Enhancing Media Literacy, Academic Achievement, and Engagement in Primary Education through ICT-Supported Critical Thinking Pedagogy

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***Abstract*—Despite the growing integration of digital technologies in education, their impact on primary students' media literacy, academic achievement, and engagement remains underexplored. The main objective of the study is to assess the effectiveness of Information and Communication Technologies (ICT)-supported critical thinking pedagogy in enhancing media literacy, academic achievement, and engagement among primary school students. The study involved 106 primary school students. The experimental group was taught using ICT-based critical thinking pedagogy over 12 weeks. Assessment included a media literacy test, an engagement questionnaire, classroom observations, analysis of academic performance in Natural Science, and evaluation of the effectiveness of digital tools. The experimental group showed a statistically significant increase in media literacy (Cronbach's $\alpha = 0.82$), engagement, and academic achievement compared to the control group. Specifically, media literacy improved by +17.6 points ($p < 0.001$), and engagement increased by +1.1 points ($p < 0.001$), while the control group's gains were +3.5 and +0.3, respectively. An increase in academic achievement in Natural Science was also observed ($\Delta = +13.6$, $p < 0.001$). Observations of learning activities and digital tool use confirmed more active and critical participation of students in the experimental group. The results demonstrate that ICT pedagogy focused on critical thinking effectively improves students' media literacy, academic performance, and engagement. This study highlights its potential to inform curriculum design and teaching strategies, providing valuable insights for enhancing learning outcomes in primary education.**

***Keywords*—academic achievement, engagement, enhancing, Information and Communication Technologies (ICT)-supported critical thinking pedagogy, media literacy, primary education**

I. Introduction

The United Nations Educational, Scientific and Cultural Organization United Nations Educational, Scientific and Cultural Organization (UNESCO) has identified media education as a key area of cultural and pedagogical development in the 21st century [1, 2]. In today's society, media education goes beyond merely acquiring skills for working with media and information—such as searching, processing, and analyzing information using digital technologies [3–6]. It also plays a crucial role in fostering a well-rounded personality that is resilient to external influences and pressures. Media education is a pedagogical process aimed at building media literacy skills through Information and Communication Technologies (ICT)-supported critical thinking pedagogy, emphasizing critical thinking and the ability to analyze information from multiple perspectives [7, 8]. The ultimate goal is to develop an understanding of media texts and the nature of communication.

Modern students face increasing demands to develop skills in analyzing, evaluating, and conveying information [9–11]. The Convention on the Rights of the Child affirms the right to receive instruction in media literacy [12]. As the main educational environment for children, schools provide equal opportunities to acquire media literacy [13, 14].

Extensive research confirms the importance of integrating Information and Communication Technologies (ICT) into education to enhance media literacy among primary students [15–17]. Furthermore, studies focused on fostering critical thinking demonstrate that such approaches help students engage with information consciously and deliberately [18].

Recent research shows that digital technologies effectively develop critical thinking and media literacy in primary education. For example, McKnight *et al.* [19] found that teachers and administrators actively use ICT tools, which increase student engagement and benefit learning. Similarly, Soriano-Sánchez [20] reported that ICT integration positively impacts science learning and motivation, including among students with special educational needs. These findings emphasize the importance of incorporating ICT-supported critical thinking pedagogy into teaching practices to foster essential competencies in young learners.

Research indicates that primary school is a crucial stage for developing foundational information-processing skills [21–23]. At this age, habits of critical thinking begin to form, and students learn to differentiate between reliable and unreliable sources. Building media literacy at this stage ensures sustainable cognitive and communicative development, enabling students not only to receive but also to critically evaluate information. However, a meta-analysis revealed a lack of research examining the combined effect of critical thinking instruction and ICT on media literacy in primary school students [24, 25].

This study is grounded not only in the development of media literacy but also in the cultivation of critical thinking, regarded in pedagogy as a core cognitive competence for consciously working with information. Following Glaser and Ennis, critical thinking is defined as "reasonable and reflective thinking focused on deciding what to believe or do" [26]. In the school context, it involves the ability to analyze, interpret, and evaluate information, identify arguments and counterarguments, and avoid cognitive biases [27].

In primary education, critical thinking is still developing; therefore, pedagogy must consider children's cognitive characteristics. Research shows that students aged 8–10 can acquire basic strategies for analysis and verification when instruction uses age-appropriate methods such as games, multimedia, and collaborative discussions [28]. Thus, critical thinking should be cultivated at the primary level as a foundation for media literacy.

