit learning architectures, can achieve identical or superior validity compared to traditional brick-and-mortar methodologies.

From an instructional standpoint, the exceptionally high appraisal for the platform's syntax (87.50%) and learning impact (87.50%) sheds light on the effectiveness of integrating VARK-aligned multi-modal content with structured inquiry phases.

Traditional digital learning materials frequently suffer from an institutional "one-size-fits-all" homogeneity that suppresses student agency and overlooks distinct cognitive modalities. By implementing a 16-item diagnostic framework that dynamically filters and channels students into customized visual, auditory, reading/writing, or kinesthetic environments, this application operationalizes real-time instructional personalization. The expert reviews validate that when students are supplied with targeted media assets—such as interactive simulations for visual learners or high-fidelity audio streams for auditory learners—their motivation to ask questions, formulate answers autonomously, and engage in productive academic debates is markedly accelerated. This finding expands upon Sweller's cognitive load theory, as it proves that modifying instructional delivery based on personal learning profiles significantly reduces extraneous cognitive load, thereby freeing up working memory capacity for complex, higher-order critical thinking tasks (Hanham et al., 2023; Sweller, 2023). Additionally, by placing the student at the center of the inquiry cycle, the application supports Pintrich's Self-Regulated Learning (SRL) theory, showing that adaptive environments cultivate a heightened sense of metacognitive monitoring and autonomy, which are crucial precursors for sustained critical inquiry (Ortube et al., 2024; Teng, 2022).

Crucially, the psychometric robustness of the embedded assessment infrastructure is mathematically verified by the item analysis metrics. Both the pre-test and post-test mathematical instruments displayed optimal discriminatory power, with biserial coefficients consistently exceeding the critical threshold of $D \geq 0.3$. Furthermore, the item difficulty indices fell securely within the ideal psychometric continuum of $0.3 \leq P \leq 0.7$ (ranging from 0.440 to 0.585 for the pre-test and 0.680 to 0.700 for the post-test). These figures indicate that the application's assessment engine is not only structurally sound but also highly calibrated to track and measure subtle cognitive shifts in student performance over time, adhering closely to the fundamental tenets of Classical Test Theory (CTT) (Siegert et al., 2025) and Item Response Theory (IRT) for diagnostic instrument design (Reeve, 2024). Because the backend platform empowers instructors to dynamically configure and adjust this question bank, it resolves a common limitation in educational software: the lack of pedagogical flexibility for teachers. Rather than relying on rigid, pre-programmed assessment scripts, the system operates as a dynamic, teacher-managed ecosystem that bridges formative diagnostics with summative accountability, facilitating what Vygotsky described as the dynamic scaffolding within a student's Zone of Proximal Development (ZPD) (Raslan, 2024).

The dual validation of the supplementary print components—namely the Model Guidebook (84.82% for material; 83.33% for linguistics) and the Teacher's Guide (81.44% for graphics; 82.16% for module content)—adds an essential layer of institutional sustainability to the digital tool. The high scoring of these instruments demonstrates that a technology-driven intervention cannot succeed in isolation; it requires clear, well-structured offline documentation to guide teachers through the subtle details of adaptive inquiry scaffolding, thereby reinforcing the "blended learning" paradigm which emphasizes that digital tools must be accompanied by strong teacher facilitation to prevent instructional fragmentation. In line with the recommendations of the expert panel, the post-validation refinement phase successfully corrected minor typographic inconsistencies, balanced visual white space to prevent visual fatigue, simplified linguistic structures, and expanded active learning time allocations. Ultimately, this study contributes a highly innovative, validated, and theoretically sound digital paradigm. By shifting from a static instructional delivery method to a fluid, Adaptive Inquiry Approach, this platform offers a scalable and empirically verified blueprint for restoring and accelerating student critical thinking skills within contemporary educational landscapes, offering a concrete solution to the post-pandemic cognitive gaps identified in recent literature.

This study offers a dual contribution to the fields of educational technology and digital pedagogy by establishing a scalable framework for personalized higher-order learning. Theoretically, it advances the literature on instructional design by successfully synthesizing Sweller's Cognitive Load Theory with inquiry-based models, demonstrating that dynamically aligning digital scaffolding with VARK learning modalities significantly reduces extraneous cognitive load and frees up working memory capacity for critical inquiry. Practically, the study introduces a fully validated, cloud-hosted Adaptive Inquiry Approach application that overcomes the limitations of traditional "one-size-fits-all" educational software. By providing an algorithmic diagnostic profiling system coupled with an agile, teacher-managed backend infrastructure, this research delivers an empirically proven, sustainable blueprint for educators aiming to remedy post-pandemic cognitive gaps and foster robust, measurable critical thinking skills in contemporary elementary classrooms.

4. CONCLUSION

In conclusion, this study successfully engineered, validated, and refined a cloud-hosted learning application based on the Adaptive Inquiry Approach, establishing its high conceptual, pedagogical, and technical viability for empirical deployment. The rigorous multi-dimensional expert evaluation validated that transitioning from traditional classroom instructional models to an adaptive, personalized digital architecture does not dilute pedagogical substance, provided the system is anchored in systemic scientific exploration and responsive to individual learning modalities. Furthermore, the optimal psychometric properties of the embedded assessment infrastructure demonstrate the application's capacity to accurately trace and measure cognitive gains over time, while the high feasibility scores of the supplementary guidebooks ensure institutional sustainability for blended learning integration. Ultimately, by shifting from a static, uniform instructional delivery model to a dynamic, algorithmically tailored inquiry framework, this platform offers a powerful, scalable blueprint for bridging the digital-pedagogical divide and systematically empowering students' critical thinking skills in the post-pandemic era.

To maximize the pedagogical and technological potential of the developed Adaptive Inquiry Approach application, several strategic pathways are recommended for future research and implementation. First, while the current system demonstrates exceptional theoretical validity and algorithmic responsiveness, prospective empirical studies should deploy the platform in large-scale, longitudinal field experiments across diverse institutional settings to evaluate its sustained, long-term impact on students' critical thinking trajectories. Second, future software iterations should consider integrating advanced machine learning algorithms to transition from static diagnostic profiling to real-time, predictive adaptive paths that adjust dynamically to a student's evolving cognitive state. Finally, educational policymakers and school administrators should establish continuous professional development programs for teachers, ensuring they can fully leverage the backend administrative features to cultivate a highly synchronized, sustainable, and inclusive blended learning ecosystem.

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