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Integrating IoT and Inquiry Social Complexity to Empower Digital Literacy in Primary Education

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Abstrak

The increasing demand for digital literacy in 21st-century education necessitates the development of innovative instructional media that effectively integrates technology with pedagogical depth. This study aims to develop and evaluate an Internet of Things (IoT)-based learning medium integrated with the Inquiry Social Complexity (ISC) model to empower digital literacy among elementary school students. Utilizing the ADDIE framework, the research included stages of analysis, design, development, implementation, and evaluation. The media was validated by experts in content, language, and media, and tested for practicality and effectiveness in real classroom settings. Expert validation results showed high validity across all components. Practicality tests involving teachers and students yielded scores of 81% and 84% respectively, indicating the media's ease of use and pedagogical value. Effectiveness was measured through pre-test and post-test assessments, revealing a significant increase in students' digital literacy scores from 47.17% to 84.39% with the highest improvement observed in digital ethics. The N-Gain score reached 0.75, categorized as high. These findings suggest that integrating IoT technology with inquiry-based learning fosters critical, ethical, and collaborative competencies. The study offers a replicable, socio-technological approach to digital literacy development in primary education and contributes to the discourse on smart, ethical learning environments in the digital age.

Keywords: Internet of Things (IoT), Inquiry Social Complexity (ISC), digital literacy, instructional media, elementary education, ADDIE model, ethical learning

Introduction

The emergence of the digital era has profoundly reshaped the educational landscape, necessitating fundamental shifts in how students learn, interact, and process information. In this context, digital literacy has become an essential competency for 21st-century learners, particularly for students in elementary schools. As young learners are increasingly exposed to digital devices and online platforms, the development of skills to critically assess, manage, and ethically use digital information has grown more important than ever. Research by Handriyanto et al. (2022) emphasizes that digital literacy significantly influences students' morality and ethical behaviors in the digital age, thus extending its relevance beyond technical proficiency to character development. Furthermore, fostering digital literacy from an early age is closely linked to students' capacity to become responsible digital citizens who understand both the opportunities and challenges of living in a technologically saturated society.

Digital literacy, as defined by Gilster (1997), refers not only to the ability to operate digital tools but also to the critical evaluation of digital content, ethical reasoning, and responsible participation in digital communities. Ng (2012) expands this view by asserting that

digital literacy also encompasses cognitive, technical, and socio-emotional dimensions. However, despite growing awareness of its importance, integrating digital literacy effectively into elementary school curricula remains a major challenge. One prominent issue lies in the lack of educational media that is not only technologically advanced but also pedagogically sound and contextually relevant. Many schools still rely heavily on conventional tools such as textbooks and whiteboards, which are often inadequate to cultivate complex digital skills such as information evaluation, digital creativity, or collaboration (Tafonao, 2018).

Another major challenge in embedding digital literacy into primary education is the limited exposure of both educators and learners to emerging technologies such as the Internet of Things (IoT). Although IoT has been widely adopted in various industries, its application in classroom learning environments is still relatively underexplored, particularly at the elementary level. The IoT's ability to connect devices and collect real-time data presents immense potential for enhancing digital learning experiences. For instance, IoT-based tools such as wearable devices, smart sensors, and interactive displays can facilitate personalized learning, real-time feedback, and contextual engagement (Al-Fuqaha et al., 2015; Zhou et al., 2016).

Compounding this challenge is the scarcity of instructional media designed specifically to enhance digital literacy through hands-on engagement with IoT technologies. While multimedia and digital learning platforms have grown in number, very few effectively integrate complex inquiry-based learning with tangible digital tools. This leads to another key gap: instructional strategies and resources often fail to go beyond surface-level engagement with digital content. According to Julianti et al. (2022) and Zahwa & Syafi'i (2022), many existing media do not adequately stimulate student motivation or active learning.

To address these limitations, this study introduces the integration of the Internet of Things (IoT) with the pedagogical approach of Inquiry Social Complexity (ISC) as an innovative framework for media development in elementary education. The ISC model is grounded in the principles of active learning, critical thinking, and social awareness. When combined with IoT tools, ISC can provide a highly interactive and contextual learning environment. This dual emphasis on technology and inquiry-based learning aligns with 21st-century educational goals.