The critical thinking pedagogy in this study is based on problem-based learning, inquiry tasks, work with conflicting sources, and reflective dialogue. ICT-supported critical thinking pedagogy plays both instrumental and methodological roles: interactive platforms, multimedia tasks, and educational games support analysis, comparison, and fact-checking [29]. Teacher preparation is also crucial, as competence in applying ICT-supported critical thinking pedagogy directly influences outcomes [30].

There are significant prospects for media education in Central Asian countries, including Kazakhstan [31, 32]. Multimedia resources, online platforms, and digital tools are increasingly integrated into schools [33], boosting students' media competence and engagement [34].

Despite these initiatives, the potential of media education and media-critical pedagogy in Kazakhstan remains underutilized [35, 36]. Media education is mostly studied at the university level, particularly in journalism faculties. In general education, it is often limited to a section within "Global Competencies," which is insufficient for primary students. Moreover, media education in Kazakhstani schools is not systematic: many regions lack qualified teachers, and Internet access is limited in rural areas. Consequently, students in remote regions are less prepared to navigate modern information challenges.

Although Kazakhstan has implemented digital initiatives such as Digital Kazakhstan, promoting media literacy in primary schools remains an unresolved issue [37]. A meta-analysis of local studies found no research on adapting digital resources to the age characteristics of primary students. As more children interact with the digital world, it is increasingly important to cultivate their ability to critically evaluate multimedia sources and recognize misinformation [38, 39].

Accordingly, this study aims to assess the effectiveness of ICT-supported critical thinking pedagogy in enhancing media literacy, academic achievement, and engagement among primary school students.

A. Research Questions

Q1: What is the effect of ICT-supported critical thinking pedagogy on primary school students' media literacy, academic achievement, and engagement?

B. Conceptual Framework

To provide a clearer theoretical and pedagogical foundation for this study, a conceptual model was developed linking ICT, critical thinking, and the three outcome variables: media literacy, engagement, and academic achievement. In this framework, critical thinking serves as the central mediator: ICT tools—including interactive platforms, multimedia presentations, and educational games—offer opportunities for students to analyze, evaluate, and reflect on information. These activities foster critical thinking skills, which in turn enhance students' media literacy, increase engagement in learning activities, and improve academic achievement in Natural Science. Fig. 1 illustrates the proposed conceptual framework.

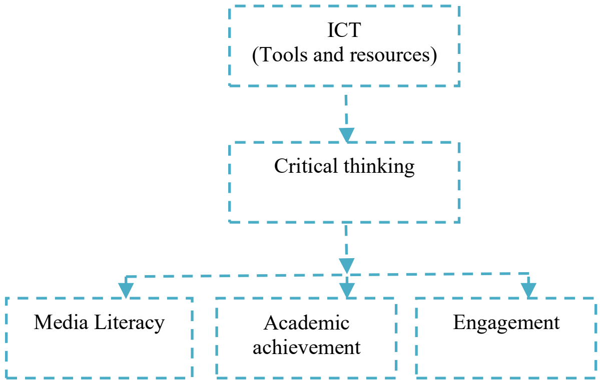

Fig. 1. Conceptual framework of ICT-supported critical thinking pedagogy.

II. Materials and Methods

A. Data Collection and Sample

The study employed a controlled intervention design to examine the causal effects of the program on primary school students' media literacy, academic achievement, and engagement. This design involved two groups: an Experimental Group (EG), which received a targeted intervention, and a Control Group (CG), which followed the standard curriculum without intervention. In the EG, students studied the subject Natural Science using ICT-supported critical thinking pedagogy, incorporating digital educational tools, multimedia resources, and tasks aimed at developing skills in critically analyzing information. This subject integrates scientific concepts with practical tasks, allowing for the assessment of students' ability to analyze, interpret, and evaluate information critically within the context of the educational material.

The use of pre-tests and post-tests enabled the measurement of student progress, evaluation of the approach's effectiveness, and control for potential confounding factors. A key advantage of this intervention design with a control group is its high internal validity: differences in outcomes between groups can be attributed with high confidence to the implemented intervention.

