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Developing a Guided Inquiry Electronic Student Worksheet to Foster Students' Creative Thinking and Collaboration Skills

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ABSTRACT

Objective: *This study aims to develop a guided inquiry–based Electronic Student Worksheet (ESW) and analyze its effectiveness in improving high school students' creative thinking and collaboration skills, two essential competencies required in 21st–century learning.* ***Method:*** *The research employed the ADDIE development model, consisting of analysis, design, development, implementation, and evaluation stages. The product was validated by material, media, and language experts. A one-group pretest–posttest quasi-experimental design was implemented with 30 Grade XI students. Data were collected using a validated creative thinking test and collaboration observation sheet. Normality tests and paired sample t-tests were used for data analysis, followed by effect size calculations.* ***Results:*** *The developed ESW obtained an average feasibility score of 72.75%, categorized as "eligible." The creative thinking test and collaboration observations were also validated with scores of 71.25% and 66.25%, respectively, both in the "valid" category. Implementation results showed a significant improvement in creative thinking (from 3.33 to 6.97; $p < 0.05$; Cohen's $d = 1.08$, large effect) and collaboration skills (from 12.83 to 16.23; $p < 0.05$; Cohen's $d = 1.44$, very large effect).* ***Novelty:*** *This study integrates the guided inquiry model directly into a digital ESW, producing substantial learning gains in two higher-order competencies simultaneously creative thinking and collaboration. Unlike previous studies that developed conventional or non-inquiry ESWs, this research demonstrates that inquiry-driven digital worksheets can generate strong cognitive and social skill enhancement in a single learning instrument.*

INTRODUCTION

The Industrial Revolution 4.0 demands adaptation across various aspects of life, including education. In this context, students must master 21st-century skills encompassing creative and critical thinking, collaboration, information and technology literacy, problem-solving, innovation, entrepreneurship, social responsibility, leadership, as well as digital and computational literacy (Arafat et al., 2024; Kaya et al., 2025). Mastery of these skills is essential because it enables students to adapt to rapid societal changes and prepare for future careers (Molla et al., 2023; Uyar, 2023). However, the development of 21st-century skills in schools remains suboptimal, particularly in technology integration and the implementation of student-centered learning models (Dönmez Usta & Ültay, 2025; Rizaldi et al., 2020). Therefore, student-centered learning models must be systematically integrated into classroom practice. To achieve this integration, learning approaches grounded in constructivist principles are required, as constructivism emphasizes active knowledge construction through interaction and experience (Mir et al., 2025; Siregar et al., 2025). One such approach is inquiry-based learning, which emphasizes exploration and problem-solving as central processes in knowledge construction.

One inquiry-based model that aligns closely with student-centered principles is guided inquiry. Guided inquiry encourages students to discover concepts through investigative activities structured around teacher-posed questions and scaffolded guidance, without providing direct answers (Eshtu & Wakuma, 2024; Ford et al., 2023). This model promotes active engagement in scientific investigation and has been shown to improve learning outcomes compared to conventional instruction (Kansoy & Çıbık, 2022; Owolade et al., 2022). Compared with open inquiry, which requires high levels of student autonomy, guided inquiry provides structured scaffolding that is more suitable for students with limited prior knowledge and inquiry experience. The teacher's guidance helps maintain cognitive focus, reduces misconceptions, and supports gradual development of creative and collaborative skills (Areepattamannil, 2025; Dah et al., 2024). Nevertheless, the implementation of guided inquiry remains limited due to insufficient teacher understanding, low student readiness and literacy levels, inadequate technological competence, and limited institutional support (Hastuti et al., 2020; Rusdiyana et al., 2024). These challenges indicate the need for supportive learning media that can operationalize guided inquiry principles in a structured and practical manner.

