
Implementation of Web-Based Educational Games in Addition and Subtraction Learning for Grade II Elementary School Students

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ABSTRACT

Basic numeracy and learning engagement in the lower grades of Indonesian primary schools remain persistent concerns, yet qualitative accounts of how web-based educational games unfold in ordinary classrooms are scarce. This qualitative case study examines a web-based educational game, Game Counting Ceria, used in Grade II addition and subtraction lessons at a state primary school in Sambas Regency, West Kalimantan. Data were generated across five lessons through non-participant observation of 28 enrolled pupils (26 present in the focal session), a structured teacher observation of twelve implementation indicators, child-friendly interviews with ten pupils sampled for maximum variation in attainment, dated field notes, and documentation. Four focal cases (X01 to X04) are reported in depth. Thematic analysis followed six phases, with every theme traced back to dated raw-data references through an explicit analytic chain, an audit trail of coding decisions, and member checking with the class teacher. Five themes were constructed: behavioral engagement expressed as self-initiated retrying; emotional engagement tied to immediate scoring feedback; cognitive engagement that remains procedural; implementation constraints driven by the device ratio rather than connectivity; and the teacher's role, strong in scaffolding yet weak in conceptual consolidation at closing. Discrepant cases are reported, including pupils who waited for peers before attempting, enthusiasm that decayed after the tenth minute among those queuing, and a persistently limited capacity to justify answers despite high enthusiasm. Claims are therefore bound to engagement and learning experience rather than numeracy attainment.

Keywords: *addition and subtraction, learning engagement, lower-grade primary school, qualitative case study, web-based educational games*

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INTRODUCTION

Basic numeracy skills determine success in mathematics at the next level, yet mastery of them in many elementary schools in Indonesia is inadequate. Mapping the numeracy ability profiles of elementary school students found that some children still struggle with simple number operations, and these difficulties often stem from presentation methods that fail to generate engagement (Supriyanto et al., 2024). In lower grades, this problem is even more pronounced. Addition and subtraction, which should be mastered fluently, are instead learned through repetitive, monotonous exercises, quickly eroding students' attention and rendering the class passive.

A similar pattern was seen among second-grade students at a public elementary school in Sambas Regency, West Kalimantan. Teachers faced two challenges simultaneously: some students' arithmetic skills were unstable, and their engagement during lessons tended to be low. The two interlocked. Children who found learning activities boring were reluctant to participate, and this reluctance hindered conceptual mastery. The need for more interactive learning media that better suited the characteristics of lower-grade children was therefore urgent, not merely complementary.

One avenue that has grown rapidly over the past decade is the use of games as a learning tool. A large-scale meta-analysis showed that game-based learning has a positive effect on student achievement (Karakoç et al., 2022), including on critical thinking skills (Mao et al., 2022) and science achievement compared to conventional methods (Lei et al., 2022). A previous systematic review reached a similar conclusion: well-designed digital games are associated with higher learning outcomes (Clark et al., 2016). This evidence provides a strong basis for the idea that learning to count doesn't have to feel like a burden.

The benefits of games extend beyond entertainment to fostering engagement and motivation. Digital games integrated into learning activities have been reported to increase engagement and an internal drive to continue trying (Nadeem et al., 2023), and the growth of learning motivation is often mediated by students' level of engagement during play (Li et al., 2024). In mathematics, adaptive math game applications have been reported to support personalized learning and improve early grade achievement (Bang et al., 2023), purpose-built digital games improve understanding of number concepts (Kärki et al., 2022), and gamified e-books enhance student performance, motivation, and metacognitive awareness (Zhao et al., 2021). Comparisons of classrooms with and without digital games have even shown that mathematical knowledge acquisition is influenced by students' intrinsic motivation and cognitive load (Xiang et al., 2025).

Behind these achievements lies an interesting behavioral dimension. Observations of student behavior in video game-assisted math classes show an increase in the proportion of time actually spent on task and a decrease in off-task behavior (Beserra et al., 2019). This finding is important because what is expected of a lively classroom is purposeful activity, not noise. More broadly, gamified learning has been reported to have a positive impact on cognitive learning outcomes, motivation, and behavior simultaneously (Sailer & Homner, 2020).

Web-based media offers unique advantages. Unlike apps that require installation, web-based games run directly through a browser on a variety of devices, are easily updated by developers, and don't require large storage space. These characteristics ease the technical burden on teachers and schools, particularly in areas with limited facilities. The development of web-based mathematics media for elementary schools has demonstrated practical feasibility (Fasa & Purwanti, 2023), and a broader review confirms the potential of digital media to foster engagement in elementary education (Salam et al., 2024).

However, there are gaps that remain largely unexplored. The research corpus reviewed in this article relies on a quantitative paradigm and focuses on measuring effectiveness through the difference between pre-test and post-test scores or other experimental designs (Karakoç et al., 2022; Lei et al., 2022; Mao et al., 2022). This approach answers the question of whether a medium has an effect but fails to explain how this process occurs in real classrooms. It should be emphasized that the literature search in this article is targeted, not a systematic review: references were collected through a search of Scopus, Crossref, and Google Scholar using a combination of the keywords *game-based learning*, *digital game*, *engagement*, *numeracy*, and *primary school*.

for publications from 2016 to 2025, and then filtered for relevance to lower-grade numeracy. Because this search strategy did not employ the PRISMA protocol, the gap claims in this article are limited to the corpus reviewed and are not presented as a comprehensive mapping of the entire available literature.

This study fills this gap by in-depth describing what actually happens when a web-based educational game is used to teach addition and subtraction to second-grade students at a public elementary school. The research question is stated in descriptive-interpretive language, consistent with the capabilities of a qualitative case study design that explores manifestations, experiences, and mechanisms, rather than establishing causal influences. Four research questions guide this research. First, how is the web-based educational game implemented in addition and subtraction learning in this classroom? Second, what forms of behavioral, emotional, and cognitive engagement are manifested during implementation? Third, how do students interpret their learning experiences? Fourth, what is the teacher's role and what obstacles arise in actual classroom conditions?

