UJME 15 (2) 2026: 93-103
UNNES JOURNAL OF MATHEMATICS EDUCATION
https://journal.unnes.ac.id/journals/ujme
ISSN: 2252-6927 (print); 2460-5840 (online)

Needs Analysis for Developing a Board Game for Integer-operation Procedural Fluency in Junior High School

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ARTICLE INFO

Article history:
Received 26 September 2026
Received in revised form 5 October 2026
Accepted 7 October 2026

Keywords:
Board game; Mathematics learning media; Needs analysis; Procedural fluency; Research and development

Abstract

This study presents a needs analysis for developing a board game to support integer-operation learning and procedural fluency among seventh-grade junior high school students. Conducted as the preliminary stage of a research and development study, the analysis combined classroom observation, structured teacher interviews, and a timed written test. Participants were one mathematics teacher and 26 seventh-grade students at a public junior high school in Kudus Regency, Indonesia, selected through purposive sampling. Observation and interviews showed that instruction remained dominated by written drills without game-based media, while school policy restricted mobile-phone and internet use, making non-digital media a more realistic option for this context. Test results showed an average accuracy of only 60.7 percent, well below the 75 percent fluency threshold, with 30.8 percent of students classified as requiring intervention; addition and subtraction showed the weakest performance, with addition also showing a dual weakness in accuracy and speed. Ability was highly heterogeneous across students, and no significant correlation was found between integer-operation fluency and social-arithmetic performance. These findings indicate that students need meaningful, repeatable, non-digital practice media, while teachers need media that accommodate diverse abilities without adding to their instructional design workload. This study contributes empirically grounded design requirements that can guide the development of board-game media for procedural fluency in similarly resourced junior high school settings.

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1. Introduction

The *Fase D* Learning Outcomes (*Capaian Pembelajaran*), which apply to grades 7–9 under Indonesia's national curriculum, require seventh-grade junior high school students to read, write, and compare integers, rational numbers, decimals, integer exponents and roots, and numbers in scientific notation; to apply arithmetic operations on real numbers; and to make estimations in solving problems, including those related to financial literacy (Decree of the Head of BSKAP No. 046/H/KR/2025). This study focuses specifically on the ability to read, write, compare, and operate on integers, given that this ability underlies the mastery of more complex mathematical content at later stages. In particular, the ability to perform integer operations correctly and efficiently is a manifestation of procedural fluency, the skill of carrying out procedures accurately, efficiently, and flexibly, together with knowledge of when and how such procedures should be used (Kilpatrick et al., 2001). Bay-Williams and SanGiovanni (2021) further describe procedural fluency through four interrelated indicators, namely accuracy, efficiency, flexibility, and appropriateness of strategy choice. Consistent with this view, the National Council of Teachers of Mathematics (2014) emphasizes that procedural fluency concerns not only mechanical speed but also the ability to select and adapt strategies to the characteristics of a problem.

To cite this article:
Zahida, N., Nursanti, Y. B., & Sujadi, I. (2026). Needs Analysis for Developing a Board Game for Integer-operation Procedural Fluency in Junior High School. *Unnes Journal of Mathematics Education, 15*(2), 93-103. doi: 10.15294/ujme.v15i2.64508

Without adequate procedural fluency, students' working memory becomes occupied with basic calculation, leaving little capacity for higher-order mathematical reasoning (Sweller, 1988). This concern is not confined to a single context. Maryanti and Asmara (2025) found that the difficulties experienced by junior high school students in number-related material are multidimensional, encompassing conceptual difficulty with negative numbers, procedural difficulty with computational algorithms, and representational difficulty in translating contextual problems into mathematical models. A similar pattern was reported among seventh-grade students elsewhere: Nurhaliza et al. (2025) found that students' conceptual understanding of integer operations varied considerably with mathematical ability, with lower-ability students satisfying only one of three assessed indicators of conceptual understanding.

A closely related finding comes from Qori and Hidayati (2022), who examined junior high school students' mathematical problem-solving ability on integer material using written tests, classroom observation, and teacher interviews, the same combination of techniques adopted in the present study, and found that although students' overall problem-solving ability fell into the high category, the re-checking indicator remained comparatively weak, with teachers reporting that students continued to underestimate integers as a transitional topic between elementary and junior high school. Taken together, these findings indicate that ability gaps in integer-operation material recur across different school contexts, underscoring the need for learning media that can accommodate this diversity of ability.

