DEVELOPMENT OF A STEAM-BASED DIGITAL LEARNING MODEL IN SOCIAL STUDIES TO ENHANCE CRITICAL THINKING SKILLS OF PHASE D STUDENTS

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ABSTRAK

Dominasi pendekatan pedagogis konvensional yang bersifat tekstual dan monodisiplin dalam pembelajaran Ilmu Pengetahuan Sosial (IPS) sering kali menghambat pengembangan keterampilan berpikir tingkat tinggi siswa di era revolusi industri 4.0. Penelitian ini bertujuan mengembangkan model pembelajaran digital berbasis STEAM (*Science, Technology, Engineering, Arts, and Mathematics*) yang valid, praktis, dan efektif untuk meningkatkan kemampuan berpikir kritis siswa Fase D. Penelitian ini menerapkan metode *Research and Development* (R&D) model Borg & Gall yang dimodifikasi, meliputi tahapan analisis kebutuhan, perancangan desain, validasi ahli, serta uji coba terbatas pada siswa kelas VIII. Hasil penelitian menunjukkan bahwa model yang dikembangkan memenuhi kriteria sangat valid dengan skor validasi ahli mencapai 92,6% dan tingkat kepraktisan 88,4%. Secara kuantitatif, efektivitas model terbukti signifikan melalui uji-t ($p < 0,05$) dengan peningkatan skor *N-gain* sebesar 0,67 yang tergolong kategori sedang hingga tinggi, di mana rata-rata kemampuan berpikir kritis meningkat dari 37,5% menjadi 71,25%. Kesimpulan utama studi ini menegaskan bahwa integrasi pendekatan transdisipliner STEAM dengan teknologi digital mampu mentransformasi pembelajaran IPS menjadi lebih kontekstual, holistik, dan adaptif, sehingga direkomendasikan sebagai solusi strategis dalam memperkuat kompetensi analitis dan evaluatif siswa sesuai tuntutan kurikulum abad ke-21.
Kata kunci: *STEAM, pembelajaran Ilmu Sosial, pemikiran kritis, Fase D*

ABSTRACT

The dominance of conventional pedagogical approaches that are textual and monodisciplinary in Social Sciences (IPS) learning often hinders the development of students' higher-order thinking skills in the era of the industrial revolution 4.0. This study aims to develop a valid, practical, and effective STEAM (Science, Technology, Engineering, Arts, and Mathematics)-based digital learning model to improve Phase D students' critical thinking skills. This study applies the modified Borg & Gall Research and Development (R&D) method, including the stages of needs analysis, design planning, expert validation, and limited trials on grade VIII students. The results showed that the developed model met the criteria of very valid with an expert validation score reaching 92.6% and a practicality level of 88.4%. Quantitatively, the effectiveness of the model was proven significant through a t-test ($p < 0.05$) with an increase in the N-gain score of 0.67 which is classified as medium to high category, where the average critical thinking ability increased from 37.5% to 71.25%. The main conclusion of this study confirms that the integration of the STEAM transdisciplinary approach with digital technology is able to transform social studies learning to be more contextual, holistic, and adaptive, so it is

recommended as a strategic solution in strengthening students' analytical and evaluative competencies according to the demands of the 21st century curriculum.

Keywords: *model development, STEAM, Social Studies learning, critical thinking, Phase D*

INTRODUCTION

The transformation of the educational paradigm in the Fourth Industrial Revolution necessitates a shift from conventional pedagogical approaches to a more holistic, integrative, and technology-oriented learning model (Ismail et al., 2020; Tishana et al., 2023; Wicaksono, 2020). Within this context, Social Studies education which is epistemologically multidimensional—requires a transdisciplinary approach that transcends the mere delivery of declarative knowledge to foster critical, creative, and reflective thinking skills in students. One of the most relevant approaches to meeting 21st-century challenges is the integration of the STEAM framework into instructional design. This approach simultaneously synergizes students' cognitive, affective, and psychomotor dimensions by combining five core disciplines. Ideally, the national education system must adopt this innovation to ensure graduates possess high global competitiveness. However, this integration process requires infrastructure readiness and a teacher mentality that is fully adaptive to massive digital technological changes to ensure that meaningful learning objectives are achieved optimally and sustainably across all educational units (Jayanti et al., 2021; Nurhidayat et al., 2022).