The study was conducted in a public primary school in the Almaty region of Kazakhstan. The school was selected based on accessibility, willingness to participate, and sufficient ICT infrastructure. Participants included 106 fourth-grade students with balanced gender distribution and regular attendance. Although individual socio-economic data were not collected, the sample reflects the typical range of socio-economic backgrounds in the Almaty region. Baseline levels of media literacy, engagement, and academic achievement were comparable between groups. Participants were then assigned to the EG or CG in a way that ensured comparability based on age, initial levels of media literacy, academic achievement, engagement, and parental/guardian consent. The EG included 54 students who received instruction through ICT-based critical thinking pedagogy, while the CG comprised 52 students following the standard curriculum.

Inclusion criteria were: (1) age 9–10 years; (2) enrollment in the 4th grade of the specified school; and (3) signed informed consent from parents or guardians. Exclusion criteria included: (1) serious medical conditions preventing participation; (2) absence of written parental consent; and (3) extended absence from school during the study period.

In addition to obtaining written parental consent, children's assent was also obtained in accordance with ethical standards for research involving minors. Prior to the study, objectives, activities, and procedures were explained to students in age-appropriate language. They were explicitly informed that participation was voluntary, that they could ask questions at any time, and that they had the right to withdraw without any negative consequences for their education. Only students who provided verbal assent and demonstrated readiness to participate were included in the study. This procedure ensured respect for children's rights and safeguarded their autonomy and well-being throughout the research process. The study protocol was reviewed and approved by the Ethics Committee of the Abai Kazakh National Pedagogical University, ensuring compliance with international ethical standards for research involving minors.

Table 1 presents the demographic characteristics of the study participants.

Table 1. Demographic characteristics of study participants

Parameter	EG	CG	Notes
Age	9–10 years	9–10 years	Mean age 9.5 years; groups comparable at baseline
Gender	Boys—28 Girls—26	Boys—27 Girls—25	Balanced gender distribution
Grade	4th grade	4th grade	Same education level
Attendance	≥90%	≥90%	Regularly monitored
Baseline media literacy	55.2±8.1	54.8±7.9	Groups comparable at baseline
Baseline engagement	3.1±0.6	3.0±0.5	Groups comparable at baseline
Baseline academic achievement (Natural Science)	68.5±7.2	69.0±6.9	Groups comparable at baseline

B. *Intervention and Procedure*

During the 2023–2024 academic year, the experimental group studied Natural Science through ICT-supported critical thinking pedagogy. This approach consisted of an integrated system of elements—including content, pedagogical principles, instructional forms and methods, and ICT tools—that collectively provided a structured process aimed at achieving the planned research outcomes. The intervention did not involve a separate media literacy course; rather, it modified the standard Natural Science curriculum so that each lesson combined the study of scientific concepts and practical tasks with embedded media literacy components.

ICT-based digital tools, such as interactive platforms, multimedia presentations, and educational games, were incorporated into the lessons. The effectiveness of these tools was not measured directly but was inferred from students' outcomes in media literacy, engagement, and academic achievement. The intervention lasted 12 weeks, with two 45-minute lessons per week. The CG followed the traditional Natural Science curriculum without the integration of ICT or critical thinking tasks.

Table 2 presents the weekly lesson plan.

Table 2. Weekly lesson plan

Week	Topic	Tools & Activities	Integration with Natural Science
1	Introduction to media literacy	Presentation; interactive platform	"What is Science?"— differentiating scientific and non-scientific sources
2	Recognizing disinformation	Games; analytical tasks	"Living & Non-living Nature"—verifying photos of rare animals
3	Online fact-checking	Practical exercises	"Earth & Natural Phenomena"—assessing website reliability
4	Bias in news	Presentation; Discussion	"Humans & Health" —analyzing articles on nutrition and sports
5	Strategies against fake news	Case studies; games	"Natural Resources" —detecting false claims about resources
6	Advertising and persuasion	Interactive exercises; tests	"Humans & Health" —analyzing "miracle medicine" advertisements
7	Media influence on opinion	Role-play; group tasks	"Ecology"—evaluating media campaigns on recycling
8	Information synthesis	Collaborative platform work	"Scientific Research" —compiling reports on ecological projects
9	Critical video evaluation	Games; peer review	"Physical Phenomena" —analyzing educational videos
10	Information verification techniques	Case analysis; group work	"Water & Air" —verifying news about water pollution
11	Critical Thinking in Tasks	Project assignments; multimedia	"Earth & Space"— evaluating media reports on space discoveries
12	Final project and reflection	All tools	Integration of all natural science topics; student presentations