One type of learning media that can support guided inquiry implementation is the Electronic Student Worksheet (ESW). ESW is an interactive digital worksheet designed to facilitate structured learning activities through engaging and accessible digital features (Elvanuari et al., 2024; Hamidah et al., 2025). Grounded in constructivist learning theory, ESW positions students as active constructors of knowledge by engaging them in exploration, reflection, and problem-solving tasks. From the perspective of cognitive engagement theory, its interactive elements, such as simulations, embedded questions, and feedback features, encourage deeper processing and sustained attention (Q. Huang et al., 2025; Lin et al., 2025). ESW supports student-centered learning by enhancing engagement, learning independence, and conceptual understanding through visually rich and interactive content (Fadilah et al., 2024; Herlina et al., 2025). Additionally, ESW contributes to the development of critical, creative, collaborative, and communicative skills while strengthening digital literacy (Ricky Ardiansah & Zulfiani, 2023; Syar et al., 2023). However, its utilization remains limited due to inadequate infrastructure and insufficient teacher readiness (Sudirman et al., 2024). Unlike conventional student worksheets that primarily function as digitized worksheets, the proposed Guided Inquiry–based ESW is conceptually designed to embed inquiry phases problem orientation, hypothesis formulation, investigation, data analysis, and reflection within its digital structure (Br Tarigan & Sugiharti, 2024; Irdinansyah et al., 2025). This integration differentiates it pedagogically by aligning digital tasks directly with inquiry processes rather than merely presenting electronic exercises.

One essential 21st-century skill that must be strengthened is creative thinking. Creative thinking refers to the skills to generate multiple ideas (fluency), produce original responses (originality), propose varied approaches (flexibility), and elaborate ideas in detail (elaboration) (Kholid et al., 2024; Paz-Baruch et al., 2025). This study operationalizes creative thinking through these four measurable dimensions. Fluency is assessed by the number of relevant ideas generated in response to open-ended problems. Originality is evaluated based on the uniqueness of responses compared to peers. Flexibility is measured by the diversity of solution strategies used, and elaboration is determined by the depth and clarity of explanation provided (Torrance, 1974). Creative

thinking supports students' cognitive and social development and enables them to address real-world challenges effectively (Chaozheng et al., 2024; Oudat et al., 2025). However, students' creative thinking levels remain low due to dominant traditional teaching practices and limited teacher epistemological understanding, which often restrict student expression (Ekayana et al., 2025; Varlık, 2024). Therefore, structured learning interventions are required to foster this skill.

In addition to creative thinking, collaboration skills are key competencies in 21st-century learning. Collaboration involves the skills to work effectively with others, communicate ideas, resolve conflicts, and respect diverse perspectives (Ashley & Patrone, 2022; X. Huang & Ochoa, 2025). These skills enhance participation and responsibility in contextual problem-solving activities (Priyambodo et al., 2023; Sajidan et al., 2023). However, students' collaboration skills remain limited due to monotonous learning models that provide minimal opportunities for meaningful group interaction (Erina et al., 2025; Tendri & Ulli, 2025). In the context of ESW based guided inquiry, collaboration is facilitated through structured group investigations. During the problem-orientation phase, students articulate initial ideas; in the hypothesis formulation and investigation phases, they collaboratively divide roles, collect data, and negotiate interpretations; and in the analysis and reflection phases, they engage in peer discussion and collective evaluation of findings, whereby such structured digital inquiry tasks foster shared responsibility, peer feedback, and joint problem-solving as core components of collaborative learning (Chen & Chen, 2025; Zheng et al., 2015). Thus, integrating guided inquiry with ESW provides a systematic framework for strengthening collaboration alongside creative thinking.

Several studies have attempted to enhance creative thinking and collaboration. Research conducted by Muskita et al. (2020) found that inquiry-based worksheets significantly improved students' creative thinking skills. However, the study relied on conventional print-based worksheets and did not integrate digital interactive features that could support sustained inquiry processes. Moreover, the inquiry procedures were not explicitly structured within a coherent digital framework. Additionally, Felitasari & Rusmini (2022) reported that ESW significantly improved collaboration skills, with a 94% increase based on questionnaire results. However, their ESW functioned primarily as a digital assignment platform and did not embed guided inquiry phases systematically. Additionally, previous studies tended to examine creative thinking and collaboration separately rather than within an integrated pedagogical framework. There remains a lack of research that combines a structured guided inquiry model with a digitally integrated ESW explicitly designed to develop both creative thinking and collaboration simultaneously**.** This gap highlights the need for a comprehensive digital learning framework that aligns inquiry processes with measurable 21st-century skill development.