To maintain a streamlined and hierarchical theoretical framework, this study positions student engagement theory as the primary analytical lens and uses four other perspectives as supporting lenses with limited functions. Student engagement theory was chosen as the primary lens because it provides the analytical distinction that most directly addresses the research problem, namely the behavioral, emotional, and cognitive dimensions (Fredricks et al., 2004). Game-based learning is used in a limited way to interpret the cycle of play experiences (Kiili, 2005); constructivism to interpret the construction of knowledge through interaction and gradual assistance (Vygotsky, 1978; Wood et al., 1976); cognitive development theory to consider the appropriateness of representations to the characteristics of children in the concrete operational stage; and TPACK to interpret how teachers integrate content, pedagogy, and technology (Mishra & Koehler, 2006). The position of each perspective is summarized in Table 1.

Table 1. Conceptual framework of the research and the function of each theoretical perspective

Theoretical framework	Position	Limited interpretive function	References
Student engagement	Main analytical lens	Provides differentiation of behavioral, emotional, and cognitive dimensions as a framework for coding and naming themes.	Fredricks et al. (2004); Li & Xue (2023)
Game-based learning	Support lens	Interpreting the cycle of trying, receiving feedback, and retrying observed in play sessions.	Kiili (2005); Clark et al. (2016)
Constructivism and gradual assistance	Support lens	Interpreting teacher assistance that guides without giving answers and interactions between students during turns playing.	Vygotsky (1978); Wood et al. (1976)
Concrete operational stage cognitive development theory	Support lens	Considering the suitability of the problem representation and counting strategies of grade II students with their developmental stage.	Bang et al. (2023); Karki et al. (2022)
TPACK	Support lens	Interpreting how teachers integrate addition and subtraction content, pedagogical strategies, and technology operations.	Mishra & Koehler (2006); Zeng et al. (2022)

METHOD

This research is a qualitative case study that has been implemented, not a proposed design. The design choice stems from the nature of the problem formulation, which requires an in-depth description of a practice, not an examination of relationships between variables. Qualitative design is intended to understand human meaning and experience in its natural context (Creswell & Poth, 2018), and in the tradition of educational research in Indonesia, this approach is

commonly used to examine learning processes in a naturalistic manner ([Sugiyono, 2019](#)). The case study was chosen because the phenomenon being studied is tied to a specific class and cannot be separated from its environment ([Yin, 2018](#)), allowing researchers to trace it through various sources of evidence and interpret it as a whole ([Stake, 1995](#)).

Background, participants, and researcher position

The research took place at an elementary school in Selakau sub-district, Sambas Regency, West Kalimantan Province, with a second-grade class consisting of 28 registered students. Observations were conducted throughout five addition and subtraction learning sessions. The session focused on reporting was the second meeting, which took place from 7:30 to 8:40 a.m. and was attended by 26 of the 28 students; attendance was recorded for each session so that differences between sessions could be tracked. The second-grade teacher in charge of the lesson, hereinafter referred to as GX, served as the primary informant for the implementation aspect.

Interviews were conducted with ten students purposively selected using maximum variation logic, representing high, moderate, and needing support in numeracy according to the teacher's daily assessment and the results of the first session observation. Inclusion criteria included attendance at the observed session, participation in playtime, child willingness, and written parental consent. Four of these students were reported as focal cases and coded X01, X02, X03, and X04; these four were chosen because they together spanned all ability categories in the class, allowing for both patterns and deviations from the patterns to be equally visible. Six other students served as data saturation checks and are not reported separately because they did not generate new codes.

The researcher acted as a non-participant observer and had no employment or kinship relationship with the school. During the session, the researcher sat at the back of the classroom, giving no instructions, and intervening in the lesson; the teacher remained the sole administrator of the classroom. This position was noted because it affected what could and could not be observed: the researcher could record behavior and speech, but could not directly test students' understanding. Awareness of this limitation contributed to the decision to limit the research claims to engagement and learning experiences. Ethical considerations were met by explaining the purpose of the study to the principal and class teacher, obtaining written permission from the school, requesting parental consent by letter, and inquiring about each child's willingness to participate before the interview began. All identities were disguised using code. Children were informed that they could stop at any time, and this right was exercised: one interview was stopped at the twelfth minute when the child became distracted by friends leaving the classroom.

Implementation description

Fidelity of implementation requires that the game used be described in sufficient detail to allow for replication. The game, called Game Angka Ceria (Certain Counting Game), is run through a browser by opening a link without installing an app or creating an account. It is written in Indonesian and displayed on an interactive screen at the front of the class. The questions focus on adding and subtracting numbers below one hundred, presented as answer choices that are pressed directly on the screen. Correct or incorrect feedback appears immediately in the form of an on-screen mark, with stars added for correct answers, and a repeat button allows students to retry incorrect questions. The difficulty level is set by the teacher before the session begins and does not change automatically based on student performance. Detailed specifications are presented in [Table 2](#).

Table 2. Game implementation specifications as a basis for replication

Implementation elements	Conditions observed in the field
Name of the game	Fun Counting Games and Math Games
Access mode	Web browser via link; no app installation, no account, no additional paid quota
Interface language	Indonesian

Implementation elements	Conditions observed in the field
URL	https://Game.afifedu.com https://coolmath4kids.com
Types of question items	Addition and subtraction of numbers under one hundred, including two-digit subtraction by borrowing; answer choice format pressed on the screen
Feedback mechanism	True or false signs appear instantly on the screen; Star score increases on correct answers; there is a retry button to try again
Difficulty settings	Some difficulty levels are selected by the teacher before the session; they do not adjust automatically to student performance.
Features not available	Leaderboards, simultaneous player competition, adaptive difficulty, and personalized learning paths
Devices and ratios	One interactive screen for 26 students present (ratio 1 : 26)
Sequence of use in the lesson	The teacher writes and reads the learning objectives, opens the game, demonstrates one question in front of the class, divides the class into five groups taking turns, pauses the game to discuss questions that were answered incorrectly, and then closes the lesson.
Playtime per child	Less than five minutes into the observed session
Network conditions	There were no network or device disruptions during the observed session.