The STEAM learning model integrates various disciplines into a unified, contemporary approach aligned with current industrial needs. As a modern pedagogical paradigm, STEAM offers not only cross-disciplinary integration but also emphasizes the application of knowledge in real-life contexts through authentic, project-based problem solving. When implemented in Social Studies, STEAM holds significant potential to revitalize the learning process, making it more contextual, rational, and profound (Ilma et al., 2023; Juliharti et al., 2024; Sigit et al., 2022). This is particularly crucial for students in Phase D, who, according to cognitive development theory, are at the stage of formal operational thinking. At this stage, students begin to reason logically about abstractions and complex hypotheses. By honing analytical and evaluative skills through these five pillars, students are expected to make informed decisions regarding social phenomena in their surroundings. This integration transforms the students' perspective on social issues from rote memorization into a structured scientific analysis (Adnyana et al., 2024; Ilham & Hardiyanti, 2020; Safruddin & Ahmad, 2020).

Despite the significant academic promise of this model, current Social Studies classroom practices are still dominated by textual and monodisciplinary approaches. Preliminary observations indicate that approximately 75% of teaching and learning activities remain tied to textbooks, with interactive digital media usage limited to below 30%. This reality results in students' critical reasoning potential being under-stimulated during the learning process. Consequently, a substantial gap exists between the 21st-century skill requirements expected by the *Merdeka Curriculum* and actual field practices. The dominance of fact-memorization and verbalistic learning models has hindered the realization of higher-order thinking potential among junior high school students. This discrepancy serves as a strong basis for the urgent development of a new learning model capable of bridging the needs of a modern curriculum with the reality of limited school media. A transformation toward a digital STEAM-based model is a strategic necessity to enhance educational output quality, ensuring it is more competitive and responsive to the changing times.

Therefore, the development of a digital STEAM-based learning model integrated into Social Studies instruction is an urgent epistemological necessity. This developmental process

is not merely a matter of technological engineering; it represents a profound reconstruction of the teaching and learning process for digital natives. An effective model must possess a strong theoretical foundation, accurate empirical validation, and practical functionality that is easily adaptable across various instructional contexts. In this study, the development follows a systematic framework encompassing four main stages: Define, Design, Develop, and Disseminate (4D). This learner-centered approach ensures that every digital tool produced aligns with the cognitive characteristics of Phase D students. Integrating technology into this model serves not only as a visual aid but as a strategic instrument to broaden student access to participatory and meaningful learning. In this way, geographical barriers and resource limitations can be minimized through evaluation and delivery systems that are much more flexible, interactive, and responsive to the individual needs of each student (Sari et al., 2025; Simbolon & Samosir, 2025).

The novelty of this research lies in the development of a digital model that specifically merges STEAM principles with the conceptual and multidimensional content of Social Studies. This innovation aims to create a learning prototype that is valid, practical, and effective in enhancing students' critical thinking skills. Through this approach, students are encouraged not only to describe social phenomena but also to analyze them critically, seek innovative solutions, and represent their ideas through creative digital works. The theoretical and practical contributions of this research are expected to serve as a compass for the advancement of technology-based education and contemporary pedagogical innovation in Indonesia. The ultimate target is to produce tangible changes in students' social literacy and numeracy scores, reaching higher standards in line with global educational demands. The successful development of this model is expected to foster an adaptive learning ecosystem where technology and humanity synergize to form reflective and socially responsible citizens amidst the inevitable wave of digital disruption.

METHOD

This study utilizes a *Research and Development* (R&D) approach, adapting the systematic procedures of the *Borg and Gall* model, which have been modified to meet the demands of 21st-century learning. This approach was specifically chosen to produce a *STEAM*-based digital learning model that is valid, practical, and effective within the Social Studies curriculum. The research procedures are structured through a series of stages, including a preliminary study for *needs analysis*, the creation of model designs and digital platforms, validation by content and media experts, and limited field trials. The needs analysis stage serves to map out the gaps in conventional learning, while the design phase focuses on integrating science, technology, engineering, arts, and mathematics into social studies materials. This entire process culminates in a model prototype that is not only technically innovative but also responsive to the cognitive characteristics of *Fase D* students within the *Kurikulum Merdeka*.

