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Enhancing Students’ Computational Thinking Skills through Digital Ethnomathematics Learning with ECOPEDIA

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Abstract
This study investigated the improvement of students’ computational thinking abilities through the implementation of digital ethnomathematics instruction supported by the ECOPEDIA platform. A quantitative methodology was adopted, employing a quasi-experimental pretest-posttest control group design. The research involved two class groups, namely an experimental cohort and a comparison cohort. The primary data collection tool was a computational thinking assessment, which had undergone validity and reliability testing prior to use. Based on the analysis, the experimental group’s mean score rose from 50.7 at pretest to 84.8 at posttest. The Independent Sample T-Test revealed a statistically meaningful difference between the two groups ($p < 0.05$). Furthermore, the experimental class achieved an N-Gain of 0.69, falling into the moderate category and surpassing that of the control class. In light of these results, the ECOPEDIA-based digital ethnomathematics approach proved to be more effective than conventional teaching methods in this particular sample (Cohen’s $d = 0.82$, indicating a large effect size). These outcomes suggest that culturally grounded digital media can serve as a promising instructional alternative for fostering 21st-century competencies, although further studies with broader sampling are recommended to confirm the generalizability of these findings.

Keywords: Computational Thinking Skills; Digital Ethnomathematics; ECOPEDIA; Learning Media; Students

Introduction

The rapid digital transformation in education demands that students acquire higher-order cognitive capacities, with computational thinking emerging as a foundational skill in this landscape. Computational thinking refers to a systematic problem-solving framework encompassing decomposition, pattern recognition, abstraction, and algorithmic reasoning (Maharani, 2020). The urgency of developing this competency at the elementary level is underscored by Indonesia's performance in the 2022 Programme for International Student Assessment (PISA), where only 18% of students reached the minimum proficiency level in mathematics, a significant drop from 28% in 2018 and far below the OECD average of 69% (OECD, 2023). This persistent gap indicates that conventional instructional approaches have been insufficient in fostering the analytical and logical reasoning skills that computational thinking aims to cultivate.

In response to these challenges, Indonesia's Merdeka Curriculum has explicitly integrated computational thinking into the primary education framework, particularly within mathematics instruction (Kemendikbudristek, 2022). Furthermore, recent policy directions from the Ministry of Primary and Secondary Education have introduced coding and artificial intelligence as elective subjects, starting from fourth grade, with the explicit goal of nurturing systematic and computational thinking skills from an early age (Kemendikdasmen, 2025). Within mathematics education, computational thinking has thus been positioned as an indispensable competency that must be systematically developed from elementary school onward as part of the broader 21st-century skillset (Suarsana et al., 2023).

However, in practice, students' computational thinking skills remain relatively underdeveloped. Empirical evidence from a recent study involving 380 elementary students in Indonesia revealed that while the mean computational thinking score reached 73.87, only 12.37% of students were categorized as having high-level CT, whereas 19.47% fell into the low category (Indrawati et al., 2025). More critically, when examined across specific CT dimensions in the context of fraction problem-solving, pattern recognition emerged as the weakest component (mean score of 59.8%), followed by algorithmic thinking (75.8%) and decomposition (79.6%), with abstraction showing the highest performance (84.2%) (Indrawati et al., 2025).

A more granular diagnostic investigation specifically on fraction addition among sixth-grade students in Mojokerto found that 78.9% struggled with abstraction, 73.7% with decomposition, 68.4% with algorithmic thinking, and 63.2% with pattern recognition (Agustin et al., 2026). These difficulties manifest when students apply whole-number reasoning to fraction operations, fail to identify equivalence patterns, and are unable to construct systematic solution procedures, indicating that their challenges are multidimensional and stem from insufficient scaffolding in linking conceptual understanding with procedural fluency (Agustin et al., 2026).

Furthermore, national-level data from the Bebras Challenge 2023, which assessed computational thinking skills among Indonesian students across educational levels, showed a mean score of 67.41 for participants who achieved at least the minimum threshold, with substantial variation across grade levels. This finding aligns with broader international assessments, as the PISA 2022 framework indicates that Indonesian students remain weak in technology-based problem solving and mathematical reasoning, which are foundational to computational thinking development (OECD, 2023).