Based on the above discussion, this study aims to develop a Guided Inquiry–based ESW that supports student-centered learning and to analyze its effectiveness in enhancing students' creative thinking and collaboration skills. Theoretically, this study contributes to strengthening 21st-century learning through the integration of constructivist inquiry approaches and digital media. Practically, the findings may guide teachers and researchers in designing innovative instructional practices. From a policy perspective, the study emphasizes the importance of institutional support and

continuous professional development in digital pedagogy. Pedagogically and technologically, it underscores the need for synergy between technology and structured inquiry to prepare students for the challenges of the Industrial Revolution 4.0.

RESEARCH METHOD

This study is a Research and Development project employing the ADDIE development model, which consists of five stages: Analyze, Design, Develop, Implement, and Evaluate. This model was selected because it is systematic and flexible, making it suitable for developing an effective and efficient guided inquiry–based ESW.

This design was selected due to administrative constraints that prevented the inclusion of a control group and was considered appropriate for evaluating the preliminary effectiveness of the developed Guided Inquiry–based ESW in an authentic classroom setting. However, it presents potential threats to internal validity, particularly maturation and testing effects. To minimize these threats, the intervention was implemented within a short and controlled instructional period; equivalent but non-identical pretest and posttest items were administered; and instructional conditions including duration, objectives, and classroom environment were kept consistent throughout the study. Although causal generalization is limited, this design remains suitable for initial product evaluation prior to broader experimental testing. Classroom observations were conducted by two observers with educational backgrounds who were not directly involved in the instructional implementation. Prior to data collection, both observers participated in a calibration session to align their understanding of the observation guidelines and scoring criteria. Inter-rater consistency was subsequently evaluated using Cohen's kappa coefficient to ensure reliability between the observers. These procedures were implemented to enhance the reliability and credibility of the collaboration data collected during the intervention.

The test items were systematically developed based on the predefined indicators of creative thinking, namely fluency, originality, flexibility, and elaboration. Each indicator was represented by open-ended problem-solving questions designed to elicit divergent responses rather than single correct answers. The items required students to generate multiple relevant ideas (fluency), propose unique or uncommon responses compared to peers (originality), apply varied solution strategies (flexibility), and provide detailed and coherent explanations (elaboration). A scoring rubric was constructed analytically, with explicit performance descriptors for each indicator to ensure objective and consistent assessment. The rubric specified scoring criteria ranging from low to high levels of performance, including the number of ideas generated, the rarity of responses, the diversity of approaches used, and the depth and clarity of explanation. The development of the items and rubric was aligned with the theoretical framework of creative thinking derived from divergent thinking theory, ensuring conceptual consistency between the assessment design and the underlying construct being measured. The stages of the study followed the five phases of the ADDIE model, as described below.

Analyze

The initial stage aimed to identify and analyze learning needs in the field. A preliminary study was carried out through observations and interviews with teachers and students to determine the actual conditions of physics learning, particularly the extent of students'

engagement in creative and collaborative thinking activities. Additionally, a literature review was conducted to examine the concepts of guided inquiry, ESW, creative thinking skills, collaboration skills, and relevant previous studies.

Design

Based on the analysis results, the researcher began designing the initial draft of the guided inquiry–based ESW. At this stage, test blueprints were also developed for the research instruments, including the creative thinking skills test and the collaboration skills observation sheet (Table 1 and Table 2). Furthermore, product and instrument validation sheets were prepared to assess the feasibility of the ESW in terms of content, construct, visual presentation, and language.