Collection techniques and instruments

Data were generated through five complementary techniques, as summarized in [Table 3](#). Student observations used a structured sheet containing fifteen indicators divided into behavioral, emotional, and cognitive dimensions; each indicator was scored from one to three as a recording tool, while the description of behavioral evidence in the notes column was analyzed. Teacher observations used a separate sheet containing twelve indicators spanning planning, content, technology, pedagogy, TPACK, scaffolding, differentiation, interaction, feedback, classroom management, handling technical problems, and closing; indicators that were not observed were recorded as unobserved along with a description of the situation to ensure information about the implementation conditions was not lost.

Student interviews were semi-structured and written in child-friendly language. Each interview lasted approximately ten to fifteen minutes, was conducted in the front foyer of the classroom immediately after the session ended to allow for fresh impressions, and was recorded with the child's consent using a mobile phone voice recorder. Recordings were transcribed verbatim on the same day, and each turn was assigned a number and a student code that matched the transcript header so that each quote could be traced back. Interviews were not repeated with the same child; any necessary clarifications were sought through member checking with the teacher. Nonverbal notes, interruptions, and the time and reason for interruptions were recorded on the same sheet as the transcript.

Field notes were compiled per meeting, coded CL followed by the meeting number. They included time-stamped events, spontaneous student remarks, important teacher remarks, technical obstacles, and interactions. The event column contained only what was seen and heard, while the researcher's interpretation was placed in a separate reflection section, allowing readers to distinguish observations from conclusions. Documentation in the form of activity photos, student worksheets, and teaching modules was collected for comparison.

Table 3. Data collection techniques, sources, information focus, and form of notes

Technique	Data source	Information focus	Note form
Classroom observation (non-participant)	26 students attended the focus session, 5 meetings	Forms of behavioral, emotional, and cognitive engagement during play turns	Student observation sheet 15 indicators

Technique	Data source	Information focus	Note form
Observation of teacher practice	Grade II (GX) teacher	Planning, operating technology, scaffolding, feedback, and closing the lesson	Teacher observation sheet 12 indicators
Student interviews	10 students (maximum variation), 4 reported in-depth	Feelings, likes, difficulties, ways of coping, and evidence of understanding	Turn-numbered verbatim transcript
Field notes	Class atmosphere per meeting	Time-stamped events, spontaneous speech, technical obstacles, and interactions	CL coded narrative notes
Documentation	Learning archives	Activity photos, student worksheets, teaching modules, and game links	Documentation files

Data analysis

The analysis used thematic analysis with six stages: familiarizing the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and compiling a report (Braun & Clarke, 2006). The process was iterative, not linear, so the researcher returned repeatedly to the raw data whenever a theme needed to be refined. Coding was conducted by a single researcher. Because there was no second coder, intercoder agreement could not be reported; instead, three compensatory strategies were used: a dated audit trail of analytic decisions, tracing each theme back to the raw data reference, and member checking with the classroom teacher. This limitation is openly acknowledged and discussed again in the limitations section.

Open coding on the second day yielded 34 initial codes from field notes and observation sheets. These codes were then simplified: on the fourth day, the codes "repeat yourself" and "try again" were combined because they referred to the same behavior; on the sixth day, network barriers were separated from device barriers after data indicated they did not co-occur; and on the ninth day, "pleasure" was demoted from a theme to a category under "emotional engagement" because it did not stand alone. On the eleventh day, a summary of the findings was returned to the GX teacher for confirmation. All decisions, along with their rationales, are recorded in the audit trail presented in Table 4.

Table 4. Audit trail of analytical decisions

Time	Activities or decisions	Reason	The resulting file
Day 2	Compile 34 initial codes from CL-02 and observation sheets	First stage open coding	initial-code-v1
Day 4	Combine self-repeat and retry codes into one	Both refer to the same behavior	initial-code-v2
Day 6	Separating network bottlenecks from device bottlenecks	Data shows that the two do not appear together.	category-v1
Day 9	Relegating the theme of pleasure to a category under emotional engagement	Pleasure does not stand alone as a theme	theme-v2
Day 11	Return the summary of findings to the GX teacher	Member check	confirmation note

To allow for auditability of the chain of analysis, each theme in this article is traced back to a specific raw data reference. Pointers such as CL-02 at 08:05 or Transcript X02 turn 8 allow the reader to move from a theme back to the data fragment that gave rise to it. A complete example of moving from raw data to initial codes, categories, and themes is presented in Table 8, while a summary of the themes and their deviant cases is presented in Table 9.

Trustworthiness

Trustworthiness was maintained through four criteria common in the qualitative tradition: credibility, transferability, dependability, and confirmability ([Lincoln & Guba, 1985](#)), each of which was implemented through concrete steps, not simply stated. Credibility was achieved through source and technique triangulation and member checking. Source triangulation compared student accounts, teacher accounts, and the researcher's observations of the same event; technique triangulation compared observation sheets, interview transcripts, field notes, and documentation. For example, X02's statement in turn 8 that she repeated and counted on her fingers was compared with CL-02's field notes at 8:05 AM and with indicators 5 and 12 on the observation sheet; all three indicated the same behavior, so the code "initiative to repeat" was retained. Member checking was conducted on the eleventh day by returning a summary of the findings to GX's teacher; the teacher confirmed that the description of the turn-play and the device ratio constraints were consistent with her experience ([Morse et al., 2002](#); [Shenton, 2004](#)).

