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Improving Scientific Thinking Skills Through a Value-Based Mobile Seamless Learning Model: A Quasi-Experimental Study in Physics Education

Isa Iskandar[1], Mustaji[2], Andi Mariono[3], Fajar Arianto[4]

[1,2,3,4] Educational Technology Study Program, Faculty of Educational Sciences, Surabaya State University, Surabaya

Correspondence: Fajar Arianto, Educational Technology Study Program, Faculty of Educational Sciences, Surabaya State University, Surabaya. E-mail: fajararianto@unesa.ac.id

Abstract
This study investigated the effectiveness of the iSCan learning model combined with Mobile Seamless Learning (MSL) in improving students' scientific thinking skills on static and dynamic fluid topics. A quantitative approach using a quasi-experimental pretest–posttest control group design was applied. The study involved 102 eleventh-grade students at SMA Muhammadiyah 10 GKB, Gresik, who were randomly assigned to an experimental group ($n = 51$) and a control group ($n = 51$). The experimental group received instruction through the iSCan–MSL model across four seamless learning phases: informal, formal 1, formal 2, and combined formal–informal. The control group followed conventional instruction. Data were collected using a validated two-tier scientific thinking test, which had a content validity score of 90% and a reliability coefficient of Cronbach's $\alpha = 0.869$. The results showed a statistically significant improvement in scientific thinking skills for students in the iSCan–MSL group compared to the control group. These findings suggest that the continuous integration of value-based learning and mobile technology can effectively strengthen scientific reasoning and enhance student engagement in 21st-century physics learning.

Keywords: iSCan Model, Mobile Seamless Learning, Scientific Thinking Skills, Physics Education, Fluid Mechanics

1. Introduction

1.1 Introduce the Problem

The rapid changes in society and technology in the 21st century have gradually pushed education to rethink its traditional role. Schools can no longer stay focused only on delivering information, because students today need a broader set of abilities—especially critical thinking, creativity, collaboration, and communication—to deal with increasingly complex global issues (Utami et al., 2024; Zharylgapova et al., 2025). In reality, however, many physics classes, including those covering topics such as fluid mechanics, still rely heavily on teacher explanations and routine exercises. Learning tends to emphasize remembering formulas instead of helping students understand how scientific ideas actually work. Because of this, a number of students find it difficult to interpret abstract concepts, follow the mathematical reasoning behind them, or use these concepts to solve problems they encounter in daily life. Their scientific literacy and problem-solving skills naturally become limited. This condition shows that there is still a wide gap between what modern science education expects and what happens in many classrooms. Unless more innovative and flexible learning models are introduced, physics education will continue producing students who know the surface of the material but struggle to analyze or apply it in meaningful ways.

The situation described above does not simply call for recognizing the mismatch in current practice; it also requires researchers to offer practical ways to improve it. In recent years, learning models that blend values, technology, and student-driven inquiry have become more relevant, especially for classrooms that expect both academic progress and character formation. One possible direction is to connect value-based approaches with learning environments that allow students to move more freely across activities and contexts. Building on this idea, the present study integrates an Islamic value–oriented model (iSCan) with Mobile Seamless Learning (MSL) as a combined strategy to address the learning challenges identified earlier. Through this integration, the study seeks not only to strengthen students' conceptual understanding but also to encourage scientific habits of mind, ethical sensitivity, and sustained engagement in studying science. Such an approach is particularly suitable for educational settings where moral development and cognitive competence are viewed as complementary goals rather than separate concerns.

For these reasons, the present study focuses on examining how effective the iSCan–MSL model is in improving students' scientific thinking abilities within physics learning. At the heart of this inquiry is a simple but important question: can an integrative design like this address the weaknesses of conventional physics instruction, especially in fostering deeper conceptual understanding and more mature scientific reasoning? Should the model demonstrate clear benefits, it may serve as a realistic alternative for science classrooms that need to respond to both the cognitive demands and the learning contexts of 21st-century students. Such efforts are in line with broader international expectations that call for teaching approaches capable of nurturing scientifically literate learners who can think critically and make informed judgments.