Boaler et al. (2015) argue that conventional approaches such as flash cards, timed tests, and repetitive drills disconnected from meaningful context are “damaging” and fail to build mathematical fluency, because they do not actively engage students in meaningful practice. In contrast, Rohrer and Taylor (2006) demonstrated experimentally that distributed practice, that is, practice spread across several separate sessions, significantly improves long-term retention compared with practice massed into a single session. Educational games are one vehicle capable of packaging distributed practice in an engaging way. Habgood and Ainsworth (2011) showed that the effectiveness of an educational game stems from how intrinsically its learning content is integrated into the game's core mechanics, rather than from the type of technology used to run it, meaning a physical board game can be just as effective as a digital game provided its content is appropriately designed.

At the same time, teachers' readiness to design instruction that accommodates diverse student ability remains a persistent challenge. Sujadi et al. (2024), examining junior high school mathematics teachers' conceptions of differentiated instruction within Indonesia's *Kurikulum Merdeka*, found that although teachers' conceptual understanding of differentiated instruction was reasonably good, they continued to face obstacles in instructional design, limited teaching time, and classroom management, and therefore required additional support in the form of training and resources for more effective implementation. This finding suggests that learning media which already accommodate differences in student readiness at the design stage would considerably help teachers reduce the burden of adapting instruction independently in the classroom.

A needs analysis is a crucial stage in the preliminary study of research and development, as it ensures that the product being designed genuinely addresses the gap experienced by users, both at the policy level and in day-to-day instructional practice (Wibowo et al., 2022). In the context of developing the Cannibal Fish board game, a physical board-game mathematics learning medium adapting a game concept from Gordon Hamilton's MathPickle, a needs analysis provides the basis for ensuring that the game-mechanic design aligns with the real conditions of students and teachers in the field, rather than resting solely on researchers' assumptions.

Although prior studies have documented students' difficulties with integer operations (Maryanti & Asmara, 2025; Nurhaliza et al., 2025; Qori & Hidayati, 2022) and have argued conceptually for the value of intrinsically integrated, non-digital educational games (Boaler et al., 2015; Habgood & Ainsworth, 2011), few studies have combined classroom observation, teacher interviews, and a timed, session-based accuracy-and-efficiency test to derive concrete, field-grounded design requirements for a board game targeting integer-operation procedural fluency specifically at the junior high school level. Most existing Indonesian board-game development studies proceed directly to product design and expert validation without first establishing, through triangulated field data, precisely which aspects of accuracy, efficiency, and differentiation the product must address. The present study addresses this gap by treating the needs-analysis stage as a distinct, reportable piece of empirical work rather than a brief preliminary note, thereby making the link between field evidence and subsequent design decisions explicit and open to scrutiny.

Based on the foregoing, this article aims to describe the results of a needs analysis for developing the Cannibal Fish board game as a learning medium for integer operations among seventh-grade junior high school students, covering classroom conditions based on observation and teacher interviews, students' accuracy and efficiency profiles in solving integer operations, and a synthesis of needs that forms the empirical basis for the design of the Cannibal Fish prototype.

2. Methods

This study constitutes the needs-analysis stage of a preliminary study within a research and development framework, adapting the model of Sukmadinata (2016), using a descriptive quantitative-qualitative approach to capture real conditions as the basis for product design. Data were collected through three techniques: direct observation of mathematics teaching and learning activities, structured interviews with the seventh-grade mathematics teacher, and a timed written test.

The study was conducted on 12–14 March 2026 at a public junior high school in Kudus Regency, Central Java, Indonesia, involving one mathematics teacher and 26 seventh-grade students selected through purposive sampling based on their direct involvement in learning integer operations. Observation focused on the availability and use of interactive or game-based learning media in the classroom, while the structured interview elicited information on the teacher's experience using game-based media for integer material and the infrastructural constraints encountered.

The test instrument consisted of a timed written test comprising five sessions: addition, subtraction, multiplication, and division of integers (16 items each) and multiples of numbers (12 items), with a duration of two minutes per session, yielding 76 items in total. Accuracy was measured as the proportion of correct answers among items attempted, while efficiency was measured as the number of items completed within the allotted time.