Previous research has highlighted the benefits of integrating inquiry-based learning with technology. Faridah et al. (2022) demonstrated that project-based learning models can significantly improve students' digital and numeracy literacy. Similarly, Asnil & Eliza (2021) underscored the value of context-aware digital tools in fostering deeper learning experiences. However, there remains a limited number of studies that specifically examine the impact of combining IoT and ISC in the development of instructional media for young learners. This gap in the literature underscores the novelty of this research, which seeks to design, develop, and evaluate an IoT-based learning medium that leverages ISC to empower digital literacy at the elementary level.

The objectives of this study are threefold: first, to assess the feasibility of IoT-based media integrated with ISC for digital literacy instruction; second, to evaluate its practicality in classroom settings through teacher and student feedback; and third, to determine its effectiveness in improving students' digital literacy competencies through empirical testing.

Metode

This study employed a Research and Development (R&D) approach using the ADDIE model as its framework. The ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation, offers a structured and iterative methodology that enables researchers to systematically design and assess instructional materials (Branch, 2009). Each phase in the ADDIE process was carefully executed to ensure the development of an

instructional medium that is valid, practical, and effective in improving the digital literacy of elementary school students. The methodology was implemented in SDN 3 Karang Anyar, focusing on fifth-grade students and science material on the human digestive system.

1. Analysis Stage

The analysis phase served as the foundation of the research, aiming to identify problems and learning needs in the existing elementary education context. To gather empirical data, the researchers conducted classroom observations and interviews with teachers at SDN 3 Karang Anyar. These interactions revealed a significant gap between the current instructional media used in classrooms—primarily conventional and static tools—and the need for innovative media that can enhance 21st-century skills, particularly digital literacy. Teachers expressed difficulties in encouraging critical thinking, collaboration, and ethical awareness among students through the available learning resources.

Moreover, the analysis identified that students' interaction with technology was largely limited to entertainment purposes and lacked structure and educational depth. While digital devices were available, they were not integrated into learning activities in a meaningful way. This gap emphasized the urgent need to develop a digital learning medium that not only presents subject content but also empowers learners to access, evaluate, and utilize information critically.

In alignment with this, the researchers concluded that integrating the Inquiry Social Complexity (ISC) learning model with Internet of Things (IoT) technology would provide a more contextual and engaging approach to digital literacy. ISC emphasizes inquiry into real-world, ambiguous, and socially relevant problems, while IoT offers interactive digital tools that can transform traditional classroom environments into dynamic learning spaces (Bell et al., 2010; Zhou et al., 2016).

2. Design Stage

The design stage involved planning the learning media's structure, content, and technological platform. The selected topic was the human digestive system, a subject that is relevant to students' daily experiences and can be explored through inquiry-based tasks. The learning medium was developed using Google Sites, a web-based platform that allows for the integration of text, images, videos, interactive activities, and sensor-based data input from IoT components.

Instructional tasks were designed using the ISC approach, which guided students through problem identification, information gathering, data analysis, and reflective discussion. The digital literacy indicators targeted in the design included digital access, information literacy, digital collaboration, digital creation, digital safety, and digital ethics, aligning with frameworks proposed by Ng (2012) and Belshaw (2011).

Each task and feature in the media was mapped against specific learning objectives, ensuring alignment with Indonesia's elementary school curriculum (KI/KD). The instructional flow supported multimodal learning, as recommended by Mayer (2009), to accommodate various student learning styles and promote deeper engagement.

3. Development Stage

During the development phase, the prototype of the digital learning media was constructed based on the finalized instructional design blueprint. Upon completion, it was subjected to expert validation involving three specialists: a content expert, a language expert, and a media expert. The content expert assessed the degree to which the material aligned with curriculum standards and verified the accuracy of scientific concepts, resulting in an Aiken's V score of 0.765, which falls within the valid category. The language expert evaluated aspects of clarity, linguistic correctness, and age-appropriateness of the instructional text, yielding a validity score of 0.776, also categorized as valid. Meanwhile, the media expert examined the visual aesthetics, interface functionality, and overall user experience of the digital platform, awarding a score of 0.938—classified as highly valid.

In parallel, the research team developed a digital literacy questionnaire comprising 40 items aimed at assessing student competencies. Through item-total correlation testing, 28 items were deemed valid and retained, while 12 items were excluded for not meeting the validity threshold. Reliability testing using Cronbach's Alpha resulted in a coefficient of 0.844, signifying a high level of internal consistency and confirming that the instrument was highly reliable (Arikunto, 2013). Following this rigorous validation process, both the learning media and the assessment instruments were revised based on expert feedback to ensure optimal quality before moving forward to the implementation phase.