1.2 Explore Importance of the Problem

The need to strengthen students' scientific thinking becomes even more apparent when we look closely at how fluid mechanics is taught in secondary physics courses. Topics such as pressure, buoyancy, and fluid flow deal with phenomena that cannot be observed directly, so students must rely on mental models, visualizations, and the ability to connect several abstract ideas at once. These processes are not easy to carry out without sufficient scaffolding or meaningful interaction during learning. When instruction does not provide room for inquiry, hands-on exploration, or contextual explanations, many students fall back on memorizing equations rather than understanding why those equations work. As a result, their grasp of the material tends to be shallow and easily breaks down when they are asked to solve problems or apply the concepts in unfamiliar situations.

The need for students to develop scientific thinking skills is even more visible when we examine current global issues. Many problems today, such as environmental degradation, technological change, and public debates related to science, require people who can understand evidence and make careful judgments. Students, therefore, must learn how to read information critically, check the reliability of data, and think about the wider impact of their decisions. These abilities are not only important for school learning but also for daily life. For this reason, developing scientific thinking has become a responsibility for the whole education system, not only for science teachers. Society now depends on individuals who are able to participate in solving problems and contribute to sustainable and healthy communities.

Based on this situation, the combination of a value-based learning approach, represented by the iSCan model, with the flexible structure of mobile seamless learning becomes very relevant. This combination offers two important advantages. It can make learning more meaningful because moral or religious values are included in ways that fit students' daily experiences. At the same time, it can improve learning effectiveness by using mobile technology to support continuous study inside and outside the classroom. Therefore, this research is not only useful for strengthening educational theory but also has practical value for science education, especially in settings where attention to values and the use of technology are both considered important.

1.3 Describe Relevant Scholarship

Several studies have shown that inquiry-based learning (IBL), especially when supported by technology or mobile devices, can help improve students' higher-order thinking skills and their scientific literacy. One meta-analysis, for example, reported that mobile-based inquiry learning produced a strong positive impact on students' creative thinking, with a high effect size and a very significant p-value ($p < 0.001$). This result suggests that using mobile technology within IBL can be an effective approach for developing students' cognitive abilities (Suyatmo et al., 2023). In the field of physics education, research that combines inquiry learning with virtual simulations, such as PhET, also shows better outcomes in higher-order thinking and conceptual understanding when compared to traditional classroom methods (Nasar et al., 2025).

Recent studies in physics education also show that guided inquiry, whether carried out through virtual activities, hybrid formats, or with the help of mobile media, can enhance students' science process skills, their understanding of concepts, and their critical thinking abilities (Fitriyana et al., 2025; S. Ida Kholida et al., 2025). The findings indicate that when learners take part actively by exploring phenomena, performing experiments—either real or simulated—and discussing the outcomes, their reasoning and problem-solving abilities tend to grow stronger. Their scientific literacy also increases. Overall, this body of research offers solid support for the idea that inquiry-based methods, when combined with technology and flexible learning conditions, can be effective strategies for improving science learning.

Even with the progress found in previous studies, there is still limited research that connects value-based frameworks, such as religious or moral orientations, with inquiry-based mobile learning in physics classes. Many investigations mainly discuss cognitive results, including thinking skills and understanding of concepts, while paying less attention to how value orientation may shape students' motivation, their ethical judgment in science, or the depth of their engagement in learning—especially in contexts that are influenced by certain cultural or religious backgrounds. This situation highlights the novelty of the present study. It seeks to examine whether the iSCan–MSL model can help students develop scientific thinking while also encouraging value-aware scientific inquiry in a way that fits the educational environment.

1.4 State Hypotheses and Their Correspondence to Research Design

Based on the theoretical rationale and empirical evidence presented, this study formulates the following hypotheses:
H1: Students who receive instruction through the iSCan–MSL model will demonstrate significantly higher scientific thinking skills compared to students who receive conventional physics instruction.
H2: Improvements in scientific thinking skills among students in the iSCan–MSL group will be mediated by enhanced continuity of learning across formal and informal contexts, increased active engagement, value-integrated inquiry, and the affordances of mobile learning that support flexible, contextual, and collaborative learning.

To test these hypotheses, this study employs a quasi-experimental pretest–posttest control group design, which enables rigorous comparisons between the experimental and control groups. This design provides a strong basis for inferring whether observed differences in scientific thinking can be attributed to the instructional model. If the hypotheses are supported, the findings will offer theoretical contributions by demonstrating how value-based, technology-enhanced inquiry learning can strengthen students' scientific reasoning. In addition, the results are expected to provide practical implications for physics education, particularly in settings where value orientations and modern pedagogical approaches intersect.