Table 1. Indicators for creative thinking skills tests

Nu	Indicators	Description	Test Number
1	Fluency	Presenting various possible answers and generating more than one alternative solution by compiling a list of ideas relevant to a theme or problem.	1
2	Flexibility	Identifying various approaches to solving problems, devising unconventional solutions, and classifying ideas or solutions according to different categories.	2
3	Originality	Developing answers or solutions that are not commonly used, devising new approaches that differ from the usual methods, and presenting unusual but logical arguments or opinions.	3
4	Elaboration	Explain ideas completely and systematically, add detailed explanations or descriptions to the main ideas, and organize complex and structured ideas.	4

Table 2. Collaboration skills observation sheet indicators

Nu	Collaboration Skills Aspects	Indicators
1	Contribute actively	Contribute to presenting
		Synthesize discussion results
		Seek solutions to problems
2	Work productively	Actively participate in discussions
		Complete tasks effectively and efficiently
		Focus on discussing solutions
		Communicate smoothly during discussions
3	Demonstrating a sense of responsibility	Be responsible for assigned tasks
		Complete tasks on time
		Follow instructions
4	Demonstrating flexibility and compromise	Accept criticism and suggestions
		Discuss differences of opinion
		Accept assigned tasks
5	Showing mutual respect	Respect and honor the opinions of others in the forum
		Not imposing opinions
		Accepting joint decisions in problem solving

Development

At this stage, the initial version of the ESW (prototype) was developed based on the previously designed framework. The product was subsequently validated by four senior high school physics teachers who possess expertise in physics instruction and classroom assessment. The validators were selected based on the following criteria: (1) a minimum of five years of teaching experience at the senior high school level, (2) demonstrated experience in developing instructional materials and assessment instruments, and (3) active involvement in curriculum implementation. The validation process focused on evaluating the feasibility of the content, visual presentation, and language clarity. Based on the feedback and recommendations provided by the validators, necessary revisions were made to refine the product before proceeding to the field-testing phase.

Implementation

The revised ESW was then implemented in the physics learning process in the classroom. The purpose of this stage was to observe the use of the guided inquiry–based ESW in real learning situations and to evaluate its effectiveness in improving students' creative thinking skills and collaboration skills. The learning activities were carried out by the teacher under the guidance of the researcher, and data were collected using the previously prepared instruments.

Evaluation

Evaluation was conducted to measure the effectiveness of the product. The data collected during the implementation stage were analyzed to determine the extent to which the use of the ESW improved students' creative thinking abilities and collaboration skills. Overall, the research procedure is illustrated in the Figure 1.

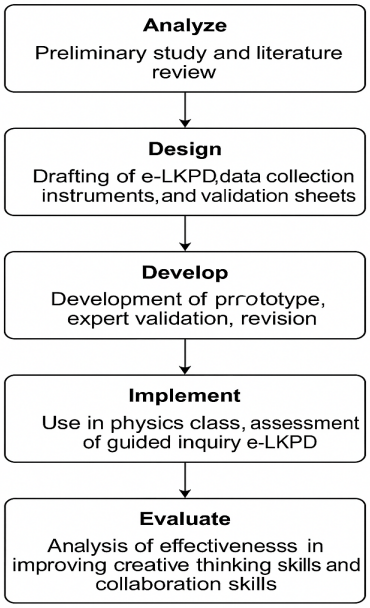

Figure 1. Research flowchart

Percentage calculations use the following formula 1 and the results were then classified based on the criteria in Table 3.

$$\%\text{validation} = \frac{Total\ Score}{Maximum\ Score}\ x\ 100\% \quad (1)$$

Table 3. Percentage of validation assessment

Percentage (%)	Valid Category	Eligible Category
0-25	Invalid	Not Eligible
26-50	Less Valid	Less Eligible
51-75	Valid	Eligible
76-100	Very Valid	Very Eligible

Although a percentage threshold of ≥51% may appear relatively moderate, this criterion was adopted based on the categorical feasibility interpretation framework commonly used in educational development research, in which scores above 50% indicate that an instrument meets the minimum acceptability standard and can be classified as "adequately valid" or "feasible with revision." It is important to note that this cut-off does not imply that the instrument is fully valid; rather, it indicates that the instrument satisfies the minimum content and construct alignment requirements to proceed to revision and limited field testing. In practice, instruments falling within the 51–75% range are subjected to revision based on expert feedback before further implementation. Moreover, the final decision regarding feasibility was not based solely on percentage scores but was also supported by qualitative feedback from validators, ensuring that the validation process remained rigorous and iterative rather than merely numerical. Therefore, the ≥51% threshold functioned as an initial eligibility benchmark rather than a definitive indicator of high validity.