Discrepancies between sources were not smoothed over but rather maintained and reported. When high enthusiasm on the emotional observation sheet was inconsistent with low scores on the indicator of ability to explain answers, both were recorded and became the basis for limiting the study's claims. Similarly, when the initial suspicion that the primary obstacle was network disruption was not supported by the data, it was dropped and replaced by the category of limited device access. Reliability and confirmability were supported by an audit trail that documented dates, decisions, rationales, and the resulting files at each stage, including decisions that were later changed. Transferability was achieved through a sufficiently rich contextual description of the setting, device ratio, and lesson flow, allowing readers to assess the relevance of the findings to their own classes. Reflexivity was maintained by separating the event column from the reflection column in the field notes and by recording the researcher's initial biases for cross-examination ([Adler, 2022](#)).

RESULTS AND DISCUSSION

Result

This section reports what actually happened to second-grade students at an elementary school in Selakau sub-district, Sambas regency, when the Fun Counting Game and the Math Game were used to teach addition and subtraction, and then interprets the results. To clearly distinguish the research findings from theoretical interpretations, each theme is presented in three consistent steps. The first step presents the case findings along with evidence and references to the raw data. The second step interprets the findings through analytical lenses and prior research. The third step reports divergent evidence, deviant cases, and contextual limitations that limit the applicability of the findings. This order is maintained consistently across the five themes so that readers always encounter the case evidence first, followed by the literature-based explanations.

Analysis of all data yielded five themes: behavioral engagement, emotional engagement, cognitive engagement, implementation barriers, and the teacher's role in technology integration. Before describing the five themes, [Table 5](#), [Table 6](#), and [Table 7](#) present a basic overview of the cases: the engagement profiles of the four focal cases based on observations, interview findings for each of the four, and teacher practices across the twelve implementation indicators.

Table 5. Involvement profile of four focus cases based on classroom observations

Code	Ability Categories	Behavior	Emotional	Cognitive	The Main Difficulty	Typical Responses Observed
X01	Tall	Tall	Tall	Currently	Not yet visible	Answer quickly and often precede the teacher's signal
X02	Currently	Tall	Tall	Currently	Reduction by borrowing	Repeating oneself after making a mistake; counting on fingers for subtraction problems

Code	Ability Categories	Behavior	Emotional	Cognitive	The Main Difficulty	Typical Responses Observed
X03	Currently	Currently	Currently	Low	Reading questions	Wait for your friend to answer first before trying
X04	Need support	Low	Currently	Low	Not yet recognizing the minus symbol	Need to be encouraged to move forward; after being helped once, willing to try

Table 6. Interview findings from four focus cases

Code	Feeling	Things to Like	Difficulty	How to Overcome	Source of Help	Evidence of Understanding
X01	Happy and want to continue	Time challenge	Not yet visible	Answer directly	Don't ask for help	Explaining how to add tens
X02	Like	Stars and scores	Subtraction	Repeating and counting with fingers	The teacher approached without being asked	Cannot explain the reason for the answer
X03	Happy but shy	Images in the game	Reading questions	Waiting for a friend	Seatmate	Imitating a friend's way
X04	Afraid of making mistakes at first	Sound sign is correct	Minus symbol	Guided by the teacher	Teacher	Not yet visible

Table 7. Teacher practices in implementation based on teacher observation sheets

No	Aspect	Indicator	Observed	Evidence and description
1	Planning	Conveying learning objectives	Yes	Write the objectives on the board and then read them aloud with the students.
2	Content	Game material according to class II	Yes	The questions revolve around addition and subtraction under one hundred.
3	Technology	Able to operate the game	Yes	Open links and set difficulty levels without assistance
4	Pedagogy	Explaining the rules of the game in simple terms	Yes	Demonstrate a problem in front of the class before students try it.
5	TPACK	Connecting games with mathematical concepts	Part	Connects at the start of the session, but does not repeat at the close
6	Scaffolding	Helping students who are having difficulties	Yes	Come to X04 and guide him to count on his fingers, not give him the answer.
7	Differentiation	Providing different support according to ability	Not observed	Because one screen is used in turns, the teacher handles the class simultaneously.
8	Interaction	Asking a provocative question	Yes	Ask the class how to know if the answer is correct.
9	Feedback	Discussing right or wrong answers	Yes	Pause the game for a moment to discuss a question that many people answered incorrectly.
10	Classroom management	Keeping students learning	Yes	Arrange turns per group so that students who are waiting can continue working on the worksheet.
11	Technology	Troubleshoot network or device issues	Not observed	There were no interruptions in this session

No	Aspect	Indicator	Observed	Evidence and description
12	Closing	Invite students to conclude the concept	Part	Asking students how they feel, but not drawing conclusions about their mathematical concepts

Behavioral Engagement That Emerges as a Repeat Initiative

The most prominent form of behavioral involvement in this case was not simply a willingness to participate, but the initiative to repeat after an incorrect answer without being prompted. Field notes recorded at 8:05 AM that X02 made a mistake on the question 23 minus 7, pressed the repeat button without being prompted, and answered correctly on the second try (CL-02 at 8:05 AM). The same behavior was recorded on the observation sheet under indicator 5, which noted that after making a mistake on the question 14 plus 9, the child immediately pressed the repeat button and tried again without being prompted (Observation X02 indicator 5). The child himself explained this pattern during the interview: he stated that he repeated the question and counted on his fingers before pressing the option (Transcript X02 turn 8). All three sources pointed to the same behavior, so the code of initiative to repeat persisted through triangulation.