2. Method

2.1 Identify Subsections

This study employed a quantitative approach using a quasi-experimental method to investigate the effect of the iSCan–Mobile Seamless Learning (iSCan–MSL) model on students' scientific thinking skills in physics learning. A detailed description of the participants, instruments, research design, intervention procedures, and data analysis is provided to ensure methodological transparency and allow for replicability.

2.2 Participant (Subject) Characteristics

The study was conducted at SMA Muhammadiyah 10 GKB, Gresik, Indonesia, involving eleventh-grade students with an average age of 17 years. All participants were formally enrolled in physics courses during the academic year in which the study was implemented. No exclusion criteria were applied, and the students were assumed to possess relatively comparable prior knowledge of the physics topic. Participant involvement was supported by the school and carried out in regular classroom settings, with no incentives provided.

2.3 Sampling Procedures

A simple random sampling technique was used by mixing students from the two classes and then assigning them evenly to the experimental and control groups to reduce possible bias. In total, 102 students took part in the study, with 51 students in each group. The data were collected in the school setting under normal classroom supervision. Ethical approval was obtained from the school administration, and students participated voluntarily.

2.3.1 Sample Size, Power, and Precision

All 102 students in the population were taken as the sample so that the results would be more precise and fairly represent the group being studied. The experimental and control groups were kept equal in number ($n = 51$ for each group) to support a balanced comparison during analysis. Even so, the conclusions of this study should be understood as applying mainly to settings that share similar demographic and academic characteristics.

2.3.2 Measures and Covariates

The data in this study were collected through a questionnaire and a two-tier test designed to assess students' scientific thinking skills. These skills were evaluated using eight indicators. First, asking scientific questions or formulating problems, which refers to the ability to state questions that are clear, measurable, and testable (Darman et al., 2024). Second, formulating hypotheses and predictions, meaning the skill of proposing reasonable assumptions and anticipating possible outcomes of an experiment (Kalinowski & Pelakh, 2024). Third, designing experiments and controlling variables, which includes planning procedures to test a hypothesis and identifying independent, dependent, and control variables (Lawson, 1978). Fourth, measuring and collecting data, which covers choosing suitable tools, recording information systematically, and maintaining reliability and validity (Darman et al., 2024).

The fifth indicator is analyzing and interpreting data, referring to the use of quantitative or qualitative techniques to answer research questions and draw conclusions (Darman et al., 2024). Sixth, scientific reasoning, which involves probabilistic, proportional, and correlational reasoning such as comparing ratios, estimating probabilities, and distinguishing correlation from causation (Bao et al., 2018). Seventh, evaluating evidence and constructing arguments, meaning the ability to judge the strength of evidence, consider alternative explanations, and build arguments based on the claim–evidence–reasoning structure (Seeratan et al., 2020). (Darman et al., 2024). Student responses were scored using a four-point Likert scale, where 4 = very good, 3 = good, 2 = fair, and 1 = poor.

Table 1: Scientific Thinking Skills Indicator Matrix

No.	Indicators	Operational sub-indicators	Activity
1	Formulating scientific problems and questions	Identifying researchable phenomena, formulating measurable and testable questions	Students write a scientific question based on a phenomenon.
2	Forming hypotheses and predictions	Relating two variables and predicting experimental outcomes	Create a hypothesis based on the phenomenon and predict the outcome.
3	Planning experiments and controlling variables	Identifying independent, dependent, and control variables and determining experimental steps	Design a simple experimental step.
4	Conducting measurements and collecting data	Determining measuring instruments, units, recording methods, and data reliability	Fill in a data table of experimental results using the correct format.
5	Analyzing and interpreting data	Processing data into graphs/tables and drawing logical conclusions	Create a graph of the relationship between variables and a brief conclusion.
6	Evaluating scientific evidence and arguments	Determining the validity of evidence and writing data-based arguments (claim-evidence-reasoning)	Analyze a claim and provide reasons based on the data.
7	Representing and communicating scientific results	Preparing reports or presentations of experimental results	Write a scientific report or poster.
8	Reflecting and developing scientific attitudes	Identifying experimental limitations and suggesting improvements	Write a reflection after the experiment.