4. Implementation Stage

The implementation stage began with a **limited-scale trial** to assess the practicality of the media in real classroom settings. Six teachers and six fifth-grade students of varied academic abilities (high, medium, low) were involved. Teachers provided feedback on media content, presentation, ease of use, and implementation potential. The average practicality rating was 81%, categorized as "very practical." Students' ratings on ease of use, coherence, and interest yielded a mean score of 84%, also "very practical."

Following these positive results, a **field trial** was conducted involving 33 students from SDN 3 Karang Anyar. The trial assessed the effectiveness of the IoT-ISC media in improving students' digital literacy. Pre-test and post-test were administered using the validated instrument. Students completed a learning session with the developed media, which incorporated interactive tasks and IoT-based simulations to visualize digestive processes and promote ethical reflection through ISC scenarios.

5. Evaluation Stage

The final phase of the research was dedicated to evaluating the effectiveness of the developed digital learning media through quantitative statistical analysis. This evaluation primarily compared pre-test and post-test results, reinforced by normality testing and the calculation of N-Gain scores. Normality testing using the Liliefors formula indicated that both pre-test and post-test data were normally distributed, as the calculated Lhitung values (0.110 for pre-test and 0.107 for post-test) were lower than the critical Ltabel value of 0.154. The average N-Gain score was 0.75, which is categorized as high, indicating a substantial increase in students' digital literacy performance following the intervention. Additionally, the gain percentage of 75.13% confirmed that the media met the criteria for effectiveness. Further analysis revealed that all six digital literacy indicators demonstrated marked improvements. The most significant gain occurred in digital ethics, which increased from 42.08% in the pre-test to 97.08% in the post-test—highlighting the effectiveness of the ISC-based inquiry model in enhancing students' moral reasoning and social responsibility in digital contexts. Other indicators, including digital access, information literacy, and collaboration, also showed meaningful advancements. These findings confirm that the learning media is not only theoretically robust but also practically effective in fostering comprehensive digital literacy among elementary school students. The integration of IoT tools with socially contextual inquiry tasks transformed passive instruction into a dynamic, ethical, and student-centered learning experience.

Findings and Discussion

This section presents the results of the research and development process of an IoT-based learning medium integrated with the Inquiry Social Complexity (ISC) approach to enhance digital literacy among elementary school students. The research followed the ADDIE development model and included stages of analysis, design, development, implementation, and evaluation. The outcomes are organized into four primary sub-sections: validation results, practicality testing, effectiveness testing, and analysis of digital literacy indicators. These

results serve as the foundation for concluding the feasibility, usability, and impact of the developed learning media.

3.1. Validation Results

To ensure the academic quality and instructional relevance of the developed media, validation was conducted by three experts covering content, language, and media design. Figure 1 illustrates the Aiken's V scores provided by each expert, reflecting the degree of agreement on the validity of the media components. All scores exceeded the acceptable threshold, indicating that the media was considered valid or very valid across all evaluated aspects.

Figure 1. Expert Validation Results

Figure 1 illustrates the expert validation outcomes for the developed IoT-ISC learning media, evaluated across three domains: content, language, and media. The content expert rated the media with an Aiken's V score of 0.765, confirming its alignment with the national curriculum and conceptual relevance for elementary students. The language expert assigned a score of 0.776, validating the clarity, grammatical accuracy, and age-appropriateness of the instructional language. The media expert provided the highest score of 0.938, indicating the media's high validity in terms of visual design, interactivity, and technical functionality. These results confirm that the learning media meets the essential standards for educational use and is well-suited for classroom implementation. These validation results indicate that the learning media met the required academic and usability standards prior to field testing. The feedback collected was used to revise the prototype before moving to implementation.

3.2. Instrument Validity and Reliability

To ensure the quality of the assessment instruments used to measure students' digital literacy, validity and reliability tests were carried out. Construct validity was determined through expert review and statistical testing, resulting in 28 out of 40 test items being classified as valid. The validation process confirmed the alignment of items with six core digital literacy indicators: access, information, creation, collaboration, safety, and ethics. In addition, instrument reliability was measured using Cronbach's Alpha, which yielded a value of 0.844 indicating high internal consistency.