To determine the magnitude of the intervention effect, the effect size was calculated using Cohen's d. Cohen's d measures the standardized difference between two means, allowing the researcher to evaluate the practical significance of the treatment beyond statistical significance. In this study, Cohen's d was computed by subtracting the pretest mean score from the posttest mean score and dividing the result by the pooled standard deviation, as expressed in Formula 2 and interpretation of effect size mark following Table 4.

$$effect\ Size\ Cohen'sf = \sqrt{\frac{\eta^2}{1-\eta^2}} \quad (2)$$

Where, η^2 is partial eta squared.

Table 4. Interpretation of effect sizes (Cohen, 1988).

Cohen's d	Category
0.00 ≤ ES ≤ 0.20	Very Small
0.20 ≤ ES ≤ 0.50	Small
0.50 ≤ ES ≤ 0.80	Moderate
0.80 ≤ ES ≤ 1.30	Large
1.30 ≤ ES	Very large

RESULTS AND DISCUSSION

Results

At this stage, product feasibility testing and instrument validity testing were conducted to ensure that the developed learning media and assessment tools meet appropriate quality standards and are suitable for use in the learning process. The product feasibility test was carried out by expert validators with relevant expertise, while the validity test

focused on the creative thinking assessment items used in this study. The results of the validators' assessments were analyzed in the form of percentages and categorized based on predetermined criteria to determine their level of feasibility and validity. A summary of the product feasibility test results and the validity test of creative thinking questions is presented in Table 5 and Table 6.

Table 5. Product feasibility test results

Validator	Percentage (%)	Category
1	67	eligible
2	72	eligible
3	72	eligible
4	80	very eligible
Average	72.75	eligible

Table 6. Results of the validity test for creative thinking questions

Validator	Percentage (%)	Category
1	70	valid
2	70	valid
3	70	valid
4	75	very valid
Average	71.25	valid

Table 6 presents the results of the validation of the creative thinking skills test instrument by four validators. The average validity score is 71.25%, which falls into the 'Valid' category. This indicates that the instrument is appropriate for measuring students' creative thinking skills.

Table 7. Validation results of the collaboration skills observation sheet

Validator	Percentage (%)	Category
1	65	valid
2	65	valid
3	70	valid
4	65	valid
Average	66.25	valid

Table 7 shows the results of the collaboration skills observation sheet validation. All validators gave scores in the "Valid" category, with an average of 66.25%, indicating that the instrument can be used to observe students' collaboration skills. Before conducting the hypothesis test, an assumption test in the form of a normality test was first carried out. The normality test results for the pretest and posttest data are presented in Table 8.

Table 8. Results of normality test (Shapiro Wilk)

Variable	Sig.	Variable	Sig.
Pre-test on creative thinking skills	0.135	Collaboration skills pretest	0.299
Post-test on creative thinking skills	0.224	Collaboration skills posttest	0.203

The significance values (Sig.) of both the pretest and posttest are greater than 0.05, indicating that the data are normally distributed. This means that the data meet the assumptions required for parametric statistical analysis (t-test).

Table 9. T-test results for creative thinking skills variable

Variable	Min	Max	Mean	N	Std. deviation	Sig.	Cohen's d
Pre-test	1.987	4.788	3.3333	30	3.3475	0.000	1.08
Post-test	5.333	8.998	6.9667	30			

There is a significant increase in creative thinking scores before and after the use of the ESW (Sig. = 0.000 < 0.05). The Cohen's d value of 1.08 indicates a large effect size, meaning that the use of the ESW has a strong impact on improving students' creative thinking skills (Table 9). This can be seen more clearly in the graph in Figure 2.