A social-arithmetic test, covering contextual applications such as profit, loss, and interest calculations, a topic within the Indonesian mathematics curriculum, was additionally administered as an indicator of applied ability, because this topic had just been completed by students at the time of data collection and was therefore relevant for examining the relationship between integer-operation fluency and the ability to solve newly learned contextual problems. Data from all 26 students who took the test were valid and used in the analysis. One student did not attempt the addition session, so the mean accuracy for that session specifically was calculated from the 25 students who attempted it, while that student's total score and fluency category were still calculated in full.

Test results were analyzed using a criterion-referenced approach, comparing student scores against absolute criteria established prior to measurement (Mardapi, 2008). Accuracy was categorized as fluent at a minimum of 75%, developing between 50 and 74%, and requiring intervention below 50%, following educational evaluation mastery criteria (Mardapi, 2008), reinforced by the operational definition of mathematical fact automaticity, which requires responses that are both fast and accurate on timed tests (Baker & Cuevas, 2018). Observation and interview data were analyzed descriptively and qualitatively to characterize classroom conditions, media availability, and infrastructural constraints. The two sets of findings were then synthesized to formulate the product-development needs.

To support content validity, the timed-test items were constructed to align directly with the integer-operation indicators specified in the *Fase D* Learning Outcomes and were reviewed by the class mathematics teacher for grade-level appropriateness and item clarity before administration. The observation checklist and interview guide were similarly developed from the procedural fluency indicators of accuracy, efficiency, flexibility, and appropriateness (Bay-Williams & SanGiovanni, 2021), ensuring that all three data sources addressed a common conceptual framework. Triangulating test, observation, and interview data in this way allowed each source to corroborate or qualify the others, for example by checking whether the low accuracy and speed observed on the written test were consistent with the teacher's own account of classroom practice, thereby strengthening the trustworthiness of the synthesized needs presented in the following section.

3. Results & Discussions

3.1. Observation and Interview Results

Observation of seventh-grade mathematics teaching and learning showed that instruction in integer operations remained dominated by written practice exercises without interactive media support. No game-based media, physical or digital, was found in routine use in the observed classroom. This was confirmed through the interview with the mathematics teacher, who stated that mathematical game-based media had never previously been used in teaching integer-operation material.

The interview also revealed structural constraints limiting the choice of learning media. The school enforces a policy prohibiting mobile phones, does not provide Wi-Fi access freely available to students, and has limited time and access to computer-laboratory use. These conditions mean that digital-based media cannot be routinely implemented in daily teaching, making media that do not depend on electronic devices a more realistic option for this school context.

3.2. Accuracy and Efficiency Test Results

The test results showed that students' average accuracy across all 76 items reached only 60.7%, with an average of 35.2 out of 76 items completed within the allotted ten minutes total. Total correct scores ranged from 5 to 62, with a standard deviation of 16.18, indicating a highly heterogeneous spread of ability among students. The distribution of students' fluency categories (n = 26) is presented in Table 1.

Table 1. Distribution of accuracy categories in integer operations (n = 26)

Category	Number of students	Percentage
Fluent (≥75%)	7	26.9%
Developing (50–74%)	11	42.3%
Requires intervention (<50%)	8	30.8%
Total	26	100%

Item-session profiles showed that the addition and subtraction sessions were students' weakest points. In the addition session, mean accuracy was only 40.3%, with an average of only 4.65 out of 16 items attempted (a low-speed category), so that 76.9% of students were classified as requiring intervention on this session. In the subtraction session, mean accuracy was slightly lower, at 41.5%, with 69.2% of students requiring intervention. The multiplication session showed better accuracy, at 64.8%, with 53.8% of students requiring intervention. The division and multiples sessions showed the highest mean accuracy, 81.0% and 80.6% respectively, although the proportion of students requiring intervention in division remained high (76.9%) owing to low completion speed, whereas in the multiples session that proportion was comparatively lower (42.3%). A summary of the per-session profile is presented in Table 2.

Table 2. Speed and accuracy profile per integer-operation session

Session	Mean Items Attempted	Speed Category	Accuracy	%Req. Intervention
Addition	4.65/16	Low	40.3%	76.9%
Subtraction	10.50/16	Moderate	41.5%	69.2%
Multiplication	8.27/16	Moderate	64.8%	53.8%
Division	5.46/16	Low	81.0%	76.9%
Multiples	6.35/12	Moderate	80.6%	42.3%

A correlation analysis between total integer-operation scores and social-arithmetic test scores (12 items) yielded a coefficient of $r = 0.23$ ($n = 26$), which was not statistically significant ($t = 1.17$; $df = 24$; $p > .05$).