Table 3. Content of teacher training

Training Module (duration)	Activities	Learning objectives
1.Introduction to ICT in education (2 hours)	Lecture, demonstration of digital educational platforms	Understand the pedagogical benefits of ICT and familiarize with tools applicable to Natural Science teaching
2. Pedagogy of critical thinking (3 hours)	Seminars, group discussions	Master strategies for fostering critical thinking in primary school Natural Science lessons
3. Integrating ICT and critical thinking into natural science (4 hours)	Lesson planning practice, classroom simulations	Develop skills to integrate ICT tools with media literacy and critical thinking tasks
4. Assessment and feedback (2 hours)	Training in pre- and post-tests, analysis of student work	Learn to assess students' media literacy, engagement, and comprehension in Natural Science
5. Classroom Management in ICT-supported lessons (2 hours)	Role-playing exercises, situational analysis	Acquire techniques to ensure active participation and manage classroom dynamics effectively

C. Teacher Training

Prior to the intervention, teachers underwent comprehensive training to implement ICT-supported critical thinking pedagogy in Natural Science lessons. This training provided subject-specific preparation and ensured consistent application of the methodology across all classes. Teachers were equipped with detailed manuals and received weekly guidance to maintain fidelity and standardization within the EG. The content and structure of the teacher training program are presented in Table 3.

Fig. 2 illustrates the overall research design, which includes: teacher training, the 12-week ICT-supported critical thinking intervention in Natural Science, the control group, and the measured outcomes (media literacy, engagement, and academic achievement).

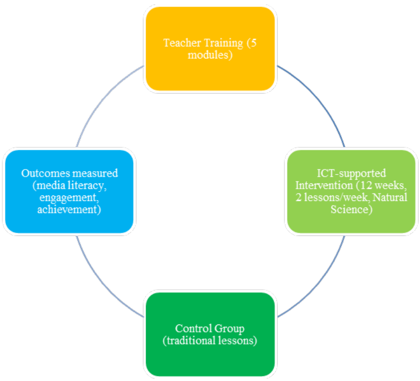

Fig. 2. Research design cycle.

D. Data Collection Tools

To quantitatively assess outcomes, four established instruments were employed (see Table 4): (i) Media Literacy Test (20 items: multiple-choice, matching, and fake news detection; Cronbach's $\alpha = 0.82$ for both pre- and post-tests in the main study; a pilot study with 36 students confirmed age-appropriateness and content validity; full test items are provided in Table A1); (ii) Student Engagement Questionnaire (10 items, 5-point Likert scale; validated by teachers and psychologists, Cronbach's $\alpha = 0.79$ for pre- and post-tests; see Table A2); (iii) Systematic Classroom Observation (tracking participation, task completion, and ICT interaction over 12 weeks using standardized protocols with established inter-rater reliability, Cohen's $\kappa = 0.85$); and (iv) Academic Achievement Assessment (pre- and post-test comparison in Natural Science between the EG and CG).

Table 4. Instruments and statistical validation

Instrument	Description / Structure	Reliability / Validity
Media Literacy Test	20 items: multiple-choice, matching, fake news detection	Pilot validation; Cronbach's $\alpha = 0.82$
Student Engagement Questionnaire	10 items, 5-point Likert scale; adapted for children (9–10 years)	Expert review; validated by teachers & psychologists
Classroom observation	Systematic recording of participation, assignments, ICT interaction (12 weeks)	Standardized protocols; inter-rater reliability (Cohen's κ)
Academic Achievement Assessment	Pre- and post-test comparison in Natural Science (EG vs. CG)	Statistical analysis (M, SD, p)

All instruments were culturally and linguistically adapted, including forward and back translation and expert review by educators and psychologists. Pre- and post-testing enabled evaluation of changes in media literacy, engagement, and academic achievement resulting from the ICT-supported intervention, ensuring transparency, reliability, and validity of the measures.

E. Data Analysis

Data were analyzed using both descriptive and inferential statistical methods in SPSS version 26.0. For each measure, Means (M), Standard Deviations (SD), and p-values were reported (see Table 5).

Table 5. Statistical analysis methods

Measure / Focus	Methods applied
Media Literacy Test	Independent- and paired-samples t-tests; descriptive statistics (M, SD, p)
Student Engagement Questionnaire	Descriptive statistics (M, SD, p); paired-samples t-tests
Classroom observation	Descriptive statistics (M, SD, 95% CI); group comparisons
Academic Achievement Assessment	Independent- and paired-samples t-tests; descriptive statistics (M, SD, p)
Effectiveness of digital tools (inferred from outcomes)	Correlation analysis with media literacy and engagement (r, 95% CI, p)

F. Handling of p-values

All p-values are reported for each statistical test. No adjustment for multiple comparisons was applied, as the analyses were confirmatory and based on pre-specified hypotheses.