Table 1. Valid and Invalid Test Items

Criteria	Item Numbers
Valid	1, 2, 4, 5, 7, 11, 13, 17, 20, 27, 29, 32, 35, 36
Not Valid	3, 6, 12, 18, 19, 28, 33, 34, 37, 38, 39, 40

Table 1 presents the results of the instrument validity test, which aimed to determine the extent to which each test item accurately measured the intended digital literacy constructs. Out of 40 test items developed, 28 items were classified as valid based on the statistical correlation analysis, while 12 items were excluded due to insufficient validity. The valid items correspond to the six digital literacy indicators defined in the study, confirming the construct alignment between the instrument and the conceptual framework. This suggests that the selected items are appropriate for assessing the intended competencies of students.

Table 2. Instrument Reliability

Metric	Value	Interpretation
Cronbach's Alpha	0.844	High Reliability

Table 2 shows the result of the instrument reliability analysis using Cronbach's Alpha, which yielded a coefficient of 0.844. This value exceeds the commonly accepted threshold of 0.70 for educational research instruments, indicating a high level of internal consistency among the test items. The high reliability score supports the conclusion that the instrument is dependable and can consistently measure digital literacy competencies across different test conditions. Together, the findings from both validity and reliability tests affirm that the instrument used in this study is both accurate and stable for evaluating student learning outcomes. These results confirm that the instruments used were both valid in content and reliable in consistency, ensuring accurate measurement of digital literacy development among students.

3.2. Practicality Testing

To assess the usability of the learning media in actual classroom contexts, practicality tests were administered to both teachers and students. Figure 2 presents the average practicality scores given by these two groups. Both teachers and students rated the media as highly practical, citing ease of navigation, clarity of content, and effectiveness in facilitating active learning.

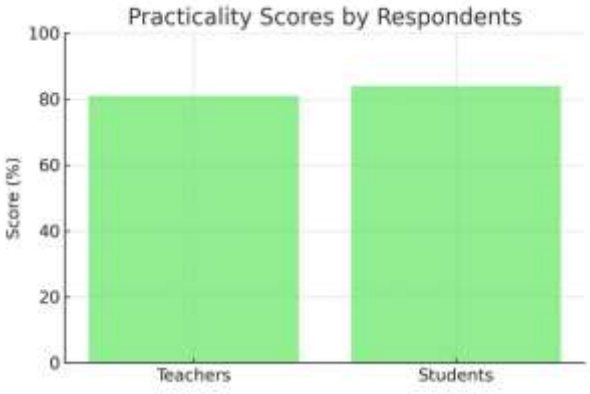

Figure 2. Practical Scores by Respondents

Figure 2 depicts the practicality assessment of the developed learning media, as evaluated by both teachers and students. Teachers highlighted the clear structure of the content, the intuitive and user-friendly interface, and the ease with which classroom activities could be conducted using the media. They particularly appreciated the integration of Internet of Things (IoT) components and inquiry-based learning tasks that stimulated student engagement. Students likewise found the media enjoyable and visually appealing, noting that its interactive features significantly enhanced their understanding of the science topic—especially the digestive system. The high average scores from both groups affirm the media's usability and effectiveness, indicating a strong acceptance and practical feasibility for elementary classroom settings.

3.3. Effectiveness Testing

The effectiveness of the IoT-ISC media was measured using a pre-test and post-test format, targeting six digital literacy indicators. Figure 3 compares the average scores for each indicator before and after using the media. The results show significant improvements across all indicators, with the most substantial gain observed in digital ethics, demonstrating the success of the ISC model in fostering ethical digital behavior in elementary students.