This condition indicates that the current learning process has not yet fully supported the optimal development of computational thinking processes, particularly in mathematics topics such as fractions, where the gap between expected competencies and actual student performance necessitates instructional innovation.

One approach that can be used to address this problem is the integration of ethnomathematics in learning. Ethnomathematics connects mathematical concepts with local culture, making learning more relevant and meaningful for students (Jannah et al., 2023). Research conducted by Mariana, Fadillah, and Wiryanto showed that culture-based mathematics learning can help students understand mathematical concepts through real-life contexts (Fadillah et al., 2022). In the context of ECOPEDIA, the ethnomathematical foundation is drawn from the cultural heritage of the Osing community in Banyuwangi, East Java, specifically the traditional kendang (drum) and angklung musical instruments (Iffah et al., 2025; Supriyadi et al., 2024). These artifacts embody mathematical concepts related to geometry, measurement, and spatial reasoning. The kendang structure contains cylindrical shapes that can be explored through volume and surface area concepts, while the angklung bamboo tubes demonstrate patterns of length, proportion, and pitch-frequency relationships that reflect linear measurement and ratio (Supriyadi et al., 2024). Additionally, the production process of these instruments involves systematic measurement, division, and proportional reasoning, which align with computational thinking processes such as decomposition and pattern recognition (Iffah et al., 2025).

Beyond these artifacts, the cultural practices of the Osing community, including the kendang and angklung performances, provide rich contextual scenarios for mathematical problem-solving. The rhythmic patterns in kendang play exhibit recurring sequences that support the development of pattern recognition and algorithmic thinking, while the collaborative nature of angklung ensemble performance requires coordination and systematic organization, mirroring the principles of decomposition in computational thinking (Iffah et al., 2025; Supriyadi et al., 2024). By embedding these cultural objects and practices into the ECOPEDIA platform, students engage with mathematical content through familiar local contexts, thereby reducing the abstraction gap and fostering meaningful learning experiences (Iffah et al., 2025).

In addition, the integration of ethnomathematics can also support the development of higher-order thinking skills because students not only understand concepts but also relate them to real experiences (Martyanti & Suhartini, 2018). When combined with a computational thinking approach, ethnomathematics learning can become an effective medium for training students' problem-solving skills systematically (Yuliana et al., 2023).

In this context, the use of digital learning media becomes important to support a more interactive learning process. Technology-based learning media can increase student engagement and help present learning materials in a more interesting and understandable way (Yuliana, 2024). Therefore, the development of learning media that integrates ethnomathematics and digital technology becomes one of the innovative alternatives in mathematics learning.

ECOPEDIA is a digital ethnomathematics learning medium designed to support the development of students' computational thinking skills. Operationally, ECOPEDIA is developed as a web-based application accessible via desktop and mobile devices, allowing flexible use both in the classroom and for independent study (Wulanningtyas et al., 2025). The platform integrates cultural artifacts from the Osing community, specifically traditional kendang and angklung instruments, into mathematics content on geometry, measurement, and proportional reasoning (Wulanningtyas et al., 2025).

The learning materials are organized into three sequential modules, each corresponding to a specific CT indicator (Wulanningtyas et al., 2025). Module 1 (Decomposition) presents the kendang production process, where students break down the instrument's construction into measurable components such as diameter, height, and volume. Module 2 (Pattern Recognition) engages students with angklung tube length sequences, requiring them to identify numerical patterns and relationships between length and pitch. Module 3 (Algorithmic Thinking) tasks students with designing a step-by-step procedure for creating a simplified angklung set, including measurement, cutting, and assembly sequences . Each module includes interactive quizzes, simulation-based explorations, and structured problem-solving exercises delivered through the ECOPEDIA interface.

The instructional sequence is designed for a total duration of four 70-minute sessions, comprising one introductory session and three module-based sessions (Wulanningtyas et al., 2025). Each session follows a consistent activity structure: (1) cultural context introduction through video or narrative; (2) guided exploration of the cultural artifact using interactive simulations; (3) independent problem-solving tasks aligned with CT indicators; and (4) reflection and group discussion to consolidate learning. The relationship between features and CT indicators is explicit: decomposition is facilitated through the artifact breakdown tool, pattern recognition through the sequence identification game, abstraction through the symbolic representation builder, and algorithmic thinking through the step-by-step procedure designer.