III. Result and Discussion

To evaluate the effectiveness of the program, students' media literacy outcomes were analyzed in both the EG and CG. The comparative results are presented in Table 6 and Fig. 3.

Table 6. Students' media literacy scores (EG: $n = 54$; CG: $n = 52$)

Group	Pre-test (mean ± SD)	Post-test (mean ± SD)	Δ Mean	t	p
EG	55.2±8.1	72.8±7.5	+17.6	12.5	<0.001
CG	54.8±7.9	58.3±8.0	+3.5	2.8	0.006

As shown, the EG demonstrated a statistically significant improvement in media literacy, with the mean score increasing by 17.6 points ($t = 12.5$, $p < 0.001$). The CG also showed a smaller but significant gain (+3.5; $t = 2.8$, $p = 0.006$), which was markedly lower than that observed in the EG.

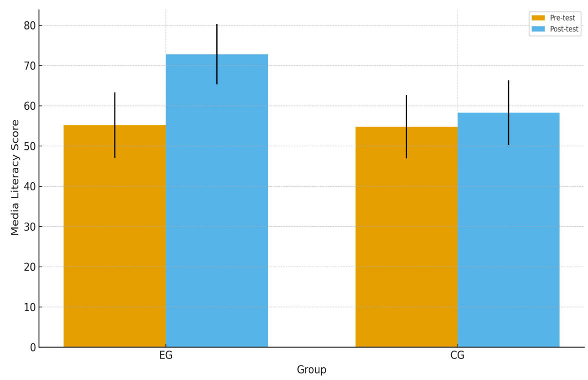

Fig. 3. Pre - and post-test media literacy scores by group.

Table 7 and Fig. 4 present the average engagement scores during the first and twelfth weeks of the experiment, along with the changes over the 12-week period for both the EG and CG.

Table 7. Student engagement and change over 12 weeks (EG: n = 54; CG: n = 52)

Group	Mean engagement (Week 1)	Mean engagement (Week 12)	Δ Mean	t	p
EG	3.1±0.6	4.2±0.5	+1.1	11.3	<0.001
CG	3.0±0.5	3.3±0.6	+0.3	2.2	0.03

The EG showed a significant increase in average engagement, from 3.1±0.6 to 4.2±0.5 (Δ = +1.1; t = 11.3, p < 0.001), indicating a substantial improvement resulting from the intervention. The CG also demonstrated a smaller but significant increase (from 3.0±0.5 to 3.3±0.6; Δ = +0.3; t = 2.2, p = 0.03). These results indicate that the teaching methods implemented in the EG produced a more pronounced enhancement in student engagement compared to the traditional instruction in the CG.

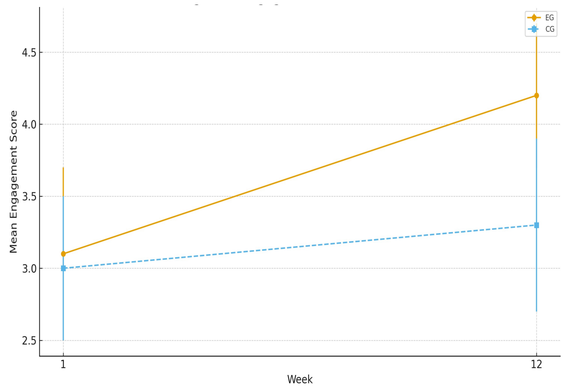

Fig. 4. Engagement over 12 weeks.

Table 8 presents the mean scores before and after the intervention, along with the corresponding changes (Δ Mean) and their statistical significance for both the EG and CG.

Table 8. Academic achievement in Natural Science (EG: n = 54; CG: n = 52)

Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Δ Mean	t	p
EG	68.5±7.2	82.1±6.8	+13.6	13.0	<0.001
CG	69.0±6.9	72.4±7.1	+3.4	2.7	0.007

As shown in Table 8, the EG's mean score increased from 68.5±7.2 to 82.1±6.8, representing a significant gain of Δ = +13.6 (t = 13.0; p < 0.001), reflecting a substantial improvement in academic achievement following the intervention. The CG also showed a smaller but significant increase (from 69.0±6.9 to 72.4±7.1; Δ = +3.4; t = 2.7, p = 0.007), indicating that the intervention had a markedly stronger effect on students in the EG.