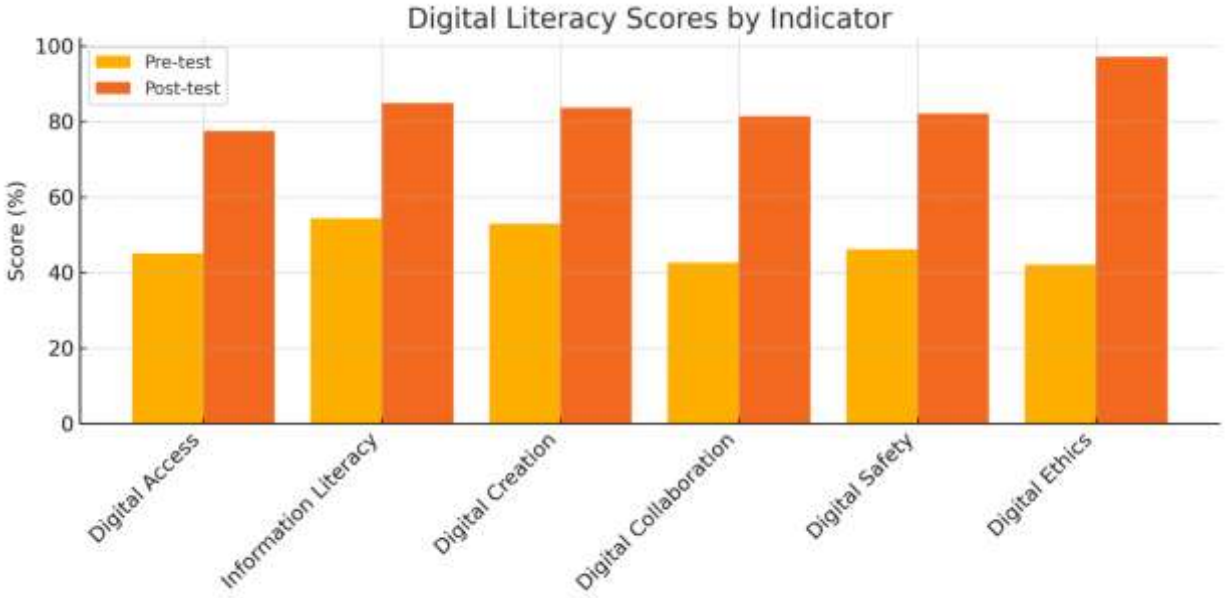

Figure 3. Digital Literacy Scores

Figure 3 illustrates the comparative results of students' digital literacy before and after using the IoT-ISC learning media across six key indicators: digital access, information literacy, digital creation, collaboration, safety, and ethics. The data show a substantial increase in all areas, with average scores rising from 47.17% in the pre-test to 84.39% in the post-test. The most significant improvement occurred in the digital ethics domain, which rose from 42.08% to 97.08%, reflecting the effectiveness of the ISC model in fostering ethical awareness and responsible digital behavior. Other indicators—such as information literacy, digital creation, and collaboration—also demonstrated strong gains, indicating that the integrated media not only enhanced technical proficiency but also supported higher-order digital competencies. These results validate the media's effectiveness in cultivating comprehensive digital literacy among elementary school students.

3.4. Digital Literacy Indicators Analysis

The analysis of digital literacy indicators revealed consistent and significant improvement across all six core dimensions, demonstrating the effectiveness of the IoT-ISC integrated learning media. The incorporation of Inquiry Social Complexity (ISC) with Internet of Things (IoT) tools provided students with authentic opportunities to engage in real-world problem-solving, ethical reflection, and collaborative digital tasks. In terms of digital access, students became more adept at using digital devices to retrieve relevant information and navigate online platforms efficiently. Their information literacy also improved markedly, as they developed the ability to critically evaluate the credibility of online sources and verify information across multiple references. In digital creation, students successfully produced content through digital storytelling, online simulations, and infographics, showcasing their ability to express ideas using modern tools. Collaboration was enhanced through group-based inquiry tasks, allowing learners to practice safe and productive teamwork in virtual settings. Notably, digital safety awareness increased, with students demonstrating a better understanding of online privacy, password security, and responsible internet behavior. Finally, the most profound growth was observed in digital ethics, where students reflected on complex digital dilemmas, including misinformation, cyberbullying, and intellectual property rights. This holistic development across all indicators affirms the strength of a socio-technological approach in fostering comprehensive digital literacy from an early age.

3.5. Statistical Tests: Normality and N-Gain

To ensure the reliability and validity of the measured outcomes, statistical tests were conducted on the digital literacy assessment data. These tests aimed to determine whether the

data distribution met the assumptions necessary for further parametric analysis and to evaluate the degree of improvement in student performance after the implementation of the IoT-ISC learning media. Specifically, a normality test was applied to verify the distribution characteristics of the pre-test and post-test scores, while the N-Gain test was used to quantify the learning gain achieved by students. The combination of these statistical approaches provides a rigorous foundation for interpreting the effectiveness of the developed instructional media.

a. Normality Test

Using the Liliefors test at $\alpha = 0.05$, the results indicated that both pre-test and post-test scores were normally distributed, thus validating the suitability of further parametric analysis.