The research participants consist of Grade VIII or *Fase D* students at the formal operational stage of cognitive development, selected through a *purposive sampling* technique at junior high schools equipped with adequate digital infrastructure. Data collection instruments include in-depth interview guides for the preliminary study, participatory observation sheets to monitor student engagement, and *Likert* scale questionnaires to measure the validity and practicality of the model. Furthermore, the primary instrument for measuring the dependent variable is an essay-based critical thinking test structured around the *Facione* framework, covering aspects of interpretation, analysis, inference, evaluation, and explanation. All test instruments underwent content validation and reliability testing using the *Cronbach's Alpha*

coefficient prior to being administered in the *pre-test* and *post-test* phases. These diverse instruments aim to gather comprehensive data regarding the model's feasibility from the perspectives of experts and practitioners, as well as its effectiveness for students.

Data analysis techniques in this study combine qualitative and quantitative approaches to derive accurate conclusions. Qualitative data obtained from validator feedback and interview results are analyzed thematically to guide product revisions, while quantitative data from validation and practicality questionnaires are processed using descriptive percentage statistics. To evaluate the effectiveness of the model in enhancing critical thinking skills, test data are analyzed using inferential statistics, specifically the *paired sample t-test* with a significance level of 0.05. Additionally, the magnitude of student competency improvement before and after the intervention is calculated using the normalized *N-gain* formula. The results of these calculations are then classified into specific effectiveness categories, providing empirical evidence as to whether the integration of a technology-assisted *STEAM* approach yields a significant impact compared to conventional instruction.

HASIL DAN PEMBAHASAN
Result
Model Validity

The validation process for this STEAM-based digital learning model involved a rigorous assessment by three experts specializing in Social Studies (*IPS*) education, instructional technology, and integrated curriculum. The combined evaluation results showed that the developed model achieved an average validity score of 92.6%, placing it in the "very valid" and "feasible for trial" category. This high score was driven by several superior components, including a systematically and coherently structured learning syntax that aligns with the principles of Project-Based Learning (PjBL) and social inquiry. Furthermore, the experts noted that the integrated STEAM approach is highly relevant to Social Studies content, particularly in contextualizing contemporary social issues. The feasibility of the interactive digital media also received high praise for its effectiveness in stimulating students' critical thinking. The content and construct validity of this model were further strengthened through expert triangulation and careful mapping against the learning objectives of the Kurikulum Merdeka, ensuring that the model is theoretically and methodologically robust.

Practicality of Implementation

A field trial involving 32 Grade VIII students at a public junior high school demonstrated that this model possesses a high level of applicability in real learning situations. Based on in-depth classroom observations and perception surveys distributed to teachers and students, a practicality score of 88.4% was obtained, falling into the "practical" category. From the perspective of educators, the model was considered highly helpful in facilitating a learning process that is more collaborative, creative, and efficient compared to conventional methods. Meanwhile, student responses to the use of STEAM-based digital media were overwhelmingly positive; they felt that this approach clarified the abstract relationship between Social Studies material and the real-world phenomena they experience. Moreover, the integration of digital simulations and STEAM-based projects proved effective in encouraging students to think analytically, construct logical arguments, and evaluate social issues more deeply, transforming the learning process into a meaningful experience rather than mere knowledge transfer.

Effectiveness in Enhancing Critical Thinking

The effectiveness of the model in improving students' cognitive abilities was measured using pre-test and post-test instruments referring to the Facione Critical Thinking Skills

framework, which includes aspects of interpretation, analysis, inference, evaluation, and explanation. Statistical analysis showed a significant improvement in students' critical thinking skills following the intervention, with an N-gain score of 0.67, categorized as a moderate-to-high improvement. A paired sample t-test further reinforced these findings with a value of p < 0.01, confirming that the STEAM-based digital model has a statistically significant impact. The most substantial improvements were observed in analytical and inferential skills. This occurred primarily when students were presented with social case studies based on digital data, requiring them to explore problems through interdisciplinary projects. These findings prove that the model is not only visually engaging but also powerful in sharpening students' reasoning power to solve complex problems.