This indicates that, on the present data, no strong association was found between integer-operation fluency and the ability to solve social-arithmetic problems.

3.3. Synthesis of Needs

Based on the observation, interview, and test results, three primary needs can be synthesized as the basis for product development. First, students need meaningful practice media that can be used repeatedly to build both accuracy and efficiency, particularly in integer addition and subtraction. Second, this medium needs to be usable routinely in classroom teaching without depending on electronic devices or internet connectivity, given the school's limited digital infrastructure. Third, given the high heterogeneity of student ability and teachers' difficulty designing instruction that accommodates such differences, the medium developed needs to provide a playful context that motivates the active engagement of all students across ability levels without adding to teachers' design workload.

3.4. Discussion

The finding that integer-operation instruction in the field remains dominated by written exercises without interactive media is consistent with Boaler et al.'s (2015) critique of conventional instructional patterns that confine students to a cycle of drilling, testing, and moving on without room for sustained, meaningful practice. This pattern theoretically explains why students' mean accuracy in this study reached only 60.7%, well below the 75% fluency threshold (Mardapi, 2008; Baker & Cuevas, 2018). When procedures have not been sufficiently internalized through adequate practice, Sweller's (1988) Cognitive Load Theory explains that students' working memory continues to be consumed by basic calculation each time they encounter a problem, leaving little cognitive capacity to process more complex procedures or to reason further.

The addition session deserves particular attention, as it showed a dual weakness in both accuracy and speed. Mean accuracy on this session was only 40.3%, far below the fluency threshold, while the mean number of items attempted was only 4 to 5 out of 16 within two minutes, such that the majority of students (76.9%) were classified as requiring intervention on this session. This finding indicates that integer addition, often conceptually regarded as the simplest of the four operations, was in fact not adequately mastered, either in terms of understanding or procedural automaticity (Baker & Cuevas, 2018). This condition is likely attributable to misconceptions surrounding addition involving negative numbers, which is procedurally distinct from the addition of natural numbers with which students are already familiar, as explained through the cognitive-load principle within Cognitive Load Theory (Sweller, 1988).

A similar pattern was found in integer subtraction, with mean accuracy of 41.5% and 69.2% of students requiring intervention. Together, addition and subtraction occupied the weakest position among all sessions, markedly different from multiplication, division, and multiples, whose accuracy exceeded 60%. This finding is consistent with Maryanti and Asmara (2025), who identified conceptual difficulty with negative numbers as one of the multidimensional obstacles faced by junior high school students in number-related material. Integer addition and subtraction, particularly items involving negative numbers, demand deeper conceptual understanding than mere algorithmic application, so that difficulty on these two sessions most likely stems from insufficiently robust conceptual understanding rather than a mere lack of procedural practice.

The non-significant correlation between integer-operation scores and social-arithmetic scores ($r = 0.23$; $p > .05$) should be interpreted cautiously, rather than as evidence that basic-fact automaticity is irrelevant to applied ability. The social-arithmetic material had only just been completed by students at the time of data collection, so their proficiency in that material was likely still at an early transfer stage and not yet mature enough to reveal its association with integer-operation procedural fluency. The limited number of participants ($n = 26$) also constrains the statistical power to detect a moderate-sized correlation. Kilpatrick et al. (2001) nonetheless maintain that procedural fluency is one of five interwoven strands of mathematical proficiency that are theoretically bound up with adaptive reasoning and conceptual understanding; however, the empirical relationship between the two within this study's population requires further testing with a larger sample before it can be concluded with confidence.

The highly heterogeneous spread of scores (standard deviation of 16.18, ranging from 5 to 62) confirms that this class is not a group with uniform learning needs. This finding connects the test results to the teacher interview and is consistent with Sujadi et al.'s (2024) study of junior high school mathematics teachers' conceptions of differentiated instruction within *Kurikulum Merdeka*, which found that although teachers

conceptually understood differentiated instruction, obstacles in design, limited time, and classroom management remained the primary barriers to its implementation. In other words, teachers are fundamentally aware of the need to accommodate diverse student readiness but do not necessarily possess concrete tools for doing so without adding to their instructional design workload. This condition reinforces the urgency of learning media that already incorporate a differentiation mechanism at the design stage, so that teachers need not independently redesign differentiation strategies at every meeting.