This persistence is also evident in indicator 9, which records X02 making three consecutive errors on a subtraction problem but still trying without complaint, and in indicator 3, which records six consecutive answers on the first turn. The most striking event in the session concerns the teacher's response: after three errors on a nested subtraction problem, the child still pressed the repeat button, while the teacher neither reprimanded him nor provided the answer, and only asked him to do the calculation slowly. Repetition initiatives were uneven. X03 and X04 waited for their peers to answer first and showed no initiative to retry at all (Table 5; Transcript X03). X04 even needed to be invited to come forward before being willing to try. The game used had no leaderboard or simultaneous competition between players (Table 2). The triggers observed in this case were immediate feedback and the possibility of retrying, not comparisons of rankings between children.

Emotional Engagement Tied to Score Feedback

Positive affective responses emerged clearly and were closely tied to a specific trigger, namely the increase in scores. The observation sheet for indicator 7 noted that X02 clapped his hands to himself and smiled broadly when the score increased (Observation X02 indicator 7). When asked which part he liked best, the child answered that it was the part with the star, because the star increases if the answer is correct (Transcript X02 turn 4). In turn 2, the child expressed happiness because the activity felt like playing, not like doing a problem. The desire to continue was also recorded in indicator 10, which noted that when his turn was over, the child asked when he could play again, and in turn 10 of the transcript, where the child stated that he wanted to play again but asked that his turn not be too short.

Field notes indicate that positive affect was not limited to the focal case. At 7:38, four students stood up to take a closer look at the screen, and at 8:35, several students responded in unison that they were happy when the teacher asked how they felt (CL-02). All four focal cases, including X04, who was initially afraid of making a mistake, eventually reported feeling happy (Table 6). Enthusiasm did not persist evenly throughout the session. Field notes recorded that at 8:14 a.m. the atmosphere became lively and students waiting for their turn began to stand, prompting the teacher to ask them to return to their worksheets (CL-02 at 8:14 a.m.). The researcher's reflection on the same notes observed that students waiting for their turn tended to lose focus after the tenth minute. In other words, the positive affect in this case was localized to the child's own playing time and faded when students merely watched.

Persistent Cognitive Engagement at the Procedural Level

Cognitive engagement emerged, but stopped at the procedural level. Positive aspects were evident in counting strategies that differed by problem type. Observation indicator 12 noted that X02 counted on his fingers for subtraction problems, while for addition problems under twenty he

answered directly (Observation X02 indicator 12). Indicator 11 noted a pause of approximately four seconds before the child pressed a choice on two-digit problems, and indicator 13 noted that after the screen displayed an incorrect sign, the child changed his choice and was correct on the second try. The child confirmed this distinction himself during the interview: the subtraction problem felt difficult while the addition problem felt easy (Transcript X02 turn 6). The verbatim statement recorded on the observation sheet, namely a request for time to count first, reinforced the impression that the child was indeed processing, not guessing.

The limiting aspect is evident in the last two indicators. Indicator 14 notes that when the teacher asked why the answer was 23, the child simply replied that he counted, without detailing how (Observation X02 indicator 14). Indicator 15 notes that the child did not yet appear to use addition or subtraction terms independently (Observation X02 indicator 15). These two indicators received the lowest scores among the fifteen indicators observed.

The most significant finding regarding cognitive engagement is a discrepancy: the ability to explain reasons for answers remained low despite high enthusiasm. This discrepancy is not smoothed over but retained as a finding. The game used does not automatically adjust its difficulty level to the child's performance ([Table 2](#)). Furthermore, because the researchers were non-participant observers and did not administer learning outcome tests, no achievement data are available to assess changes in numeracy.

Implementation Barriers Stemming From Device Ratios

The main obstacle in this case was not the internet connection, but the imbalance in the device ratio. Field notes recorded that one interactive screen was shared by all 26 students present, resulting in less than five minutes of playtime per child (CL-02, technical obstacle). The consequences of this imbalance were heard directly from students in the form of complaints that they had not yet had a turn (CL-02, spontaneous student statement). A similar complaint emerged during the interview, when X02 stated that he was willing to play again but asked that his turn not be too short because it had felt too fast (Transcript X02 turn 10).

Another consequence was recorded in classroom management. At 8:14 a.m., students waiting for their turn began to stand up, and the atmosphere became noisy, requiring the teacher to return them to their worksheets (CL-02 at 8:14 a.m.). The teacher observation sheet noted that differentiation of support based on ability was not observed precisely because one screen was used in turns, which required the teacher to handle the whole class simultaneously ([Table 7, indicator 7](#)). The researchers' initial suspicion that network disruptions would be a major barrier was not supported by the data: no network or device disruptions occurred in the observed sessions ([Table 7, indicator 11](#)). This suspicion was discontinued on the sixth day of analysis and replaced by the category of limited device access ([Table 4](#)). It is important to note that these findings are closely tied to the one-screen-per-class configuration. Schools with a large number of devices per student will likely face a different set of barriers, and the findings on implementation barriers cannot easily be transferred to such settings.

The Teacher's Role Is Strong in Gradual Assistance but Weak in Consolidation

The teacher performed strongly on ten of the twelve implementation indicators ([Table 7](#)). She wrote and read the learning objectives with students at 7:32, opened a link and set the difficulty level without assistance, demonstrated a problem in front of the class before students attempted it, and divided the class into five rotating groups at 7:41 (CL-02). The type of assistance she provided was notable. At 7:56, X04 was silent when it was her turn, and the teacher approached and guided her to count on her fingers instead of giving the answer (CL-02 at 7:56; [Table 7, indicator 6](#)). The teacher's remarks recorded in the field notes, including an invitation to count slowly and an affirmation that it was fine to be wrong, demonstrate the affective management that accompanied the technical assistance. The teacher also paused the game at 8:22 to discuss a problem that had received many incorrect answers.