Thus, the use of ECOPEDIA is expected to improve students' computational thinking skills compared to conventional learning, as each feature directly targets the specific dimensions of CT that have been identified as areas of weakness in previous studies.

Based on the explanation above, it is important to examine the extent to which digital ethnomathematics learning using ECOPEDIA can enhance students' computational thinking skills. Although previous research has explored ethnomathematics-based learning media and computational thinking separately, there remains a notable gap in the literature: studies that systematically integrate both domains through a fully digital, interactive platform designed specifically for elementary mathematics, particularly on fraction concepts. While some studies have developed ethnomathematics-based e-modules or flipbooks for geometry topics at the junior high level (Payadnya et al., 2026), these efforts have largely relied on static digital formats and have not explicitly linked each feature of the media to specific computational thinking indicators such as decomposition, pattern recognition, abstraction, and algorithmic thinking (Romandoni, 2024). Furthermore, existing research on computational thinking in elementary mathematics has primarily employed conventional instructional approaches without embedding culturally relevant contexts, leaving the potential synergy between ethnomathematics and CT development underexplored (Maharani et al., 2024; Sunzuma & Umbara, 2025).

The novelty of this study lies in three specific contributions. First, it operationalizes ECOPEDIA as a web-based interactive platform that integrates cultural artifacts from the Osing community, specifically traditional kendang and angklung instruments, into fraction and geometry content, thereby addressing the limited integration of Eastern Indonesian cultural contexts in digital mathematics learning (Sunzuma & Umbara, 2025). Second, unlike previous static e-modules, ECOPEDIA's features are explicitly mapped to CT indicators: the artifact breakdown tool targets decomposition, the sequence identification game targets pattern recognition, the symbolic representation builder targets abstraction, and the step-by-step procedure designer targets algorithmic thinking (Romandoni, 2024). Third, this study employs a quasi-experimental design with a control group to provide empirical evidence on the comparative effectiveness of digital ethnomathematics learning versus conventional instruction, addressing the methodological limitations of prior studies that often lacked control groups or relied solely on descriptive analyses (Maharani et al., 2024).

This study aims to examine the effectiveness of ECOPEDIA in enhancing students' computational thinking skills. It is hypothesized that students who learn using ECOPEDIA will achieve higher computational thinking skills compared to those who experience conventional learning.

Method

This study employed a quantitative approach with a quasi-experimental research design. The design used was a pretest-posttest control group design involving two groups, namely the experimental class and the control class (Creswell, 2014). The experimental class received treatment in the form of digital ethnomathematics learning using ECOPEDIA, while the control class received conventional learning.

The population of this study consisted of all fifth-grade students at SDN Pugeran and SDN Pohjejer. The sampling technique used was purposive sampling, resulting in two classes as research samples, namely the experimental class consisting of 23 students and the control class consisting of 29 students.

The research instrument used was a computational thinking skills test developed based on the indicators of decomposition, pattern recognition, abstraction, algorithms, and debugging. The instrument had undergone validity and reliability testing before being used in the study (Sugiyono, 2019). In addition, observation sheets were used to support the data on learning implementation.

Data collection techniques were carried out through the administration of pretests and posttests in both groups. The pretest aimed to determine students' initial abilities, while the posttest was used to measure students' final abilities after the treatment had been implemented.

Data analysis was conducted through prerequisite tests, including normality and homogeneity tests. The normality test was conducted using the Shapiro-Wilk test, while the homogeneity test was conducted using Levene's test to determine the equality of variances between groups (Ghozali, 2018).

Furthermore, hypothesis testing was conducted using the Independent Sample T-Test to determine differences in computational thinking skills between the experimental and control classes. In addition, N-Gain analysis was used to determine the improvement in students' abilities with low, moderate, and high interpretation criteria (Hake, 1999).