The digital-infrastructure constraints identified through observation and interview, namely the mobile-phone ban, the absence of student Wi-Fi access, and limited computer-laboratory access, confirm that digital-based solutions are difficult to implement routinely at this school. Nevertheless, these constraints do not necessarily foreclose the use of educational games in the classroom. Habgood and Ainsworth (2011) showed that the effectiveness of an educational game is determined more by how intrinsically its learning content is integrated into the game's core mechanics than by the type of technology used to run it. A physical board game that integrates integer operations directly into its game mechanics, as designed in Cannibal Fish, thus has the potential to offer effectiveness comparable to that of digital games without being constrained by the infrastructural limitations identified in the field.

The principle of distributed practice demonstrated experimentally by Rohrer and Taylor (2006) is also relevant to addressing the need for repeated, meaningful practice. Rather than compressing integer-operation practice into a single lengthy session, distributing practice across several separate meetings has been shown to improve students' long-term retention. This principle aligns with the plan to integrate Cannibal Fish into three separate class meetings of about 30 minutes each (5 minutes of explanation, 20 minutes of play, and 5 minutes of reflection), giving students the opportunity to practice periodically rather than once for an extended duration, an approach generally less effective for building long-term automaticity.

The feasibility of developing print- or physical, game-based media also has empirical precedent relevant to this line of work. Hendrawan (2026) reported that a printed mathematics short-story medium developed through the ADDIE model (Branch, 2009) achieved a highly feasible rating from material experts, media experts, and practitioners, and a highly practical rating based on student responses. This indicates that non-digital physical media, when designed through a systematic development process and adequately validated, can achieve high feasibility and practicality at the primary level, thereby supporting the appropriateness of choosing a physical board game as the development direction for Cannibal Fish.

Figure 1 shows the initial prototype of Cannibal Fish. The game was adapted from the puzzle of the same name by Gordon Hamilton (Hamilton, n.d.), in which players hold fish of different sizes and the smallest fish eats another fish and adds that fish's number to its own. In the version developed here, each player's score is the position of a fish-shaped magnetic piece on a physical number scale from −20 to 100, drawn as a vertical scale whose zero lies at the water surface, so that positive scores are above and negative scores below the surface (Figure 1a). Initial scores are set by throwing dice, and the player with the lowest score moves first; on each turn that player eats an opponent's piece and adds its score to their own, while the eaten piece keeps its score (it is neither reduced nor restarted) and the turn passes to the player with the lowest score. Any player may challenge a miscalculation by calling *Jaring Nelayan*, and a mistaken challenge is penalized as well; every penalty subtracts 5 points, which introduces integer subtraction and scores below zero. At Levels 2 and 3, players must also call *Kibas Sirip* whenever their score reaches a multiple of 10 or 5, respectively. The three levels correspond to three class meetings of about 30 minutes, played in mixed-ability groups of three to five students. The prototype has passed validation by media experts (a university lecturer and a practitioner); the details of that validation, and the classroom trials, are beyond the scope of this needs analysis.