Table 3. Normality Test Results

Test	N	L_{hitung}	L_{tabel}	Conclusion
Pre-test	33	0.110	0.154	H_0 accepted (Normal)
Post-test	33	0.107	0.154	H_0 accepted (Normal)

Table 3 displays the results of the normality test conducted using the Liliefors method at a significance level of $\alpha = 0.05$. Both pre-test and post-test scores yielded Lhitung values (0.110 and 0.107, respectively) that were lower than the critical value of L_{tabel} (0.154), indicating that the data were normally distributed. The acceptance of the null hypothesis (H_0) for both tests confirms the suitability of subsequent parametric statistical analyses.

2. N-Gain Test

To measure the increase in digital literacy performance quantitatively, the N-Gain formula was applied:

Table 4. N-Gain Test Results

Metric	Value	Category
N-Gain Score	0.75	High
Effectiveness	75.13%	Effective

Table 4 presents the N-Gain test results, which were used to measure the magnitude of learning improvement following the implementation of the IoT-ISC learning media. The N-Gain score of 0.75 falls within the "high" category, while the effectiveness rate of 75.13% indicates that the learning intervention was effective in significantly enhancing students' digital literacy. These statistical outcomes provide strong empirical support for the media's impact and reinforce the robustness of the study's findings. This result reinforces that the learning media significantly contributed to the digital literacy development of the students, with a high level of educational impact.

The pedagogical foundation of this study rests on the ISC learning model, which emphasizes student-centered inquiry, critical thinking, and ethical reflection in response to complex social phenomena. Bell, Smetana, and Binns (2010) suggest that ISC can foster deeper cognitive engagement and support students in navigating ambiguous and unstructured problems—skills that align with 21st-century learning demands. The application of ISC in this study was shown to be effective in guiding students through reflective and exploratory tasks embedded in the learning media. This was especially evident in the substantial gains observed in the digital ethics indicator, which rose from 42.08% in the pre-test to 97.08% in the post-test. Such an outcome supports Bereiter and Scardamalia's (2006) assertion that education for the knowledge age must go beyond rote knowledge transfer and cultivate responsible, ethical thinkers.

Moreover, the results reaffirm that ISC, when applied at the elementary level, can be a powerful pedagogical tool—not only for content mastery but also for the holistic development of digital citizenship. Through scenario-based questions, group discussions, and problem-solving tasks, students were encouraged to reflect critically on issues such as online privacy, misinformation, and cyber safety, reinforcing the social and moral dimensions of digital literacy. This aligns with the perspective of Belshaw (2011), who argues that digital literacy comprises not just technical competence but also ethical responsibility, collaborative engagement, and cultural awareness in digital spaces.

From a technological standpoint, the integration of IoT in the learning environment provided an engaging and interactive context for students to experience digital literacy in action. IoT-enabled devices and simulations allowed learners to visualize and manipulate digital representations of the human digestive system—a core science topic—while simultaneously practicing inquiry-based tasks. The result was a meaningful and multimodal learning experience that extended beyond conventional textbook delivery. According to Al-Fuqaha et al. (2015), IoT technology supports the development of *smart learning environments*, which are adaptive, data-driven, and capable of providing real-time feedback. In this study, IoT tools functioned as more than novelty; they served as cognitive scaffolds that enhanced students' engagement and understanding of both scientific content and digital tools.

The positive evaluation from teachers and students further supports the practical feasibility of this approach. With practicality ratings of 81% (teachers) and 84% (students), the media was considered easy to use, accessible, and pedagogically effective. Teachers highlighted the ease of implementation and the media's ability to stimulate active participation, while students appreciated the visual and interactive elements. This corroborates previous findings by Tafonao (2018) and Yusuf (2019), who emphasize the role of interactive and communicative media in enhancing learning motivation and participation.

In addition to its pedagogical and technological strengths, the developed media proved to be highly effective in improving multiple dimensions of students' digital literacy. The N-Gain score of 0.75, categorized as high, demonstrated a substantial learning gain across all indicators. Students exhibited notable improvements not only in basic technical skills (e.g., digital access and creation) but also in higher-order competencies such as collaboration and critical evaluation of information. These results validate the notion that digital literacy is a multidimensional construct that benefits from an integrated instructional approach combining technology with reflective inquiry (Ng, 2012).