Results and Discussion

Results

Based on the research results, data on students' computational thinking skills were obtained from the experimental and control classes through the administration of pretests and posttests. The data showed an improvement in students' abilities after being given treatment in the form of digital ethnomathematics learning using ECOPEDIA.

Descriptively, the average pretest score in the experimental class was 50.7 with a standard deviation of 13.3, while the average posttest score increased to 84.8 with a standard deviation of 9.23. The minimum pretest score was 30 and the maximum score was 80, while in the posttest the minimum score was 65 and the maximum score was 100.

To clarify the comparison between pretest and posttest results, the data are presented in the following table.

Table 1. Descriptive Statistics of Students' Computational Thinking Skills

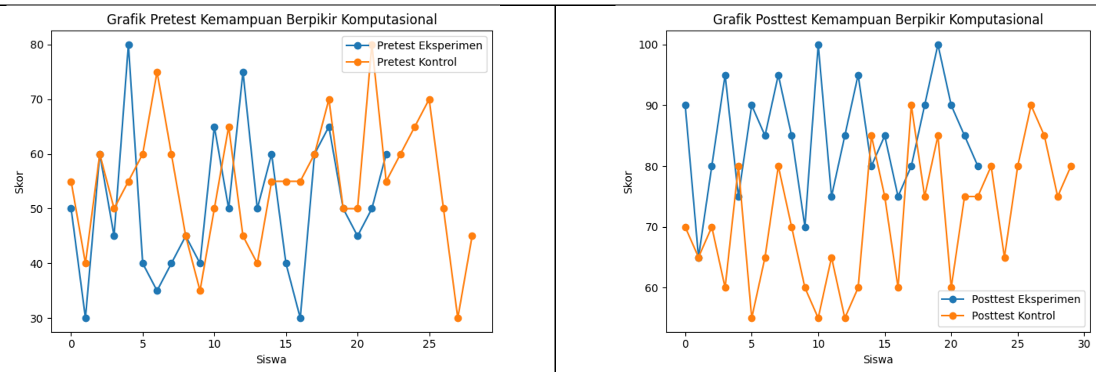
Statistic	Pretest Eksperiment	Posttest Eksperiment	Pretest Control	Posttest Control
N	23	23	29	29
Mean	50.7	84.8	54.7	71.2
Median	50	85	55	70
Standar Deviasi	13.3	9.23	11,5	10,7
Minimum	30	65	30	55
Maksimum	80	100	80	90

Based on Table 1, descriptive statistical data of students' computational thinking skills in the experimental and control classes before and after treatment were obtained. In the experimental class, the pretest mean score was 50.7 with a median of 50, indicating that students' initial abilities were still at a low to moderate level. The standard deviation of 13.3 indicated a relatively large variation in students' abilities. The minimum score was 30 and the maximum score was 80, showing a fairly wide range of initial abilities among students.

After being given treatment in the form of digital ethnomathematics learning using ECOPEDIA, the posttest mean score increased to 84.8 with a median of 85. This improvement indicated a significant enhancement in students' computational thinking skills. The posttest standard deviation of 9.23 was lower than the pretest standard deviation, indicating that students' abilities became more evenly distributed. The minimum score increased to 65 and the maximum score reached 100, indicating improvement in almost all students.

In the control class, the pretest mean score was 54.7 with a median of 55, indicating that the students' initial abilities were slightly higher than those of the experimental class. The standard deviation of 11.5 indicated a fairly diverse variation in students' abilities. The minimum and maximum scores were 30 and 80, respectively.

After conventional learning, the posttest mean score in the control class increased to 71.2 with a median of 70. This increase indicated an improvement in students' abilities, although it was not as high as that of the experimental class. The standard deviation of 10.7 indicated that the variation in students' abilities remained relatively high. The minimum score increased to 55 and the maximum score became 90.



Students' Computational Thinking Skills in the Pretest

Students' Computational Thinking Skills in the Postest

Figure 1. Comparison Graph of Pretest and Posttest Scores in the Experimental Class

Overall, the increase in scores in both classes indicated an improvement in students' computational thinking skills. However, the improvement in the experimental class was higher than that of the control class, both in terms of mean scores and maximum scores achieved. In addition, the decrease in standard deviation in the experimental class indicated that learning using ECOPEDIA not only improved students' abilities but also made their abilities more evenly distributed.