Design of the Contextual STEAM-Based Digital Learning Model

The design of this digital learning model is based on the principle of integrating Science, Technology, Engineering, Arts, and Mathematics into Social Studies instruction, with a primary emphasis on local contextuality. This design aims to connect the abstract concept of international trade with the reality of students' lives in East Aceh. The design process began with a needs identification which found that students struggled to understand export-import mechanisms. The design solution then specifically integrated STEAM elements: Science to understand natural resource commodities; Technology through the use of applications such as Canva; Engineering in designing distribution flows; Arts for creating visual infographics; and Mathematics for calculating trade profit values. The outputs of this design include digital modules, STEAM-based student worksheets (*LKS*), and media guides that have been validated by subject matter experts and educational practitioners with a feasibility score of 82%. This approach ensures that the material is not only understood theoretically but is also relevant to the students' regional potential.

Figure 1. STEAM-based student worksheets (*LKS*)

Implementation of the STEAM-Based Digital Learning Model

The implementation of this model was carried out on the topic of International Trade, involving 30 Grade VIII students through a series of structured stages ranging from orientation to reflection. The learning process began with the teacher presenting a digital video regarding the export-import routes of Aceh's agricultural commodities, followed by data exploration through interactive charts. Students then worked collaboratively in groups to design interactive posters using Canva, performed quantitative analysis by calculating simple trade balance

values, and presented their creative works. The implementation results showed a very high level of student engagement, with 85% active participation in discussions. The impact on critical thinking skills was also evident, where 80% of students were able to identify trade factors and 72% were able to analyze the socio-economic impacts. All groups successfully produced digital products in the form of posters and infographics that integrated STEAM aspects, proving that this model effectively encourages both creativity and content mastery.

Effectiveness of the STEAM-Based Digital Learning Model

The model's effectiveness was measured using a pre-test and post-test design on critical thinking skills (indicators: problem identification, analysis, evaluation, and conclusion).

Table 1 Critical Thinking Test Results

Indikator Berpikir Kritis	Pre-test (%)	Post-test (%)	Improvement
Problem Identification	45	80	35
Data Analisis	40	72	32
Argumen Evaluation	35	68	33
Drawing Conclusions	30	65	35
Average	37,5	71,25	33,75

Table 1 the t-test results ($\alpha = 0.05$) showed $p < 0.05$, indicating a significant difference between students' critical thinking skills before and after the model implementation. Thus, the STEAM-based digital learning model was proven effective in enhancing students' critical thinking skills in Social Studies.

Discussion

1. Validity and Instructional Design

The development of a digital learning model based on Science, Technology, Engineering, Arts, and Mathematics (STEAM) within Social Studies (IPS) has proven to possess exceptionally high construct and content validity. Based on expert appraisal, a validity achievement of 92.6% indicates that the instructional design—which integrates technological and artistic elements into international trade materials—has met rigorous academic feasibility standards. This success is attributed to the systematic and coherent formulation of learning syntax aligned with Project-Based Learning (PjBL) principles, allowing abstract Social Studies concepts to become more concrete and contextual for students. The integration of engineering and mathematical elements in calculating trade balances, alongside artistic elements in infographic visualization, demonstrates that a transdisciplinary approach significantly enriches students' perspectives on social phenomena. This high validity underscores that the model is not merely an adoption of technological trends, but a sophisticated pedagogical engineering effort to bridge the gap between social theory and real-world problem-solving, particularly within the context of the local economic potential of East Aceh (Elfizon, 2021; Lubis, 2023; Rajiani et al., 2023; Sumarni et al., 2025).

2. Practicality and Field Implementation

In terms of practicality, field implementation revealed highly positive reception from both educators and learners, with a practicality score of 88.4%. This figure reflects that the model is highly applicable and capable of fostering a collaborative and efficient learning climate. The use of digital platforms such as Canva and interactive data has successfully transformed classroom dynamics, evidenced by an active student participation rate of 85% during discussions and project execution. Students no longer perceive Social Studies as mere rote memorization but as a phenomenon that can be analytically and creatively visualized. This

positive response indicates that the STEAM approach successfully facilitates the learning styles of the digital generation, who tend to be visual and kinesthetic learners. The ease of media use and clarity of the learning flow motivate students to explore socio-economic issues independently, ultimately transforming the teacher's role from a primary information provider into a facilitator guiding student knowledge construction (Mamis, 2020; Mulyono & Ampo, 2021; Samikam, 2020; Saputri et al., 2023).