Weaknesses emerged at the end of the lesson. Indicator 12 noted that the teacher asked students how they felt but did not draw conclusions about their math concepts, and field notes recorded

that at 8:40 a.m. the lesson closed without conclusions about math concepts (CL-02 at 8:40 a.m.). Indicator 5 showed a similar pattern: the teacher connected the game to math concepts at the beginning of the session but did not repeat this at the end. Two indicators were reported as unobserved, and neither should be interpreted as teacher weakness. Differentiation was unobserved because the one-screen-per-class ratio forced simultaneous handling, while network constraint management was unobserved because no disruptions occurred. Observations of the teacher in this study were also limited to observable classroom behavior; the reasons behind her pedagogical decisions were not explored through in-depth interviews, so interpretations of the consolidation gap rely on behavioral evidence rather than on the teacher's own accounts.

Traceable chain of analysis

The [Table 8](#) presents ten examples of moving from raw data to initial codes, categories, and themes, complete with source references. The data source column is the most important section of the table because it allows anyone to move backward from a theme to the data pieces that gave rise to it.

Table 8. Example of analysis chain from raw data to themes

No	Raw data	Data source	Initial code	Category	Theme
1	"Repeat it again. I'll count using my fingers first, then press it."	Transcript X02, turn 8	retry after error	perseverance	behavioral engagement
2	Pressed the reset button without being asked after making a mistake on 23 minus 7	CL-02, 08.05	repeat initiative	perseverance	behavioral engagement
3	"I'm happy. Because it's like playing, not like doing questions."	Transcript X02, turn 2	feeling happy	positive affective response	emotional involvement
4	Clapping alone when the score increases	Observation X02, indicator 7	reaction to awards	positive affective response	emotional involvement
5	Counting with fingers for subtraction, answering directly for addition under 20	Observation X02, indicator 12	separate counting strategy	resolution strategy	cognitive engagement
6	When asked the reason for his answer, he only answered that he was counting.	Observation X02, indicator 14	can't explain the reason yet	limits of understanding	cognitive engagement
7	"Ma'am, it's not my turn yet."	CL-02, spontaneous speech	uneven playing time	limited access	implementation barriers
8	One interactive screen for 26 students; play time per child is less than five minutes	CL-02, technical constraints	unequal device ratio	limited access	implementation barriers
9	The teacher came to X04 and guided him to count, not giving him the answer.	GX teacher observation, indicator 6	phased assistance	teacher scaffolding	the role of teachers in technology integration
10	The teacher closed the lesson without drawing conclusions about the concept of counting.	CL-02, 08.40	cover without consolidation	pedagogical gap	the role of teachers in technology integration

A recapitulation of the five themes along with the number of codes, number of sources, and deviant cases found is presented in [Table 9](#).

Table 9. Recapitulation of themes, number of codes, number of sources, and deviant cases

No	Theme	Number of codes	Number of sources	Deviant cases found
1	Behavioral engagement	2	2	X03 and X04 waited for their friends to answer first and did not show any initiative to repeat.
2	Emotional involvement	2	2	Enthusiasm dropped sharply in students waiting for their turn after the tenth minute.
3	Cognitive engagement	2	1	The ability to explain the reasons for answers remains low even though enthusiasm is high.
4	Implementation barriers	2	1	There is no network bottleneck in this session; the bottleneck is the device ratio, not the connection.
5	The role of teachers in technology integration	2	2	Teachers are strong on scaffolding, but weak on consolidating concepts at the end of the session.

The boundary between engagement and learning

One of the most important conclusions from this case is that apparent high engagement does not necessarily indicate improved numeracy. The data in this study actually show the two moving apart. X02 scored highest on the behavioral and emotional indicators, but lowest on the ability to explain reasons for answers and connect games to concepts. The researcher's reflections in the field notes anticipated this possibility by noting that apparent enthusiasm does not necessarily equate to cognitive engagement, and that this needed to be assessed in the interview. The assessment was conducted, and the results confirmed this discrepancy: the child could describe how he felt and how he repeated, but could not explain why his answers were correct.

Therefore, all claims in this article are limited to engagement and learning experiences. This study did not administer learning outcome tests, did not collect student work as a measure of achievement, and did not conduct before-and-after comparisons. The claim that web-based educational games improve numeracy skills cannot be substantiated from the available data and is therefore not stated, although quantitative literature reports positive effects of game-based learning on achievement ([Karakoç et al., 2022](#); [Clark et al., 2016](#)). What can be stated from this case is that games create more lively conditions for participation and reduce the psychological costs of errors, while linking these experiences to mathematical concepts still requires pedagogical interventions that were not undertaken in this session.

Cross-theme synthesis

When the five themes are read together, a coherent picture emerges of how a single-screen implementation works in the lower grades. The game successfully captures attention and encourages repeated attempts, especially among children whose abilities are sufficient to experience occasional success. Immediate feedback provides a simple yet effective affective engine. At the same time, the limited turn-taking cuts the experience too short for most children, and the lack of conceptual consolidation at the conclusion prevents the play experience from transforming into articulated understanding. The teacher stands at the center of it all, acting as a facilitator, not as a device operator. This pattern emphasizes that student engagement does not exist in isolation but rather interacts continuously with their learning environment ([Li & Xue, 2023](#)); in this case, that environment takes the very concrete form of a single screen, five groups, and a seventy-minute lesson. The relationships between these domains are mapped in [Figure 1](#).