Table 2. Results of the Normality Test of Computational Thinking Skills Data (Shapiro-Wilk)

Variable	N	Statistik W	Sig. (p)	Interpretation
Pretest Eksperimen	23	0,955	0,371	Normal
Posttest Eksperimen	23	0,967	0,629	Normal
Pretest Kontrol	29	0,982	0,891	Normal
Posttest Kontrol	29	0,942	0,111	Normal

The normality test was conducted using the Shapiro-Wilk test to determine whether the data on students' computational thinking skills were normally distributed. The testing criterion used was that if the significance value (p) > 0.05, the data were considered normally distributed.

Based on Table 2, the significance values in the experimental class were 0.371 for the pretest and 0.629 for the posttest. Both values were greater than 0.05, indicating that the data in the experimental class were normally distributed.

In the control class, the significance values were 0.891 for the pretest and 0.111 for the posttest. These values were also greater than 0.05, indicating that the data in the control class were normally distributed.

Thus, it can be concluded that all data, both in the experimental and control classes, met the assumption of normality. Therefore, further analysis could be conducted using parametric statistical tests.

Table 3. Results of the Homogeneity Test of Variance in Computational Thinking Skills

Data	F	df1	df2	Sig. (p)	Interpretation
Pretest (Experimental vs. Control)	0,671	1	50	0,417	Homogeneous
Posttest (Experimental vs. Control)	1,680	1	50	0,201	Homogeneous

The homogeneity test was conducted using Levene's Test to determine the equality of variances between the experimental and control classes. The data were considered homogeneous if the significance value (p) was greater than 0.05.

Based on Table 3, the homogeneity test results for the pretest data of the experimental and control classes showed a significance value of 0.417 ($p > 0.05$). These results indicated that the variance of students' initial abilities in both classes was homogeneous.

Furthermore, the homogeneity test results for the posttest data of the experimental and control classes showed a significance value of 0.201 ($p > 0.05$). This indicated that the variance of students' final abilities in both classes was also homogeneous.

Thus, it can be concluded that the pretest and posttest data in both the experimental and control classes met the assumption of homogeneity. Therefore, the analysis could be continued using a parametric statistical test in the form of the Independent Sample T-Test.

This test was conducted to determine the differences in computational thinking skills between the experimental and control classes. The analysis results showed a significance value of $p < 0.05$, indicating a significant difference between the two classes.

Table 4. Results of the Independent Sample T-Test

Data	t	df	p-value	Interpretation
Posttest (Experimental vs. Control Group)	4,81	50	< 0,001	Significant

The Independent Sample T-Test was conducted to determine the differences in students' computational thinking skills between the experimental and control classes after receiving different learning treatments.

Based on the analysis results presented in Table 5, the t-value was 4.81 with a degree of freedom (df) of 50 and a significance value of $p < 0.001$. The significance value was smaller than 0.05, indicating a significant difference in computational thinking skills between students in the experimental and control classes.

These results indicated that students who participated in digital ethnomathematics learning using ECOPEDIA demonstrated better computational thinking skills than students who participated in conventional learning. However, it is important to interpret these findings with due caution, as the study employed a quasi-experimental design with purposive sampling rather than individual random assignment to treatment conditions . Consequently, causal claims regarding the direct effect of ECOPEDIA on students' computational thinking skills cannot be conclusively established, as unmeasured confounding variables, such as prior mathematical ability, motivation, or teacher effects, may have influenced the observed outcomes.

What can be reasonably inferred from these results is that, within the specific sample and context of this study, the ECOPEDIA-based instruction was associated with significantly higher computational thinking performance compared to conventional instruction. The statistically significant difference between groups, supported by the N-Gain and effect size values, provides empirical evidence that the intervention is effective in this particular setting. Nevertheless, the results should be viewed as indicating a difference that supports effectiveness, rather than definitive proof of causation, and generalization to broader populations requires further replication studies with randomized designs or larger and more diverse samples.

Therefore, learning using ECOPEDIA proved to be more effective in improving students' computational thinking skills within the scope of this study, with the understanding that these promising findings warrant cautious interpretation and further validation through subsequent research.