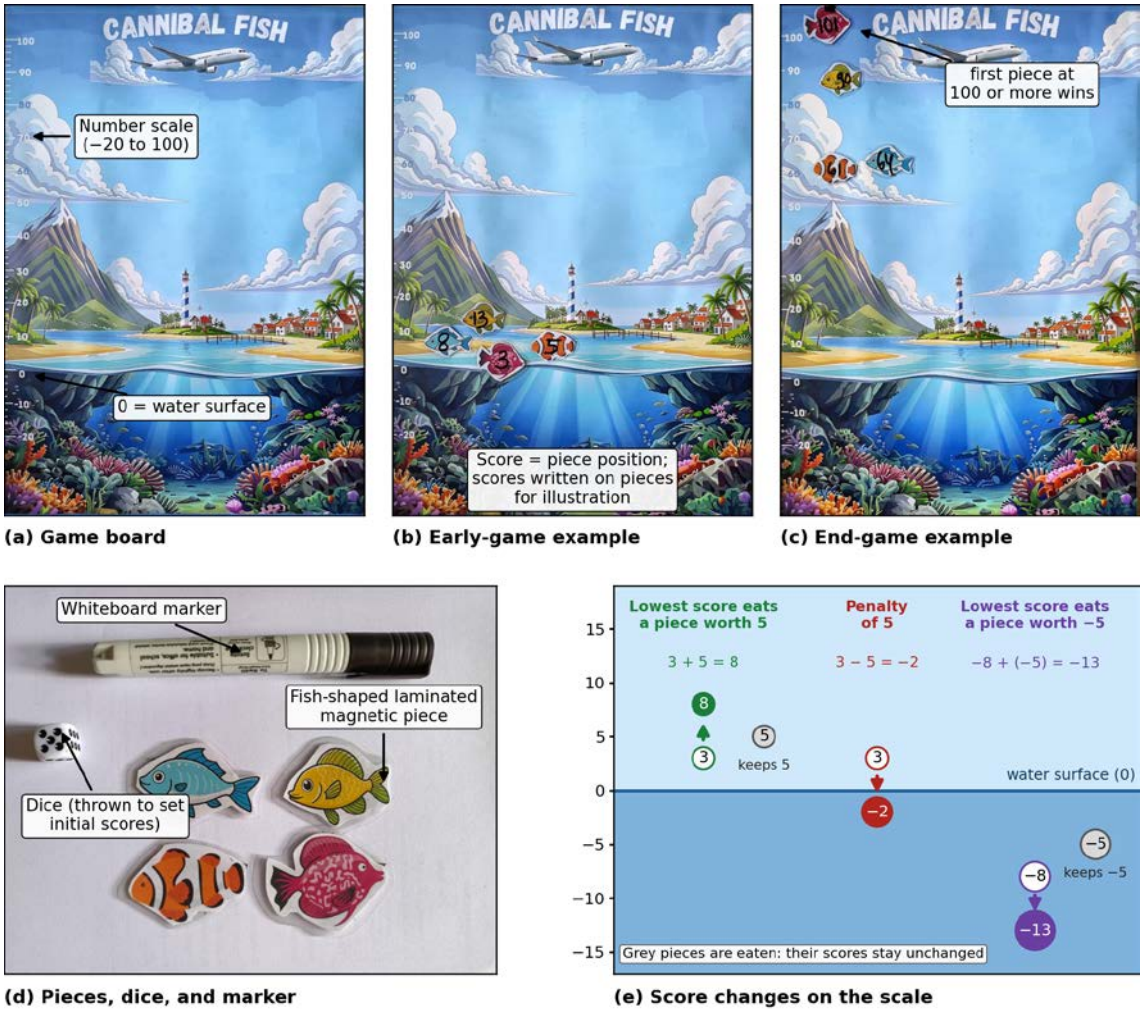


Figure 1. Initial prototype of Cannibal Fish: (a) game board with a vertical number scale from −20 to 100, in which 0 is the water surface; (b) example early-game state; (c) example end-game state in which a piece has reached 100 or more; (d) fish-shaped laminated magnetic pieces, dice, and whiteboard marker; (e) schematic of score changes on the scale (the player with the lowest score eats a piece and adds its score, the eaten piece keeps its score, and a penalty subtracts 5). The examples in (e) show possible moves; players choose which piece to eat. Scores written on the pieces in (b) and (c) are for illustration.

The three needs synthesized above, namely repeated meaningful practice, independence from electronic devices, and accommodation of diverse student ability, carry greater weight when explicitly linked to the game mechanics designed for Cannibal Fish, rather than remaining at the level of general recommendations. Establishing this link is important so that this needs analysis genuinely bridges field data and product-design decisions, rather than merely producing a list of problems without a concrete direction for resolution. Table 3 summarizes how each synthesized need corresponds to a specific design feature of Cannibal Fish, together with the field evidence from which that need was derived.