The quality of the research instrument was also ensured through rigorous validity and reliability testing, which further supports the credibility of the study's findings. Construct validity was assessed through expert review and statistical analysis, resulting in 28 out of 40 items being classified as valid. This outcome reflects strong alignment between the test items and the six core indicators of digital literacy measured in the study. Additionally, the reliability test yielded a Cronbach's Alpha score of 0.844, indicating high internal consistency and stability of the instrument. These results confirm that the digital literacy assessment tool was both accurate and dependable, ensuring that the observed learning gains were the result of effective instructional intervention rather than measurement error. The instrument's psychometric robustness thus strengthens the evidence supporting the effectiveness of the IoT-ISC media in improving students' multidimensional digital competencies.

It is important to highlight that while significant gains were observed, the improvements did not occur uniformly across all indicators. For instance, while the digital ethics score nearly doubled, indicators such as digital access and collaboration, although improved, still suggest room for further development. This may be attributed to limitations in students' home access to technology or the novelty of collaborative digital tools in their learning routines. These findings suggest that the effectiveness of digital literacy interventions depends not only on classroom innovation but also on broader infrastructural and socio-cultural factors.

The validation phase of the media also offers meaningful insights into the quality of educational product design. The expert validators, representing content, language, and media domains, assigned high Aiken's V scores across all components—ranging from 0.765 to 0.938—confirming the alignment between the media and curriculum standards, clarity of communication, and quality of technological implementation. Such validation is crucial in ensuring that digital learning media meet both pedagogical and technical criteria before field deployment. This process follows best practices in educational design research, as advocated by Plomp and Nieveen (2007), where formative evaluation and iterative refinement are integral to producing high-quality educational innovations.

Furthermore, the use of the ADDIE model as a development framework proved to be an effective and systematic approach. From the initial analysis to the final evaluation, the model facilitated structured planning, design, and assessment processes that ensured alignment with learner needs and instructional goals. Branch (2009) describes ADDIE as a robust and flexible model suitable for various educational contexts, and the outcomes of this research support this claim.

Despite the positive outcomes, the study acknowledges several limitations. First, the implementation was conducted within a single school setting with a relatively small sample size, which may limit the generalizability of the findings. Second, while the ISC model was found to be effective, its implementation requires facilitative teacher roles and structured guidance, which may pose challenges in classrooms with limited instructional support or large student-teacher ratios. Third, the use of IoT tools requires technological infrastructure that may not be equally available in all schools, especially in under-resourced areas.

Nevertheless, the findings offer valuable implications for educators, policymakers, and curriculum designers. For educators, this research provides a replicable model for integrating technology and inquiry-based learning into digital literacy instruction. For policymakers, the results highlight the importance of investing in teacher training, digital infrastructure, and curriculum frameworks that support holistic digital literacy development. Finally, for future researchers, the study opens avenues for exploring the integration of emerging technologies such as artificial intelligence (AI) and augmented reality (AR) within the ISC framework to further personalize and contextualize student learning.

In summary, this discussion affirms that the integration of IoT and ISC within a structured instructional design framework is not only feasible but also highly effective in enhancing students' digital literacy competencies. The holistic nature of this approach—combining cognitive, technical, and ethical dimensions—aligns well with the demands of 21st-century education and offers a scalable model for innovation in elementary learning environments. As digital literacy continues to be a cornerstone of modern education, approaches like the one presented in this study will be vital in preparing students to navigate and shape the digital world with competence and conscience.

Conclussion

The development of an Internet of Things (IoT)-based learning medium integrated with the Inquiry Social Complexity (ISC) model has proven to be a valid, practical, and effective instructional innovation for empowering digital literacy among elementary school students. Utilizing the ADDIE model as its development framework, the research addressed a critical gap in instructional media that bridges technological advancement with inquiry-driven pedagogy. Expert validation confirmed the media's alignment with pedagogical, linguistic, and technological standards. Practicality testing revealed high usability and acceptance among both teachers and students, indicating its feasibility for classroom implementation. Most importantly, the media demonstrated a significant positive impact on students' digital literacy, as evidenced by substantial improvements across six core indicators: digital access,

information literacy, digital creation, collaboration, safety, and ethics. The most notable increase occurred in digital ethics, highlighting the media's strength in fostering critical and responsible engagement with digital content. The integration of IoT tools with ISC-based tasks enabled students not only to engage with scientific concepts interactively but also to develop the ethical and collaborative skills essential for 21st-century learning. This study contributes to the growing body of research advocating for socio-technological approaches in digital education and provides a replicable model for innovative learning media development in primary education.

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