Table 2: Practical Assignment Assessment Rubric (Scientific Thinking Rubric)

No.	Indicators	Score			
		4	3	2	1
1	Formulating scientific problems and questions	Clear, specific, and scientifically testable questions	The question is quite clear, but still general.	Vague and difficult-to-test questions	Not writing a question / irrelevant
2	Forming hypotheses and predictions	Logical, theory-based hypotheses with measurable predictions	The hypothesis is logical, but the predictions are not measurable.	Hypotheses not based on data/facts	Not writing a hypothesis
3	Planning experiments and controlling variables	All variables are identified, and the design is realistic and controlled	Some variables are identified.	Illogical design/unclear variables	Not writing an experimental design
4	Conducting measurements and collecting data	Data is complete, organized, and uses correct units	The data is quite complete but not organized.	Incomplete data/many errors	Not taking measurements
5	Analyzing and interpreting data	Uses graphs/tables, and interpretations are based on the data	There is a simple analysis, but it is not in-depth.	Inaccurate analysis	Not doing analysis
6	Evaluating scientific evidence and arguments	Strong arguments with concrete evidence	The argument is logical, but the evidence is not strong enough.	Weak arguments/lack of evidence	Not providing arguments
7	Representing and communicating scientific results	Complete report (objectives, methods, results, and discussion)	The report is quite complete, but the analysis is lacking.	Minimal and unsystematic reporting	Not submitting a report
8	Reflecting and developing scientific attitudes	Demonstrates self-awareness and suggests	Only mentions general shortcomings.	Irrelevant reflections	No reflection

	improvements to the experiment	

Table 3: Distribution of Static and Dynamic Fluid Two Tier Test Instruments

No.	Main Aspects	Tested
1 – 4	Formulating questions/phenomena and hypotheses	Questioning, prediction
5 – 9	Experimental design and variable control	Experimental design
10 – 13	Data measurement and collection	Experimental practice
14 – 17	Data analysis and interpretation	Graphs, variable relationships
18 – 19	Evaluating evidence and arguments	Claim-evidence reasoning
20	Scientific reflection	Metacognition/scientific attitude

The scientific thinking questionnaire was first reviewed by an expert to assess its content validity. The evaluation produced a Product Score Validity (PSV) of 90%, indicating that the instrument was highly appropriate for use. The scientific thinking test, consisting of 20 two-tier questions, was then examined for construct validity. Table 4 summarizes the item-validity results based on Pearson's correlation, while Table 5 reports the reliability findings using Cronbach's Alpha. Using a sample of 30 students, the critical r-value at the 0.05 significance level (two-tailed) was 0.312. Items with correlation values above 0.361 were considered valid. The analysis showed that all 20 items exceeded this threshold, and the reliability coefficient of $\alpha = 0.869$ indicated strong internal consistency. On this basis, the entire set of items was judged to be both valid and reliable.

Table 4: Validity of Test Items

Item	Value	Validation
1	0.380	Valid
2	0.487	Valid
3	0.602	Valid
4	0.688	Valid
5	0.687	Valid
6	0.395	Valid
7	0.665	Valid
8	0.436	Valid
9	0.553	Valid
10	0.610	Valid
11	0.438	Valid
12	0.487	Valid
13	0.391	Valid
14	0.599	Valid
15	0.639	Valid
16	0.378	Valid
17	0.665	Valid
18	0.436	Valid
19	0.389	Valid
20	0.696	Valid

Table 5: Reliability of Test Items

Reliability Statistics	
Cronbach's Alpha	N of Items
.869	20

The data in this study were analyzed using an independent samples t-test. This procedure was applied to examine whether the average scores of the two groups differed significantly—the group taught with the iSCan–MSL model and the group that received conventional instruction. Prior to running the t-test, two assumptions were checked:

(1) the distribution of the data had to meet normality requirements, and (2) the variances of the groups needed to be homogeneous. After both conditions were confirmed, the independent samples t-test was carried out to compare the performance of the two groups.

2.3.3 Research Design

This study used a quantitative approach with a quasi-experimental design to examine the influence of the iSCan learning model on students' scientific thinking skills. A pretest–posttest control group design was applied. The overall design is summarized in Table 1, which shows the division between the experimental and control groups. Students in the experimental group learned through the iSCan–MSL model, while those in the control group followed conventional instruction that did not include the iSCan–MSL components. Learning in the experimental group was carried out across four seamless learning stages: an informal stage, followed by formal stage 1, formal stage 2, and a final stage that combined formal and informal activities. The intervention was implemented through physics practicum sessions centered on the topics of static and dynamic fluids.