Table 5. Results of the N-Gain Analysis

Group	Mean Pretest	Mean Posttest	N-Gain	Category
Experimental	50,7	84,8	0,69	Medium
Control	54,7	71,2	0,36	Medium

The N-Gain analysis was conducted to determine the level of improvement in students' computational thinking skills after the learning process.

Based on the calculation results, the experimental class obtained an average N-Gain score of 0.69, which was categorized as moderate. Meanwhile, the control class obtained an average N-Gain score of 0.36, which was also categorized as moderate.

Although both classes were categorized as moderate, the N-Gain score of the experimental class was higher than that of the control class. These results indicated that digital ethnomathematics learning using ECOPEDIA provided a better improvement in students' computational thinking skills compared to conventional learning.

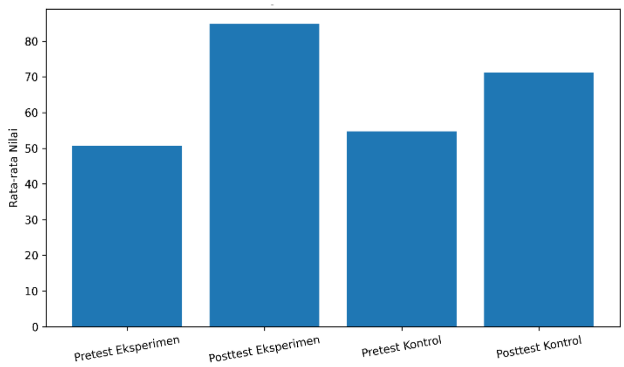


Figure 2. Graph of the Improvement in Computational Thinking Skills Based on N-Gain

Based on Figure 2, there was an improvement in students' computational thinking skills in both the experimental and control classes after the learning process. In the experimental class, the average score increased from 50.7 in the pretest to 84.8 in the posttest. Meanwhile, in the control class, the average score increased from 54.7 to 71.2.

The improvement in the experimental class was higher than that in the control class. This indicated that digital ethnomathematics learning using ECOPEDIA had a better effect on improving students' computational thinking skills compared to conventional learning.

Discussion

The results of this study demonstrate that digital ethnomathematics learning using ECOPEDIA significantly improves students' computational thinking skills. This finding is evidenced by the substantial increase in the experimental group's mean score from 50.7 in the pretest to 84.8 in the posttest, supported by a statistically significant result ($p < 0.001$). A more analytical examination of these results reveals that the improvement occurred across all four computational thinking dimensions measured, with notable variations in the magnitude of gain across indicators.

Specifically, the decomposition indicator showed the most substantial improvement, which can be attributed to the Module 1 activity where students systematically break down the kendang construction process into measurable components, identifying diameter, height, and volume as distinct sub-problems (Angeli et al., 2016; Dagienė et al., 2017). This finding aligns with the CT framework proposed by Selby & Woollard (2013), which defines decomposition as the skill to break a complex problem into smaller, understandable parts. In ECOPEDIA, students engage in this process through the artifact breakdown tool, which guides them to analyze the kendang not as a single entity but as a composite of geometric elements, thereby mirroring the decomposition process in computational problem-solving (Lee & Wu, 2025).

The pattern recognition indicator, previously identified as the weakest dimension among elementary students (Indrawati et al., 2025), demonstrated a significant gain. This improvement can be traced to Module 2 activities, where students identify numerical sequences in angklung tube lengths and their relationship to pitch frequencies. The sequence identification game within ECOPEDIA requires students to detect recurring patterns and formulate generalizations, skills that directly correspond to pattern recognition and generalization in computational thinking (Dagienė et al., 2017). This finding corroborates research by Indrawati et al. (2025), which emphasized pattern recognition as a critical area requiring instructional intervention.

The abstraction indicator showed consistent gains, likely facilitated by the symbolic representation builder feature in ECOPEDIA. This feature requires students to represent the kendang volume formula and angklung length proportions symbolically, removing extraneous details to focus on essential mathematical relationships (Angeli et al., 2016). This process reflects the core of abstraction in CT: deciding what information to keep and what to ignore. The improvement in this dimension is particularly noteworthy, as previous research identified abstraction as a common area of difficulty in fraction problem-solving, with 78.9% of students struggling to abstract mathematical relationships from contextual information (Indrawati et al., 2025).