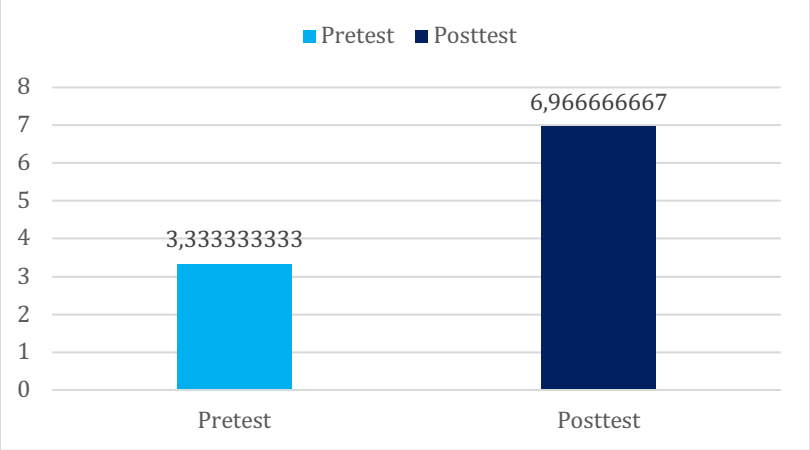

Figure 2. Average creative thinking skills scores on the pretest and posttest

Table 10. T-test results for collaboration skills variable

Variable	Min	Max	Mean	N	Std. Deviation	Sig.	Cohen's d
Pretest	9.72	14.56	12.833	30	2.357	0.000	1.44
Postest	14.47	19.98	16.233	30			

There was a significant improvement in students' collaboration skills (Sig. = 0.000 < 0.05). The Cohen's d value of 1.44 falls into the category of a very large effect, indicating that the guided-inquiry-based ESW had a strong impact on enhancing students' collaboration skills (Table 10). This can be seen more clearly in the graph in Figure 3.

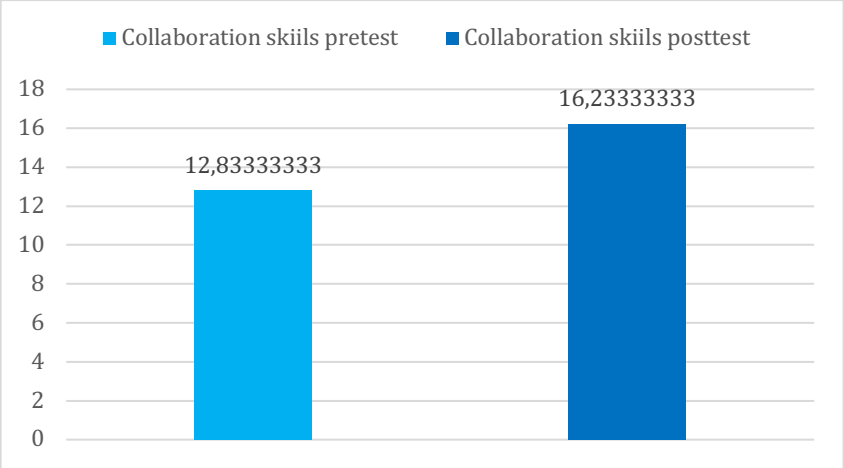

Figure 3. Average collaboration skills scores before and after

Discussion

The validation results indicate that the guided-inquiry-based ESW obtained an average feasibility score of 72.75%, categorized as "Feasible." This suggests that the content, visual design, and linguistic components generally align with digital learning media standards. These findings are consistent with Elvanuari et al. (2024) and Juliana et al. (2024), who emphasize that pedagogically structured ESW supports effective and independent learning. However, the validation process also revealed several areas for improvement, particularly in the clarity of certain investigative instructions and the consistency of visual layout across sections. These limitations were addressed through revision before implementation, yet they indicate that further refinement—especially in user-interface coherence and adaptive feedback features—could enhance future iterations of the ESW. Thus, while the product is feasible, continuous development remains necessary to optimize its quality.

With validated instruments, the effectiveness analysis showed that creative thinking improved from 3.33 to 6.97, with an effect size of 1.08, indicating a large effect. Guided inquiry requires students to formulate problems, propose hypotheses, conduct investigations, and draw conclusions independently. This aligns with Kansoy & Çıbık (2022), who found that guided inquiry enhances higher-order thinking through active investigation. From a constructivist perspective, this improvement can be explained by the process of knowledge construction through scaffolding and cognitive conflict resolution. The structured inquiry phases embedded in the ESW provide scaffolding that gradually transfers responsibility to learners, while reflective prompts stimulate metacognitive engagement. These mechanisms encourage students to generate diverse ideas, reconsider alternative solutions, and elaborate reasoning, thereby strengthening fluency, flexibility, originality, and elaboration. Similarly, Fadilah et al. (2024) reported that interactive ESW enhances creativity by offering structured yet flexible exploration opportunities. Hence, the observed improvement reflects both pedagogical structure and cognitive engagement processes inherent in guided inquiry.