Table 3. Mapping of synthesized needs to Cannibal Fish design features

Identified Need	Field Evidence	Corresponding Design Feature	Theoretical Base
Repeated, meaningful practice targeting addition and subtraction	Mean accuracy of 40.3% (addition) and 41.5% (subtraction); low completion speed on addition	Score accumulation by eating opponents' pieces (adding positive or negative scores) and 5-point penalties (subtraction), repeated across three class meetings of about 30 minutes	Distributed practice (Rohrer & Taylor, 2006); intrinsic integration (Habgood & Ainsworth, 2011)
Independence from electronic devices and internet connectivity	School policy prohibits mobile phones; no student Wi-Fi; limited computer-laboratory access	Fully physical, non-digital board and piece components requiring no power or connectivity	Effectiveness depends on mechanic integration, not technology type (Habgood & Ainsworth, 2011)
Accommodation of diverse student ability without added teacher workload	Standard deviation of 16.18 (range 5–62); teachers report design-time constraints for differentiation	Mixed-ability groups of three to five students enabling peer tutoring; Levels 1–3 progressively add *Kibas Sirip* (calling out multiples of 10, then 5), with *Jaring Nelayan* allowing peers to check calculations	Differentiated instruction barriers (Sujadi et al., 2024); process differentiation via peer interaction

The greatest difficulty found in integer subtraction, as described above, stems from weak conceptual understanding of negative numbers rather than merely insufficient procedural memorization. On this basis, each player's score in Cannibal Fish is the position of a fish-shaped magnetic piece on a vertical number scale from −20 to 100, with 0 at the water surface (Figure 1). Eating an opponent's piece moves the eater's piece up by the eaten piece's score, or down if that score is negative, which is integer addition (the eaten piece keeps its own score); each penalty moves a piece down by 5, which is integer subtraction and can carry a score below zero, that is, below the water surface (Figure 1e). Because students drag the pieces along the scale themselves, the change in value is experienced both visually and kinesthetically.

In this way, students do not merely calculate the final result of an operation but also experience the process of value change concretely through piece position, so that conceptual understanding of negative numbers is built together with procedural practice. This concrete-representation approach aligns with Kilpatrick et al.'s (2001) argument that procedural fluency cannot be developed separately from conceptual understanding, as the two are mutually reinforcing strands of mathematical proficiency.

Another notable finding is the low completion speed on the addition session, together with its low accuracy, indicating that students' calculation process is not yet automatic. To address this, Cannibal Fish is designed with a competitive yet enjoyable game mechanic, in which students are required to calculate repeatedly within a playful atmosphere rather than within the conventional practice atmosphere that tends to feel burdensome or evaluative. This packaging of repeated calculation within a game context is what Habgood and Ainsworth (2011) term intrinsic integration, in which the cognitive demands of learning merge with the demand to win the game, such that motivation to play also drives motivation to practice. Through this mechanism, the repetition required to build basic-fact automaticity, as emphasized by Baker and Cuevas (2018), can be achieved without the fatigue or reluctance that students commonly experience from conventional repeated drilling. Accuracy, the other main weakness, is targeted by the peer-checking rule *Jaring Nelayan*, which penalizes both a miscalculation and a mistaken accusation, so students must verify a calculation before challenging it.

The need to accommodate diverse student ability also aligns with current national policy on graduate competencies, which defines eight Graduate Profile Dimensions (*Dimensi Profil Lulusan*), among them collaboration (*kolaborasi*), critical reasoning (*penalaran kritis*), and communication (*komunikasi*) (Regulation of the Minister of Primary and Secondary Education No. 10/2025, Article 4). For junior high school graduates, the regulation describes the habit of caring, sharing, and cooperating in diverse groups within the school (Article 8), and it frames critical reasoning as including the use of literacy and numeracy to solve problems (Article 4). Cannibal Fish is designed for group play, so that the game trains procedural fluency individually while also fostering communication and collaboration among students at different ability levels, whether fluent, developing, or requiring intervention. Such interaction places the cognitive and social dimensions of mathematics learning within a single activity rather than separating them into two independent instructional agendas.

The group-play structure of Cannibal Fish simultaneously functions as a naturally occurring form of process differentiation, without requiring grouping based on test results, beyond the simple instruction to mix students of high, medium, and low ability within each group of three to five. Within the dynamics of group play, students who grasp calculation more quickly tend to assist or guide their group members, while students who are still lagging remain actively engaged because they are guided by the rhythm and interaction of the group, rather than being left to work alone on a worksheet. This pattern of peer tutoring is relevant to Sujadi et al.'s (2024) finding that teachers understand the importance of accommodating students' differing learning readiness but are often constrained by time and implementation strategy in the classroom. When process differentiation can occur through the dynamics of group play, teachers need not explicitly design separate learning pathways for each ability group, since the mechanism is already embedded in how the game is played.