Table 6: Research Design

Group	Pretest	Treatment	Postest
A_1	O_1	X	O_2
A_2	O_3	--	O_4

Description:
A1: Experimental group that participated in learning activities using the iSCan–MSL model
A2: Control group that participated in learning activities without the iSCan–MSL model
O1: Pretest administered to the experimental group before the learning activities
O2: Posttest administered to the experimental group after the learning activities
O3: Pretest administered to the control group before the learning activities
O4: Posttest administered to the control group after the learning activities
X: Treatment administered to the experimental group using the iSCan–MSL model
— : No treatment administered to the control group (conventional learning only)

2.3.4 Experimental Manipulations or Interventions

The iSCan–MSL model was applied to the experimental group over four weekly meetings, with each session lasting 90 minutes. The instruction followed four seamless learning phases:
(a) an informal learning stage,
(b) formal phase 1,
(c) formal phase 2, and
(d) a final stage that combined formal and informal activities.
Across these phases, students engaged in experiments, problem-solving tasks, and group discussions, all supported by mobile devices. In contrast, the control group learned through conventional direct instruction, which relied on teacher explanations, PowerPoint slides, and individual practice tasks, without any seamless learning components.

The intervention was designed to strengthen scientific thinking processes, while both groups covered the same physics content and received equal instructional time.

3. Results

This section reports the analysis of students' scientific thinking skills based on the pretest and posttest results from both the experimental group (iSCan–MSL) and the control group. All statistical procedures were carried out after confirming that the data met the normality and homogeneity requirements, ensuring that the findings could be interpreted appropriately.

3.1 Recruitment

The recruitment and data collection took place over four consecutive weeks, in line with the implementation of the intervention. All 102 eleventh-grade students who were eligible took part in the study and completed both the pretest and posttest assessments.

3.2 Statistics and Data Analysis

After all research activities were finished and the data had been collected, the dataset was checked first for normality and homogeneity before running the t-test. Both the practicum and written pretest–posttest scores were included in these checks to make sure the data met the required assumptions. The pretest scores were used to identify the initial scientific thinking abilities of students in each group and to verify that both groups started from comparable baseline levels. The posttest scores, on the other hand, were used to assess students' scientific thinking skills after the learning activities were completed.

Table 7: Results of the Normality Test of the Scientific Thinking Pretest

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Test	iSCan-MSL	.111	51	.158	.955	51	.052
	Non-iSCan-MSL	.108	51	.196	.966	51	.148
Practical	iSCan-MSL	.083	51	.200*	.979	51	.503
	Non-iSCan-MSL	.107	51	.200*	.969	51	.210

Table 8: Results of the Homogeneity Test of the Scientific Thinking Pretest

	Levene Statistic	df1	df2	Sig.
Test	.060	1	100	.807
Practical	1.614	1	100	.207

Table 9: Independent Sample t-test Scientific Thinking Pretest

	Group	N	Mean	SD	t	df	p
Test	iSCan-MSL	51	29.41	9.625	-.306	100	.760
	Non-iSCan-MSL	51	30.00	9.798			
Practical	iSCan-MSL	51	32.7451	6.60028	-.347	100	.729
	Non-iSCan-MSL	51	33.2353	7.62060			

Based on the pretest results for students' scientific thinking skills, the normality test in Table 7 showed Sig. = .158 > .050 for the iSCan–MSL group and Sig. = .196 > .050 for the Non-iSCan–MSL group. The homogeneity test also produced a Sig. value of .807 > .050. These results indicate that the pretest data were both normally distributed and homogeneous. A similar pattern was found in the practicum pretest results. The normality tests for both the iSCan–MSL and Non-iSCan–MSL groups were Sig. = .200 > .050, and the homogeneity test showed Sig. = .207 > .050. Thus, the practicum pretest data also satisfied the normality and homogeneity assumptions.

After confirming that the data met the required assumptions, an independent samples t-test was carried out. The written post-test results showed that students who learned through the iSCan–MSL model reached an average score of 83.92, while those in the conventional group scored 79.92. The p-value of .048 < .050 indicates that the difference between the two groups was statistically significant. For the practicum post-test, the iSCan–MSL group obtained a mean of 82.74, compared with 73.43 in the group that did not use the model. The p-value of .000 < .050 also shows a significant effect of the iSCan–MSL model on students' scientific thinking skills..