3. Effectiveness and Critical Thinking

The model's effectiveness in enhancing higher-order cognitive abilities is confirmed by a significant increase in students' critical thinking skills. Statistical analysis yielded an N-gain score of 0.67, placing the improvement in student ability in the "moderate to high" category. A surge in mean scores from a pre-test of 37.5 to a post-test of 71.25 proves that the model intervention has a substantial impact on students' cognitive processes. Indicators for problem identification and conclusion drawing saw the highest increases at 35% each, followed by argument evaluation (33%) and data analysis (32%). These data imply that project-based assignments—requiring trade data analysis and visual solution crafting—compel students to employ logical and evaluative reasoning. Statistical significance with a p-value below 0.01 further reinforces the conclusion that the STEAM-based digital learning model is a potent instrument for training students to dissect complex social issues systematically and measurably (Anugrahsari et al., 2025; Kusumasari et al., 2025; Lestari et al., 2025; Widarwati et al., 2021; Zahratunnura & Andromeda, 2025).

4. Theoretical Implications

Theoretically, these research findings reinforce the relevance of **Connectivism theory** in modern education, where knowledge is constructed through information networks and digital interactions. This model successfully positions technology not merely as a tool, but as a mediator enabling data-driven social investigation. By blurring the boundaries between exact sciences and the humanities through STEAM, students are trained in multidimensional literacy that combines scientific logic with social and aesthetic sensitivity. This aligns with the view that 21st-century challenges demand non-linear problem-solving capabilities. The success of students in designing interactive posters and calculating trade balances demonstrates that the integration of Arts and Mathematics in Social Studies can stimulate more holistic cognition. This model repositions Social Studies from a historical and sociological narrative into an analytical and projective study, preparing students to understand global dynamics with a comprehensive and adaptive mindset (Alim et al., 2021; Indraswati et al., 2020; Nisa et al., 2024; Wotheysen et al., 2025).

5. Limitations and Future Directions

While the model has proven valid, practical, and effective, its large-scale application involves several implications and limitations. Success is heavily dependent on the availability of adequate digital infrastructure and the technological literacy of both teachers and students. In schools with limited facilities, full implementation of the **Technology and Engineering** components may face significant technical constraints. Furthermore, the transformation toward student-centered learning with a transdisciplinary approach requires a pedagogical paradigm shift and support from flexible curriculum policies, such as the *Kurikulum Merdeka*. Time constraints within Social Studies hours also present a challenge, as the depth of STEAM projects often requires longer durations than conventional time allocations. Therefore, future research is encouraged to explore adaptation strategies for resource-limited environments and to develop intensive teacher training modules to ensure the sustainability and scalability of this learning innovation.

CONCLUSION

Based on the overall development and testing process, it can be concluded that the STEAM-based digital model developed for Social Studies has strong theoretical validity, practical feasibility, and pedagogical effectiveness in enhancing Phase D students' critical thinking skills. The model bridges the gap between the demands of 21st-century learning and the realities of conventional classroom practices that remain fragmented and minimally integrated with technology and interdisciplinary approaches. The integration of STEAM in Social Studies enriches the cognitive dimension while simultaneously engaging the affective and psychomotor domains through authentic, reflective, and data-driven digital social projects. The digitalized STEAM-based learning design provides space for students to elaborate knowledge, construct arguments, and evaluate the complexity of social phenomena critically and systematically. This demonstrates that Social Studies can be designed scientifically without losing its humanistic values and social contextuality. Furthermore, the model offers a transformative paradigm for instructional design where technology functions not merely as a tool but as a dynamic learning ecosystem. By integrating digital technology, STEAM principles, and active pedagogy, the model is relevant as a reference for curriculum development and Social Studies instruction that is adaptive to the demands of contemporary education. Thus, this study contributes both conceptually and practically to innovation in Social Studies education and opens avenues for further research through expanded contexts of implementation, differentiation across educational levels, and integration of artificial intelligence as well as socio-ecological competencies in future learning.

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