Algorithmic thinking, encompassing the ability to devise step-by-step operations and execute them in correct sequence (Angeli et al., 2016), was developed through Module 3 activities. Students design a systematic procedure for creating a simplified angklung set, including measurement, cutting, and assembly sequences. The step-by-step procedure designer in ECOPEDIA explicitly scaffolds this process, requiring students to arrange actions in the correct order and verify their sequence, a process that aligns with algorithmic thinking development as defined in the CT literature (Dagienė et al., 2017). The debugging component, though not a primary focus of this study, emerged incidentally as students identified and corrected errors in their procedural designs.

The effectiveness of ECOPEDIA can thus be explained not merely by its contextual and meaningful learning experiences, but by its systematic alignment between each feature and specific computational thinking indicators. By integrating ethnomathematics, students are able to connect abstract mathematical concepts with real-life cultural contexts, which enhances their conceptual understanding. This finding is consistent with previous studies indicating that culture-based mathematics learning improves students' understanding and engagement (Jannah et al., 2023; Fadillah et al., 2022). However, this study extends those findings by demonstrating that the improvement is not monolithic; rather, each CT indicator develops through different mechanisms and activities within the digital ethnomathematics platform, providing a more nuanced understanding of how such interventions work.

Furthermore, the integration of digital media in ECOPEDIA supports interactive and student-centered learning. Students actively engage in problem-solving processes involving decomposition, pattern recognition, abstraction, and algorithmic thinking. These processes are essential components of computational thinking and are effectively facilitated through structured digital learning environments. This supports the findings of Suarsana et al. (2023), who emphasized the importance of integrating computational thinking into mathematics learning. To provide a clearer basis for comparison, it is important to describe the instructional conditions experienced by both groups. In the experimental class, students engaged with the ECOPEDIA platform across four 70-minute sessions, each featuring interactive simulations, artifact breakdown activities, sequence identification games, and step-by-step procedure design tasks, all within culturally contextualized scenarios. Students worked individually and in small groups, with the teacher acting as a facilitator who guided exploration and discussion rather than delivering direct instruction.

In contrast, the control class followed conventional instruction using the standard school curriculum without digital or ethnomathematics components. The learning activities consisted of teacher-led explanations of fraction and geometry concepts, followed by individual worksheet-based practice. Teachers presented materials using whiteboard and textbook demonstrations, and students solved problems through repetitive exercises without explicit scaffolding for computational thinking processes such as decomposition or algorithmic thinking. This instructional approach represents the typical mathematics teaching practice in the participating schools, as confirmed through classroom observations conducted prior to the study.

The differences in instructional design between the two conditions provide a plausible explanation for the observed outcome: the experimental group's significantly higher posttest scores and N-Gain (0.69) compared to the control group (0.36). The experimental condition's emphasis on structured, interactive problem-solving with explicit CT scaffolding appears to have facilitated more robust development of computational thinking skills. By contrast, the control condition's reliance on direct instruction and rote practice may have offered fewer opportunities for students to independently engage in decomposition, pattern recognition, and algorithmic reasoning, processes that are central to CT development. This interpretation aligns with research by Wing (2006) and Shute et al. (2017), which emphasizes that computational thinking skills are best cultivated through active, problem-based engagement rather than passive reception of information.

However, it is important to note that the characterization of the control class instruction as conventional is based on observational data regarding its structural features (teacher-led delivery, worksheet practice, absence of digital tools) rather than a systematic assessment of its pedagogical quality. Without direct measures of student engagement or teacher-student interaction patterns, we refrain from labeling the control condition as "teacher-centered" in a pejorative sense. Rather, we describe the control treatment as representing the standard instructional practice in this school context, which differs from the experimental treatment primarily in its use of digital ethnomathematics content, explicit CT scaffolding, and interactive problem-solving structure.