Table 10: Results of the Normality Test for the Scientific Thinking Post-Test

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.

Test	iSCan-MSL	.114	51	.093	.958	51	.072
	Non-iSCan-MSL	.109	51	.183	.963	51	.111
Practical	iSCan-MSL	.103	51	.200*	.978	51	.457
	Non-iSCan-MSL	.103	51	.200*	.970	51	.219

Table 11: Results of the Homogeneity Test of the Scientific Thinking Post-Test

	Levene Statistic	df1	df2	Sig.
Test	.000	1	100	.990
Practical	1.846	1	100	.177

Table 12: Independent Sample t-test Posttest Scientific Thinking

	Group	N	Mean	SD	t	df	p
Test	iSCan-MSL	51	83.92	10.311	2.000	100	.048
	Non-iSCan-MSL	51	79.80	10.486	2.000	99.972	.048
Practical	iSCan-MSL	51	82.7451	6.78703	6.474	100	.000
	Non-iSCan-MSL	51	73.4314	7.71299			

The post-test normality results in Table 10 show that the written test scores from the group that learned using the iSCan–MSL model had a Sig. value of .093, which is higher than the .050 threshold. The group taught without iSCan–MSL also met the normality requirement, with a Sig. value of .183. The homogeneity test for the written assessment produced a Sig. value of .990, indicating that the variances between the two groups were similar. For the practicum scores, both the iSCan–MSL and Non-iSCan–MSL groups obtained a Sig. value of .200 in the normality test, again exceeding the .050 cutoff. The homogeneity test resulted in a Sig. value of .177. Taken together, these findings confirm that the practicum post-test data were normally distributed and had homogeneous variances, so they met the assumptions required for further statistical analysis.

After verifying that all assumptions were met, an independent samples t-test was conducted. The written post-test scores showed that students who learned through the iSCan–MSL model achieved an average of 83.92, compared with 79.92 in the group taught conventionally. With a p-value of .048, which is below the .050 threshold, this difference was statistically significant. For the practicum post-test, students in the iSCan–MSL group obtained a mean score of 82.74, while the group that did not use the model scored 73.43. The p-value of .000 further confirms that the iSCan–MSL model had a significant positive effect on students' scientific thinking skills.

3.3 Ancillary Analyses

No additional subgroup or exploratory analyses were conducted beyond the primary statistical procedures.

3.4 Participant Flow

A total of 102 students participated in the study and were randomly assigned to two groups, with 51 students in the experimental group and 51 in the control group. Throughout the intervention, no students dropped out or moved between groups. As a result, all participants' data were included in the main analyses.

3.5 Intervention or Manipulation Fidelity

For studies involving interventions or experimental manipulations, it is important to show that the procedures were carried out as planned. In basic experimental research, this could include results from manipulation checks. In applied research, it might involve keeping records and observations of intervention sessions, as well as tracking attendance to ensure that all planned activities were delivered to the participants as intended.

3.6 Baseline Data

At the baseline, students in both groups had similar demographic and academic characteristics. All participants were eleventh-grade students from the same school (SMA Muhammadiyah 10 GKB, Gresik, Indonesia), with an average age of 17 years, and were enrolled in the same physics curriculum during the study period. These similarities helped ensure that both groups experienced comparable school environments, instructional conditions, and curriculum exposure before the intervention. Before the treatment, both groups showed limited scientific thinking skills. As discussed in the introduction, traditional teacher-centered instruction in physics—particularly in abstract topics like fluid mechanics—often leads to difficulties in understanding concepts, applying scientific reasoning, and solving real-world problems. This situation was reflected in the pre-intervention data, showing that students initially tended to rely more on memorization than on inquiry-based reasoning.

The pretest results further confirmed that the two groups were equivalent. Statistical tests showed no significant difference in the initial scientific thinking skills between the experimental group (M = 29.41) and the control group (M = 30.00) for the written assessment ($p = .760 > .050$). Similarly, practicum pretest scores were comparable, with the experimental group scoring M = 32.74 and the control group M = 33.23 ($p = .729 > .050$). Both sets of data met the assumptions of normality and homogeneity, suggesting that any improvements observed after the intervention could be attributed to the instructional model rather than pre-existing differences in skill. Overall, these baseline characteristics support a valid comparison between the experimental and control groups. The data also show that before the iSCan–MSL intervention, both groups had similarly low levels of scientific reasoning and had not yet experienced inquiry-based, value-integrated, or technology-supported learning strategies, highlighting the need and relevance of the intervention applied in this study.