The results for the control group suggest that additional factors, such as student motivation and disposition, which were not directly measured in this study, may influence learning outcomes, particularly for tasks requiring higher-order skills such as description, explanation, or abstraction.

Table 9 summarizes the mean scores (on a 1–5 scale) for student activity and interaction with ICT in the EG and CG across weeks 1, 6, and 12.

At the beginning of the intervention, EG and CG showed similar activity and ICT interaction levels (95% CI: activity = 2.61–2.99 vs. 2.31–2.69; ICT = identical). By week 6, EG students demonstrated markedly higher activity (3.60, 95% CI [3.41–3.79]) compared to CG students (2.70, 95% CI [2.51–2.89]), and this gap widened by week 12 (4.30 vs. 2.90). A similar pattern was observed for ICT interaction, with the EG reaching 4.10 (95% CI [3.91–4.29]) by week 12, compared to 2.90 (95% CI [2.71–3.09]) in the CG.

Table 9. Observation of learning activities (EG: n = 54; CG: n = 52)

Week	Indicator	EG Mean ± SD	CG Mean ± SD	Δ Mean
1	Student activity	2.80±0.50	2.50±0.60	+0.30
6	Student activity	3.60±0.50	2.70±0.50	+0.90
12	Student activity	4.30±0.40	2.90±0.50	+1.40
1	ICT interaction	2.50±0.60	2.50±0.60	+0.0
6	ICT interaction	3.40±0.50	2.60±0.50	+0.80
12	ICT interaction	4.10±0.50	2.90±0.50	+1.20

These results show that the intervention produced substantial and sustained improvements in both student activity and ICT interaction, with gains significantly larger than those achieved through traditional instruction.

Table 10 presents the mean effectiveness ratings (on a 1–5 scale) with 95% confidence intervals, along with the correlations for each digital tool.

Table 10. Effectiveness of digital tools (EG: n = 54; CG: n = 52)

Digital tool	Frequency of use (per week)	Effectiveness rating (Mean ± SD)	Correlation with media literacy (r)	Correlation with engagement (r)
Interactive platform	3	4.20±0.50	0.62*	0.58*
Multimedia presentations	2	3.90±0.60	0.55*	0.52*
Educational game tasks	2	4.10±0.50	0.60*	0.57*

The interactive platform, used on average three times per week, received the highest effectiveness rating (4.20±0.50) and showed strong correlations with both media literacy (r = 0.62, 95% CI [0.44–0.76]) and engagement (r = 0.58, 95% CI [0.39–0.73]). Multimedia presentations (M = 3.90±0.60) demonstrated moderate positive correlations with media literacy (r = 0.55, 95% CI [0.35–0.71]) and engagement (r = 0.52, 95% CI [0.31–0.69]). Educational game tasks (M = 4.10±0.50) also yielded strong positive associations with both media literacy (r = 0.60, 95% CI [0.41–0.75]) and engagement (r = 0.57, 95% CI [0.38–0.73]).

Overall, all digital tools significantly supported student learning, with the interactive platform showing the strongest combined impact.

The experimental validation of the hypothesis confirms that ICT-supported critical thinking pedagogy enhances media literacy, academic achievement, and engagement among primary school students. The most pronounced effect was observed in academic performance, particularly in the experimental group, while gains in media literacy and engagement were smaller. The effectiveness of this approach is evidenced by the students' progress toward higher levels of academic performance, media literacy, and active participation in the EG. The EG showed higher media literacy scores than the CG in both pre- and post-tests, along with increased engagement and academic achievement.

The findings indicate that ICT-supported critical thinking pedagogy, implemented with a focus on media literacy, significantly improved students' academic performance in Natural Science. Although the correlations between this pedagogy and overall media literacy or engagement were moderate rather than strong, the intervention led to substantial gains in science achievement in the EG compared to the CG. This intervention also promoted concrete actions that made students' reasoning and evaluation of information visible in their work. These results highlight that integrating ICT-supported critical thinking pedagogy into instruction can effectively enhance academic outcomes, while also contributing to improvements in media literacy and engagement.

These results align with previous research suggesting that integrating digital tools and interactive tasks can effectively foster ICT-supported critical thinking pedagogy and media literacy in young learners [40]. Our results are consistent with prior studies demonstrating the positive influence of ICT on student engagement and critical thinking development [41–45]. However, some findings differ from studies reporting no significant improvements in media literacy among younger students without additional pedagogical support [46]. These outcomes underscore the need for further research with larger samples and more diverse educational contexts to validate and expand upon these conclusions.