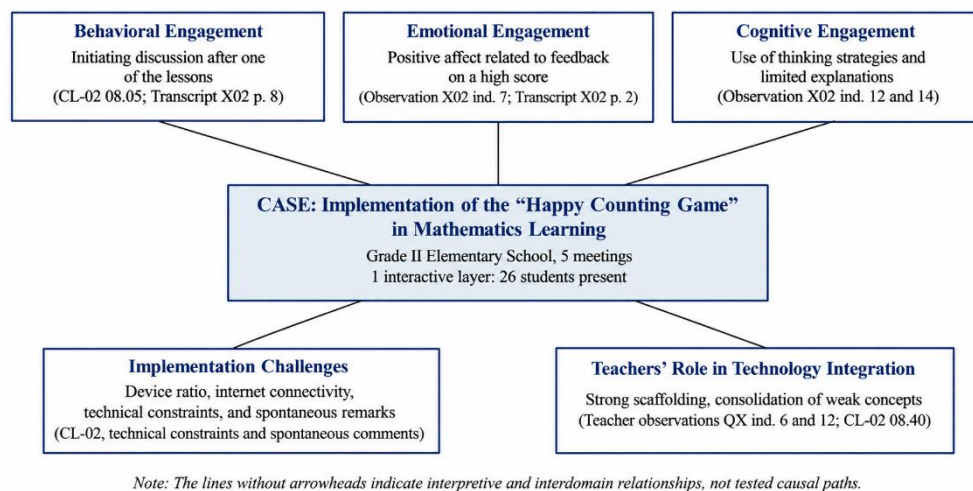


Figure 1. Interpretive domain map of case findings at one of the elementary schools in Selakau sub-district, Sambas district

Discussion

This study examined how lower-grade elementary students engaged with a web-based mathematics game played on a single shared classroom screen, and what shaped that engagement. The findings show a consistent pattern: students engaged readily at the behavioral and emotional levels, engagement was weaker at the cognitive level, and both were shaped by the limits of the device setup and by the teacher's role. The discussion that follows explains each part of this pattern and what it implies.

The initiative to repeat after an error, which appeared across the field notes, the observation sheet, and the interview, is best understood as a behavioral form of engagement, that is, the willingness to devote effort to a task and to persist in the face of difficulty ([Fredricks et al., 2004](#)). What explains it in this case is the design of the feedback. The retry button and immediate feedback made errors cheap: a wrong answer cost the child a few seconds rather than embarrassment in front of the class, so trying again was an easy choice. This pattern of trying, receiving feedback, and trying again matches the experiential gaming model, which treats learning as a cycle of play and reflection ([Kiili, 2005](#)), and it is consistent with the observation that game-assisted mathematics classes show more task-directed behavior ([Beserra et al., 2019](#)). The explanation therefore lies in the feedback loop and not in competition. Because the game had no leaderboard or simultaneous competition, accounts that rely on competitive incentives, as reported for competition-based science games ([Chen, 2019](#); [Chen et al., 2019](#)), cannot be applied here. The uneven pattern also matters: because X03 and X04 did not retry, the claim that the game fostered persistence holds only for some students and appears to depend on their initial ability level and willingness to perform.

The positive affect observed, including clapping, smiling, and asking to play again, is best understood as emotional engagement, that is, expressions of joy and the desire to continue ([Fredricks et al., 2004](#)). The findings show that this affect was anchored in a narrow trigger: correct answers and the resulting increase in stars, which students could observe immediately. It was not anchored in the freedom to choose a learning path or in social closeness between players. This places the case, an elementary school in Selakau sub-district, Sambas Regency, in line with reports that digital games increase learning engagement and motivation ([Nadeem et al., 2023](#); [Li et al., 2024](#)), while suggesting that the mechanism can be much simpler than commonly assumed. The fading of enthusiasm among students who were only watching supports this reading, because it suggests that the affect depended on being the one who plays and receives the feedback. This also fits with the literature showing that the effects of gamification on intrinsic motivation are not always positive and depend on the design and context of implementation ([Jones et al., 2023](#)).

Claims about enthusiasm here are therefore limited to playtime and do not extend to sustained learning motivation.

The counting strategies that differed by problem type suggest that the child was working at the concrete operational stage. Small addition problems were already automated, while subtraction with borrowing still needed physical support such as fingers. This is what the constructivist view would predict, since knowledge is built through meaningful experiences and interactions ([Vygotsky, 1978](#)), and it agrees with reports that specially designed digital games can support the understanding of number concepts ([Kärki et al., 2022](#)). The game gave the child a place to practice this procedure with immediate correction, which explains why cognitive engagement appeared at the procedural level.

The more important finding, however, is the gap between doing and explaining. The child could correct his answers after feedback but could not say why an answer was correct. Within the framework of student engagement, this indicates cognitive engagement that has not yet reached strategic thinking and self-regulation ([Fredricks et al., 2004](#)). A plausible reason is that the game rewarded correct answers and did not ask for reasons, so the feedback loop that produced persistence and enjoyment did not by itself produce explanation. Because the game does not adjust its difficulty to the child's performance, accounts based on personalized learning paths, as reported for adaptive math game applications ([Bang et al., 2023](#)), cannot explain this case. The discrepancy between high enthusiasm and low explanation is therefore the basis for limiting the claims made here: they stop at describing the observed thinking processes.

The implementation barrier in this case was the device ratio and not the network. The literature on gaming platforms in Indonesian elementary schools generally treats network access, data quotas, and device availability as concurrent constraints ([Wijayanti & Prasadja, 2022](#)). This case refines that picture. When a lightweight web-based game is shown on a single classroom screen, the network problem disappears, but turn-taking becomes the dominant problem: with 26 students sharing one screen, each child had less than five minutes, and this is what students' complaints, the classroom noise while waiting, and the missing differentiated support all reflect.

This finding also bears on cognitive load from a different angle. What limited the children was not the complexity of the interface, as discussed in comparisons of classes with and without digital games ([Xiang et al., 2025](#)), but the scarcity of practice opportunities. The challenge of balancing cognitive load and motivation has been reported in other game-based learning settings ([Liu et al., 2023](#)), but here the balance was disrupted by an organizational factor and not by the game design. Because this pattern is tied to a one-screen-per-class configuration, schools with many devices per student will probably face a different set of barriers.