3.6.1 Statistics and Data Analysis

Pretest scores were used to check whether the scientific thinking skills of the two groups were comparable at the start. The normality test (Table 7) showed Sig. = .158 > .050 for the iSCan–MSL group and Sig. = .196 > .050 for the control group. The homogeneity test gave a Sig. value of .807 > .050. Practicum scores also showed normal and homogeneous distributions, with Sig. = .200 > .050 for both groups and homogeneity Sig. = .207 > .050. An independent samples t-test (Table 9) showed no significant differences between the experimental and control groups for both the written test scores (M = 29.41 vs. 30.00; $p = .760 > .050$) and the practicum scores (M = 32.74 vs. 33.23; $p = .729 > .050$). These results confirm that the two groups had similar scientific thinking skills before the intervention.

3.6.2 Adverse Events

No adverse events or disruptions were reported during the intervention or data collection process.

4. Discussion

In this study, students who learned through the iScan Mobile Seamless Learning (iSCan–MSL) model achieved a higher average post-test score (M = 83.92) on the written scientific thinking assessment than those in the conventional group (M = 79.92), and the difference was statistically significant ($p = .048 < .05$). This finding is consistent with earlier studies showing that technology-supported seamless learning environments can improve physics learning outcomes. For example, Abdullah (2024) reported that implementing a seamless learning strategy positively affected achievement in basic physics courses. Similarly Asmiliyah et al. (2021) found that mobile learning combined with a STEM approach effectively enhanced students' critical thinking skills in physics. These results suggest that the “Search” and “Active” stages in the iSCan–MSL model—which encourage exploration, inquiry, and continuous engagement—may play a key role in improving students' performance on written scientific thinking assessments.

The practicum results showed that students in the iSCan–MSL group scored an average of 82.74, compared with 73.43 in the control group, with a highly significant p-value of .000 (< .05). This suggests that the iSCan–MSL model improves not only written assessment performance but also students' scientific practice skills. This finding aligns with previous studies indicating that mobile media combined with active learning approaches can enhance higher-order thinking skills (HOTS) and scientific reasoning in physics. For instance, Priatna et al. (2025) reported significant gains in students' HOTS through Android-based physics learning media. The "Creative" and "Network" elements of the iSCan–MSL model may support these improvements by promoting collaborative knowledge construction and creative exploration, which directly strengthen students' abilities in laboratory and experimental tasks.

In addition, the religious aspect within the "Islamic" component of the iSCan–MSL model seems to provide meaningful context and enhance students' internal motivation. Although studies combining religious values specifically with physics learning are limited, Muzaidin et al. (2025) found that integrating technology in Islamic education improved students' cognition and critical thinking. Similarly, Husain et al. (2024) reported that e-learning media incorporating religious contexts can enhance both cognitive processing and learning motivation from a neuroscience perspective. Therefore, the Islamic element in the iSCan–MSL model likely supports greater student engagement and deeper conceptual understanding, which in turn helps develop scientific thinking skills.

Moreover, the findings suggest that the iSCan–MSL model has a greater impact on practical skills than on written assessments, with a difference of about 9.31 points compared to roughly 4 points. This implies that mobile, seamless, active, and collaborative learning is particularly effective for supporting practical or experimental activities, rather than relying only on written instruction. Supporting this, Anggraini et al. (2024) reported that student worksheets assisted by augmented reality significantly improved students' critical thinking skills in high school physics. Therefore, the iSCan–MSL model, with its strong emphasis on the "Active" and "Search" stages, appears well-suited for developing scientific thinking skills through hands-on practice and interactive learning.

Finally, the results of this study show that the iSCan–MSL model is a promising approach for teaching physics, as it can enhance scientific thinking across both conceptual understanding (written assessments) and practical skills (laboratory performance). These findings also highlight the importance of learning designs that are contextually meaningful, active, collaborative, and seamless. This is consistent with the seamless learning framework, which emphasizes that flexibility and continuity in learning support students' cognitive development (Roshonah et al., 2022). However, this study has some limitations, including the sample size, the duration of the intervention, and variations in student characteristics. Future research should address these factors to improve the generalizability of the findings and to build on the current results.

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