The ESW also significantly improved collaboration skills, increasing from 12.83 to 16.23, with an effect size of 1.44 (very large). The ESW facilitated collaboration through structured group investigations, task division, and collective verification of findings. This finding supports Huang & Ochoa (2025) and Owolade et al. (2022), who emphasize that

inquiry-based digital learning strengthens coordinated interaction and shared meaning-making. However, collaboration in classroom settings is rarely uniform. Variations such as dominant members and passive participants were observed during implementation. The ESW design attempted to address this issue by assigning explicit roles within each inquiry phase (e.g., hypothesis formulator, data recorder, presenter) and incorporating reflection prompts that required input from all group members. Although this structure encouraged more balanced participation, differences in individual engagement levels may still have influenced outcomes.

When connected with previous studies, the findings reinforce existing evidence while offering a clearer contribution. Syar et al. (2023) and Elvanuari et al. (2024) reported that digital learning enhances independence and collaborative skills. and Molla et al. (2023) highlighted the importance of investigation-based learning for 21st-century competencies. The novelty of this study lies in the integrated design of a digital ESW that systematically embeds guided inquiry phases to simultaneously enhance two major competencies—creative thinking and collaboration within a single instructional framework. Unlike prior studies that examined these skills separately or applied digital worksheets without structured inquiry integration, this research demonstrates a dual-impact effect supported by large effect sizes in both domains.

Despite these promising results, several limitations must be acknowledged. First, the use of a one-group pretest–posttest design limits causal inference due to the absence of a comparison group. Second, the relatively small sample size (30 students) restricts generalizability. Third, the intervention was conducted over a short duration, which may not fully capture long-term skill development. Future research should involve larger samples, control-group designs, and extended implementation periods to strengthen external validity and causal claims. Overall, the findings indicate that the developed ESW is feasible and highly effective in enhancing creative thinking and collaboration in physics learning. At the same time, acknowledging measurement, participation variability, and design limitations enhances the credibility and transparency of the study while providing direction for further refinement and research expansion.

CONCLUSION

This study concludes that the guided-inquiry-based Electronic Student Worksheets (ESW) developed in this research are categorized as feasible and valid as a digital learning tool, and it is effective in enhancing students' creativity and collaboration skills. The increase in creativity from 3.33 to 6.97 and in collaboration from 12.83 to 16.23, with effect sizes of 1.08 and 1.44 respectively, demonstrates that integrating the inquiry model with ESW significantly facilitates higher-order thinking processes and structured group collaboration. These findings affirm that the guided-inquiry-based ESW can be implemented as a learning medium aligned with the demands of the Kurikulum Merdeka and the development of 21st-century competencies. However, this research have several **limitations** namely (1) The use of a one-group pretest–posttest design without a control group limits the strength of causal inference; (2) The relatively small sample size and short intervention duration also restrict the generalizability and long-term interpretation of the findings; (3) Collaboration skills were assessed through observation, which may involve a degree of subjectivity despite the use of structured rubrics. **The implications** of this study are both theoretical and practical. Theoretically,

it strengthens the integration of guided inquiry and digital learning media within a constructivist framework to support dual competency development—creativity and collaboration. Practically, the developed ESW can serve as a reference model for teachers seeking to implement structured inquiry learning in digital formats, particularly within the Kurikulum Merdeka context. At the policy level, the findings highlight the importance of supporting teacher training and digital infrastructure to maximize the effectiveness of technology-based inquiry learning. Future research is **recommended** to employ experimental designs with control groups, involve larger and more diverse samples, and implement longer intervention periods to examine sustained effects. Further studies may also explore the integration of adaptive feedback systems or learning analytics within ESW to enhance individualized scaffolding and more objective measurement of collaborative processes.

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