From the teacher's perspective, Sujadi et al.'s (2024) finding regarding limited design time as the primary obstacle to implementing differentiated instruction carries important practical implications for this product's development direction. A ready-to-use physical board game offers a solution distinct from the demands of creating interactive digital media or manually preparing differentiated worksheets for each student ability level, both of which require preparation time and technical skills that teachers do not always possess amid their daily teaching workload. By providing a ready-to-use game set that has passed media-expert validation, with classroom trials still to follow, Cannibal Fish has the potential to reduce the burden of designing differentiated instruction without compromising quality or its fit with the student needs identified through this needs analysis.

Successfully embedding a ready-to-use board game into routine teaching nevertheless still requires some degree of teacher facilitation, for example, in managing group dynamics, timing sessions appropriately within regular class periods, and interpreting how in-game performance relates to the accuracy and efficiency indicators used in this needs analysis. Brief, practical orientation for teachers on these facilitation aspects, rather than extensive training, would likely be sufficient given that the differentiation mechanism is embedded in the game itself rather than in teacher-led grouping decisions. This modest facilitation requirement further distinguishes a ready-to-use board game from digital alternatives, which typically demand more substantial technical training before teachers can deploy them confidently in the classroom.

This implication is particularly relevant to the broader rollout of *Kurikulum Merdeka*, under which differentiated instruction is officially encouraged but not always accompanied by ready-to-use classroom resources. Teachers implementing the curriculum are frequently expected to translate general differentiation principles into day-to-day practice largely on their own, a gap noted not only by Sujadi et al. (2024) but also reflected in the present study's finding that no game-based media of any kind was in routine use despite the clear heterogeneity of student ability. A board game that embeds differentiation into its mechanics, rather than requiring teachers to design differentiation separately, therefore addresses an implementation gap that is unlikely to be specific to the single school studied here.

This study is not without limitations. The findings of this needs analysis were obtained from a still-limited scope, namely one public junior high school in Kudus Regency with 26 seventh-grade students and one mathematics teacher. The heterogeneity of ability and digital-infrastructure constraints identified in this study may not fully reflect conditions at other schools with different student characteristics, policies, or facilities. These findings should therefore be understood as a snapshot of initial conditions forming the basis for product design within this study's context, rather than a generalization of the needs of seventh-

grade junior high school students as a whole. This limitation simultaneously opens space for a subsequent research stage to test the validity and practicality of Cannibal Fish across a broader scope of participants, so that findings from the development and trial stage can complement the needs-analysis findings obtained at this stage. A further limitation concerns the correlation analysis, whose statistical power was constrained by the small sample; future needs-analysis studies adopting a similar design would benefit from a larger participating cohort, potentially drawn from several schools with comparable curricular timing, to allow more conclusive testing of the relationship between integer-operation fluency and applied problem-solving ability. In addition, how often students actually meet subtraction and negative values in Cannibal Fish depends on how often penalties occur during play, which the planned classroom trials should document.

Overall, the link between field data and design decisions described above indicates that the score-accumulation mechanic for practicing addition and subtraction, the progressive *Kibas Sirip* and *Jaring Nelayan* levels, the group-play format, and the non-digital physical packaging of Cannibal Fish are not standalone design choices, but direct responses to the needs for accuracy, efficiency, and accommodation of diverse student ability revealed through the observation, interview, and test conducted in this needs analysis.

4. Conclusion

This needs analysis shows that integer-operation instruction in the junior high school classroom studied remains dominated by written practice without interactive or game-based media, that the school's limited digital infrastructure makes non-digital media a more realistic option, that students' accuracy and efficiency in integer operations, particularly addition and subtraction, fall well short of the fluency standard, and that ability is highly heterogeneous across students. These findings converge on three empirically grounded needs that can guide the development of the Cannibal Fish board game: meaningful practice media that can be used repeatedly, media that do not depend on electronic devices, and media capable of engaging students of varying ability without adding to teachers' instructional design workload. Beyond informing this particular product, the study contributes to the broader literature on mathematics learning-media development by demonstrating how classroom observation, teacher interviews, and a criterion-referenced timed test can be triangulated to derive concrete, field-grounded design requirements before a board game is designed, offering a replicable approach that other researchers developing similar media for procedural fluency may adapt to their own school contexts. The initial prototype of Cannibal Fish has since passed media-expert validation; subsequent research is recommended to examine its practicality and effectiveness through classroom trials, following established assessment criteria for research and development products (Budiyono, 2017).

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