Media literacy and critical thinking are interrelated competencies: while media literacy involves evaluating and interpreting information, critical thinking provides the cognitive processes needed to reason, analyze arguments, and identify biases. The integration of ICT tools in a structured critical thinking pedagogy allowed students to engage actively with content, evaluate digital information, and reflect on their learning processes, which aligns with contemporary theoretical perspectives on digital competence and cognitive development.

From a pedagogical and curricular perspective, adapting the Natural Science curriculum to incorporate media literacy components ensured alignment with learning objectives while fostering cross-disciplinary skills. The use of interactive platforms, multimedia presentations, and gamified tasks supported active inquiry, collaboration, and problem-solving, which are central to both ICT-supported critical thinking pedagogy and engagement. This approach illustrates how curricular integration, rather than isolated media literacy courses, can effectively enhance student outcomes.

While the results clearly indicate improvements in media literacy, engagement, and academic achievement, alternative explanations should be considered. One possibility is the novelty effect, whereby the introduction of new ICT tools and teaching methods may have temporarily increased motivation and attention. Additionally, individual differences in students' prior exposure to technology, intrinsic motivation, or learning preferences could have contributed to observed gains, independently of the pedagogy itself.

Moreover, the literature reports mixed findings regarding media literacy interventions in primary education. Some studies show substantial benefits when ICT-supported critical thinking pedagogy strategies are combined with interactive tools, while others report minimal or inconsistent effects when additional pedagogical support is absent [47–51]. Considering these mixed results provides a more balanced interpretation and highlights that the observed improvements may depend on both instructional design and contextual factors.

Thus, these considerations suggest that ICT-supported critical thinking pedagogy can be an effective approach, but its success may be moderated by novelty effects, student characteristics, and teacher expertise. Future research should examine these moderating factors, use larger and more diverse samples, and incorporate longitudinal designs to assess the sustainability of learning gains.

A. Limitations of the Study

This study demonstrates that ICT-supported critical thinking pedagogy can effectively enhance media literacy, academic achievement, and engagement among primary school students. However, several limitations should be acknowledged. First, the relatively small sample size and the fact that the research was conducted in a single school may limit the generalizability of the findings. Students' performance and engagement could be influenced by local curriculum characteristics, school culture, or access to technology, which may differ in other educational contexts. Therefore, caution should be exercised when extending these results to other schools, regions, or countries. Future studies should include larger, more diverse samples across multiple schools to strengthen external validity. Despite providing comprehensive training and standardized procedures, individual differences in teaching style, experience, and enthusiasm could have influenced the implementation of ICT-supported critical thinking pedagogy. For instance, a more motivated or experienced teacher may have used digital tools more effectively, amplifying observed effects. Future research should consider randomizing teachers or including multiple instructors per group to better control for such variability. Third, motivational factors and student characteristics were not fully controlled. Students with higher intrinsic motivation or prior familiarity with digital tools may have engaged more actively with the intervention, contributing to improvements independently of the pedagogy itself. Additionally, heightened interest in learning activities may have enhanced engagement and academic outcomes, partially mediating the observed effects. Future studies incorporating measures of student motivation, prior digital literacy, and mediation analyses could help disentangle these effects and clarify causal pathways. Finally, reliance solely on tests and systematic observations limited the depth of analysis regarding cognitive, metacognitive, and motivational mechanisms underlying media literacy development. Incorporating qualitative methods, such as interviews, focus groups, or reflective journals, could provide richer insights into how students engage with ICT-supported critical thinking tasks. Fourth, the present study relied primarily on t-tests to assess differences between the experimental and control groups. While baseline equivalence was confirmed, more advanced statistical approaches such as ANCOVA or mixed-effects models could provide a stronger control for potential baseline variations and individual differences. Furthermore, although effect size reporting (e.g., Cohen's d) was not included in the present study, future research will incorporate such measures to enhance the robustness and interpretability of statistical findings.

Thus, these limitations should be carefully considered when interpreting the results. Addressing them in future research will enhance the reliability, reproducibility, and generalizability of findings related to ICT-supported critical thinking pedagogy in primary education.