In addition, the results of the Independent Samples t-Test revealed a significant difference between the experimental and control groups ($p < 0.001$), with the experimental group achieving higher posttest scores. These findings suggest that, within this sample, ECOPEDIA demonstrated greater effectiveness compared to the conventional instructional approach. The N-Gain analysis confirmed that the experimental group (0.69) achieved a higher level of improvement compared to the control group (0.36). This finding indicates that the integration of ethnomathematics and digital technology provides a more optimal learning environment for enhancing students' computational thinking skills in this particular context.

Overall, this study highlights the importance of combining cultural context and digital technology in mathematics learning. Such integration not only improves learning outcomes but also supports the development of essential 21st-century skills, particularly computational thinking and problem-solving abilities.

Conclusion

Based on the results of the study, it can be concluded that within the scope of this research, specifically among fifth-grade elementary school students at SDN Sumberrejo 1, on the topics of fractions and geometry, and using the ECOPEDIA platform over four instructional sessions, digital ethnomathematics learning using ECOPEDIA was effective in improving students' computational thinking skills. This was evidenced by the significant increase in students' posttest scores in the experimental class compared to the control class. The results of the Paired Sample T-Test and Independent Sample T-Test also showed significant differences, with the experimental group demonstrating a higher mean gain (84.8 vs. 70.2) and N-Gain (0.69 vs. 0.36) compared to the control group. These findings indicate that, in this particular sample and context, the integration of ethnomathematics and digital media provided a more contextual, interactive, and meaningful learning experience, enabling students to better understand mathematical concepts and solve problems systematically.

However, several limitations should be acknowledged when interpreting these conclusions. First, the quasi-experimental design with purposive sampling, rather than individual random assignment, limits the ability to attribute the observed differences solely to the ECOPEDIA intervention, as unmeasured variables such as prior mathematical achievement, student motivation, and teacher effects may have contributed to the outcomes. Second, the study was conducted in a single school setting with a relatively small sample ($n=56$), which constrains the generalizability of the findings to other populations, grade levels, or cultural contexts. Third, the intervention duration of four sessions may not capture the long-term retention or transfer of computational thinking skills to novel problem-solving situations beyond the specific fraction and geometry topics addressed. Fourth, the study did not assess the durability of CT skill gains over an extended period, leaving open questions about whether the observed improvements are sustained or fade over time.

Despite these limitations, the findings offer several practical implications for mathematics instruction in elementary schools. First, the success of ECOPEDIA suggests that integrating culturally familiar artifacts, such as traditional musical instruments, into digital learning platforms can effectively scaffold specific CT processes, particularly decomposition through artifact breakdown activities, pattern recognition through sequence identification tasks, and algorithmic thinking through procedure design exercises. Second, the structured, module-based design of ECOPEDIA, with explicit mapping of each feature to CT indicators, provides a replicable instructional model that teachers can adapt to other mathematical topics or local cultural contexts. Third, the significant improvement observed across all CT dimensions, especially on pattern recognition which was previously identified as the weakest indicator, indicates that ECOPEDIA may serve as a targeted intervention for addressing specific areas of difficulty in computational thinking development.

Based on these findings, it is recommended that ECOPEDIA be considered as a supplementary instructional tool for elementary mathematics teachers, particularly in schools with access to digital devices and internet connectivity. However, practitioners should note that the platform was designed specifically for fraction and geometry content within the Osing cultural context; adaptation to other topics or cultural settings would require careful redesign and validation. Furthermore, to maximize the benefits, teachers should allocate sufficient time for each module and provide guided facilitation during exploratory activities, as the scaffolding embedded in ECOPEDIA is most effective when complemented by teacher support and peer discussion. For future research, replication studies with larger, more diverse samples and randomized designs are warranted to confirm the generalizability of these findings. Additionally, longitudinal studies examining the long-term retention of CT skills and the transferability of these competencies to other mathematical domains would provide valuable insights into the sustainability of the intervention's effects.

In summary, within the limitations and context of this study, ECOPEDIA demonstrated effectiveness as an innovative learning medium to support mathematics learning in elementary schools, particularly in developing students' computational thinking skills as part of 21st-century competencies, provided that the platform is used under conditions similar to those described in this research.

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