The teacher's guidance, in which she helped X04 count on her fingers instead of giving the answer, is a typical case of gradual assistance in the zone of proximal development: the adult takes over the part of a task the child cannot yet do while leaving the child the part he or she can complete alone ([Wood et al., 1976](#); [Vygotsky, 1978](#)). Her invitations to count slowly and her assurance that mistakes were acceptable show that this assistance was also affective, in line with reports that teachers strongly influence student motivation in technology-assisted learning ([Al-Said, 2023](#)). This helps explain why students who were hesitant, such as X04, eventually took part and reported feeling happy.

The weakness at the end of the lesson can be interpreted through the TPACK framework. The teacher showed adequate command of technology and pedagogy, but the connection between these and the mathematical content became loose at the moment it mattered most, when the play experience should have been tied back to addition and subtraction ([Mishra & Koehler, 2006](#)). This gap is not particular to one teacher: teachers' self-efficacy in integrating technology is closely related to their level of TPACK ([Zeng et al., 2022](#)), and TPACK can be developed through structured interventions such as learning assessments ([Jiménez Sierra et al., 2023](#)). The implication for professional development is clear: what needs strengthening is not the skill of operating the device, but the skill of closing the lesson with conceptual consolidation. Because the observations covered only visible classroom behavior and the teacher's reasons were not

explored in interviews, this interpretation rests on behavioral evidence and not on the teacher's own account.

Taken together, the themes explain why apparent engagement should not be equated with learning. X02 scored highest on the behavioral and emotional indicators but lowest on explaining answers and connecting the game to concepts. The researcher's field-note reflection had anticipated this, noting that visible enthusiasm does not necessarily equal cognitive engagement, and the interview confirmed it: the child could describe how he felt and how he repeated, but could not explain why his answers were correct. The five themes fit together as one account. The game's immediate feedback produced repetition and enjoyment; the single screen limited how much of that experience each child received; and the missing consolidation at the end of the lesson left the experience unconnected to mathematical concepts, so the teacher's role was central throughout.

For this reason, all claims are limited to engagement and learning experiences. The study did not administer learning outcome tests, collect student work as a measure of achievement, or make before-and-after comparisons, so the claim that web-based educational games improve numeracy cannot be supported by these data and is not made, even though quantitative literature reports positive effects of game-based learning on achievement ([Karakoç et al., 2022](#); [Clark et al., 2016](#)). What can be said is that the game created livelier participation and lowered the psychological cost of making errors, while linking that experience to mathematical concepts requires pedagogical work that was not carried out in this session.

Research limitations

Four limitations need to be stated openly. First, this study was a single case study of a single classroom in a single school, so the findings are not intended to be statistically generalized but rather to be assessed for transferability by readers familiar with similar contexts. Second, coding was conducted by a single researcher without a second coder, so intercoder agreement cannot be reported; audit trails, tracing back to the raw data, and member checking were used as counterbalances, but they do not fully replace independent verification. Third, no learning outcome data were available, so the study's claims rest on engagement and learning experiences. Fourth, the single-screen configuration for a single classroom significantly shaped the findings regarding barriers; classrooms with different device ratios are likely to present entirely different sets of barriers.

CONCLUSION

This study describes the implementation of the web-based educational game "Game Angka Ceria" (Fun Counting Game) in addition and subtraction learning for second-grade students at an elementary school in Selakau District, Sambas Regency, West Kalimantan Province, and found five interrelated patterns. Behavioral engagement emerged as the initiative to repeat after errors without being prompted, enabled by the redo button and instant feedback that made errors low-cost. Emotional engagement emerged strongly but was narrowly anchored in increasing scores and faded as children simply waited their turn. Cognitive engagement was evident at the procedural level, seen in counting strategies that were separated by problem type, but had not yet reached the ability to explain the reasons for answers. The main obstacle was not connectivity but the ratio of one screen per 26 students, which reduced play time per child to less than five minutes. Teachers performed strongly in gradual support that guided without providing answers, but did not close the lesson with conceptual consolidation. These conclusions are empirical and tied to the case study. This study does not establish causal effects or claim that games improve numeracy skills, as learning outcome data were not collected. Its primary contribution lies in providing a tractable description of what the implementation of web-based educational games actually looks like in low-resource classrooms, complete with cases of deviation that are typically not reported. Such a description complements the already abundant quantitative evidence with a different layer of understanding: how the effectiveness reported in experimental studies manifests, or is hindered, in everyday classroom interactions. Two practical implications emerge. For teachers, the most needed reinforcement is not in device operation skills, which in this case were sufficient, but

rather in closing lessons by tying the play experience back to arithmetic concepts; setting aside the final five minutes to ask children to explain how they arrived at their answers would make a significant difference without increasing costs. For principals and policymakers at the school level, the findings on device ratios suggest that simple device additions or smaller group scheduling could potentially have a greater impact than network improvements, at least in similar settings. Further research is recommended using dual coders, extending the duration of observations, and combining qualitative data with evidence of learning outcomes to directly examine the boundaries between engagement and learning identified in this article.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, D.D. and D.S.; methodology, D.D., D.S., and R.T.M.; investigation, D.D.; data curation, D.D.; formal analysis, D.D.; validation, D.S., R.T.M., A.H., and M.; writing-original draft preparation, D.D.; writing-review and editing, D.S., R.T.M., A.H., and M.; supervision, D.S. and A.H. All authors have read and agreed to the published version of the manuscript.

AI DISCLOSURE STATEMENT

During the preparation of this work, the authors used Claude (Anthropic) to improve the language and readability of the manuscript and to adjust its layout to the journal template. After using this tool, the authors thoroughly reviewed and edited the content as needed and take full responsibility for the content of the publication.

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