IV. Conclusion

The development and implementation of ICT-supported critical thinking pedagogy in Natural Science education significantly improved students' academic performance, particularly in the experimental group. While gains in media literacy and engagement were observed, the main effect was on academic achievement. The controlled intervention design allowed for a clear assessment of causal effects, confirming that the use of interactive educational platforms, multimedia presentations, and educational games can strengthen both understanding and active participation in primary school students. The intervention promoted concrete actions that made students' reasoning and evaluation of information visible in their work. The results for the control group, which showed smaller yet measurable improvements, suggest that additional factors such as student motivation and disposition may influence learning outcomes, particularly for tasks requiring higher-order skills such as description, explanation, or abstraction. These findings underscore the importance of supporting critical thinking and ICT-based learning with concrete actions. Future research should further explore diverse educational contexts, larger samples, and long-term effects to validate and extend these conclusions. Thus, ICT-supported critical thinking pedagogy represents a promising approach to fostering academic achievement and digital literacy in primary education. From a practical standpoint, the findings highlight the need to strengthen teacher training programs to equip educators with ICT integration and critical thinking strategies, as well as to adapt curriculum design to include inquiry-based, media-rich learning experiences that promote analytical and reflective skills among students. Moreover, while this study was conducted in Kazakhstan, its implications resonate with global educational priorities emphasizing digital competence, critical thinking, and equity in technology-enhanced learning. The results therefore contribute to broader international discussions on how ICT-supported pedagogy can bridge gaps in media literacy and prepare students for participation in an increasingly digital world.

Appendix

Table A1. Media literacy test

No.	Question	Answer options
1	Which of these news items seems suspicious?	a) "The moon is green" b) "It is raining today" c) "The school is holding classes"
2	What should you do if you see an interesting news item online?	a) Share it immediately b) Check the source c) Ignore it
3	Which information source is more reliable?	a) A website with well-known facts b) A message from a stranger in a messenger app c) A social media post
4	What is"fake news"?	a) News about animals b) False information that looks believable c) News in a newspaper
5	How can you distinguish a real photo from a fake one?	a) Check the source b) Just trust it c) Send it to a friend
6	Which information helps make the correct conclusion?	a) Only the headline b) The full article and reliable sources c) Rumors
7	What is important when choosing a website for a school project?	a) Attractive design b) Reliable source and factual information c) A large number of pictures
8	If a news item contradicts what you know, what should you do?	a) Ignore it b) Check multiple sources c) Only trust friends
9	Can you trust everything written on social media?	a) Yes b) No c) Sometimes
10	What should you do before sharing a news item?	a) Check the source b) Send it immediately c) Ask a friend
11	How can you identify biased news?	a) By checking if only one side of the story is presented b) By reading the headline c) By the number of likes
12	Why is it important to verify information from multiple sources?	a) To ensure accuracy b) To find the most entertaining version c) To get more opinions from friends
13	Which tool can help check the authenticity of a photo?	a) Reverse image search b) Just trust the photo c) Forward it to someone
14	What should you do if a source is unknown?	a) Consider it unreliable until verified b) Trust it immediately c) Ignore it entirely
15	How can you recognize clickbait?	a) Sensational or misleading headlines b) Informative content c) Short paragraphs
16	Which type of content often spreads misinformation?	a) Unverified social media posts b) Peer-reviewed journals c) Official news agency reports
17	Why is it important to check the date of an article?	a) To ensure the information is current b) To judge the design c) To count the number of images
18	How can you verify a claim made in a news article?	a) Compare it with credible sources b) Trust the headline c) Ask friends on social media
19	What is the best approach to learning about controversial topics?	a) Review multiple reliable sources b) Trust only one source c) Ignore differing opinions
20	Why should you question information that confirms your personal beliefs?	a) To avoid confirmation bias b) To save time c) To agree with friends

Table A2. Student engagement questionnaire

No.	Statement
1	I am interested in completing tasks during lessons using a computer.
2	I actively participate in class discussions.
3	I enjoy working with interactive assignments.
4	I feel comfortable asking questions to the teacher.
5	I try to complete all tasks on time.
6	I enjoy using multimedia presentations to support my learning.
7	I feel like a part of the class group.
8	I try to apply the knowledge I have gained in real-life situations.
9	I am interested in finding information independently.
10	I believe that lessons incorporating ICT help me better understand the material.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, LK and AA; methodology, GY; software, AR; validation, GO, SZ and AK; formal analysis, LK; investigation, AA; resources, GY; data curation, AR; writing—original draft preparation, GO; writing—review and editing, AK; visualization, LK; supervision, SZ; project administration, AA; funding acquisition, AR. All authors have read and agreed to the published version of the manuscript.

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