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Analysis of Teachers' Professional Competence in Strengthening Students' Problem-Solving Skills through the Implementation of Unplugged Coding in IPAS Learning

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Abstract: Strengthening students' problem-solving abilities is a key competency in 21st-century education; however, limited access to technology in elementary schools often hinders the introduction of computational concepts. Unplugged Coding offers an alternative learning approach that trains algorithmic thinking in a simple, accessible manner. This study aims to analyze students' initial understanding, describe teachers' strategies in implementing Unplugged Coding, and assess its effectiveness in enhancing problem-solving skills. This study employed a qualitative case study design involving fifth-grade teachers and students at SDN 1 Tumiyang and SDN 1 Glempang. Data were collected through observations and semi-structured interviews, then analyzed using thematic analysis based on Polya's problem-solving framework and Brackmann's Unplugged Coding model. The findings indicate that Unplugged Coding consistently improves students' problem-solving abilities. During the problem-understanding stage, students became more capable of identifying goals and interpreting instructions logically. During the planning stage, they developed solution steps more systematically and carefully. In the implementation stage, collaboration improved along with students' ability to correct errors. In the reflection stage, students demonstrated greater skill in debugging and generating creative ideas for solving problems. The study results that Unplugged Coding is effective in enhancing students' problem-solving skills through concrete activities that integrate algorithmic thinking, collaboration, and reflection. These findings suggest that this approach can serve as an innovative solution for elementary schools with limited technological resources and support the development of essential computational skills.

Keywords: IPAS learning; Problem solving; Teachers' Professional; Unplugged coding

Introduction

A major challenge facing 21st-century education is the gap between teachers' pedagogical and technological competencies, with the majority still relying on conventional methods. This dependence hinders student engagement and the achievement of modern curriculum competencies, particularly in problem-solving skills. Only 40% of teachers in Indonesia are confident in using technology in teaching, and 60% still use traditional methods. Consequently, elementary school students' problem-solving skills remain low because learning emphasizes memorization rather than developing critical and creative thinking. Therefore, innovative approaches are needed (Diah, 2019). The unplugged approach (without digital devices) is a solution in many schools worldwide, including in Indonesia, which face limitations in basic infrastructure such as electricity and internet (Aulia Fanani, 2025; Sunarya, 2024). The Unplugged Coding approach offers an effective way for elementary schools with limited resources to understand computing concepts and build

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problem-solving skills through games and hands-on activities. Observations in the Widya Budaya Cluster, Banyumas Regency, showed that only SD Negeri 1 Tumiyang had implemented Unplugged Coding in science lessons, while two other schools had not. This difference informed the selection of the research subjects, given that most students still struggled with answering HOTS (Higher Order Thinking Skills) questions, such as understanding problems and formulating solutions.

Teachers' professional competence is crucial for the quality of education and the implementation of interactive learning media. This competence encompasses mastery of content, pedagogical strategies, technology, as well as professional, administrative, and social skills (Niswah et al., 2025; Wulandari & Nurhaliza, 2023; Yus et al., 2025). Specifically, professional competencies in interactive media implementation include pedagogical competencies (designing learning), technological competencies (mastering digital tools), and evaluative competencies (analyzing effectiveness) (Syawitri, 2025). Problem-solving skills, which are core to 21st-century demands, are also a focus because PISA results show Indonesian students consistently performing poorly since elementary school (Budiarti, 2023). Problem-solving is a high-level cognitive process involving (Polya, 1945) four stages: understanding the problem, developing a plan, implementing the plan, and reviewing (Anugraheni, 2019; Brijlall, 2015).

Unplugged Coding is a non-digital approach to introducing programming concepts through logic games, patterns, and story-based activities to develop algorithmic and systematic thinking from an early age. This method effectively improves computational thinking skills, particularly problem-solving and logical reasoning, and has proven successful even in early childhood (Adhe et al., 2023). Its implementation involves the following stages: planning, activity presentation, concept exploration (decomposition, pattern recognition, abstraction, algorithms), problem-solving application (based on Polya's steps), and reflection. Effective implementation relies heavily on the teacher's competence as a facilitator, motivator, and innovator who master basic coding concepts, are able to manage and adapt activities, and possess patience and commitment to professional growt.

Previous studies have confirmed the effectiveness of this approach, for example, research by Rasmi et al. (2025); Xu et al. (2024), which showed increased student engagement, conceptual understanding, collaboration, and persistence; as well as research by De Los Santos et al. (2025); Kwangmuang et al. (2021) who used Puzzle Coding Blocks and Ummidlatus (Mafarja et al., 2025; Tursynkulova et al., 2023) who used Hijaiyah Coding, both showed potential for developing problem-solving and logical thinking skills. The limitations of research on the Unplugged Coding method that does not rely on digital devices prompted this research. The objectives of this study are: to analyze student understanding before Unplugged Coding-based learning, describe teacher strategies in implementing Unplugged Coding to strengthen problem-solving skills, and assess its effectiveness in improving these skills.

Method

This study employs a qualitative–descriptive approach with a case study design. This approach was selected because it aligns with the research objective, namely, to describe and analyze in depth the process of strengthening students' problem-solving abilities through the implementation of Unplugged Coding in elementary schools. Descriptive qualitative research focuses on the real meanings of words and events within their natural contexts, emphasizing detailed descriptions of participants' experiences in their own language (Bradshaw et al., 2017). This approach also aims to explore the depth of social phenomena and develop a closer understanding of subjective experiences.

Research Subjects and Objects

The subjects of this study are fifth-grade students at SD Negeri 1 Tumiyang and SD Negeri 1 Glempang in the Gugus Widya Budaya cluster, Pekuncen District, Banyumas Regency, Central Java. The selection of students at the upper elementary grade level is based on the assumption that their cognitive development has reached the concrete operational stage. The objects of this study encompass two main aspects: teachers' professional competence and students' problem-solving abilities. Teachers' professional competence includes their ability to design, implement, and evaluate learning experiences grounded in Unplugged Coding, as well as to adapt this approach to meet the diverse needs of students in inclusive classrooms. Meanwhile, students' problem-solving abilities include the skills to understand, formulate, implement, and evaluate solutions to problems encountered within the learning context.

Techniques and Instruments for Data Collection

Data collection in a qualitative descriptive study focuses on identifying the characteristics of specific events that serve as the object of investigation (Cheng et al., 2025). In qualitative research, data are gathered in natural settings from primary sources using participant observation, in-depth interviews, and documentation.

The data collected in this study consist of qualitative observations, semi-structured interviews, and documentation. The qualitative researcher functions as a human instrument, playing a central role throughout the research process. To ensure data validity, this study employed several strategies, including source triangulation, methodological triangulation, and member checking. The first data-collection technique was participant observation. This technique was implemented to obtain data on students' activities during Unplugged Coding instruction, particularly those related to problem-solving skills.

The second technique was in-depth interviewing using semi-structured interview guidelines. This technique was chosen because it allows the researcher to explore participants' understanding, experiences, and challenges with flexibility while maintaining focus. Interviews were conducted with classroom teachers to gather their perspectives on the implementation of Unplugged Coding, including instructional strategies, barriers, and potential areas for development. Additionally, interviews were conducted with students to explore their learning experiences and perceptions of Unplugged Coding activities. The questionnaire instrument used in this study was developed based on Polya's problem-solving stages and components of Unplugged Coding skills.

Table 1. Indicators of the Problem-Solving Questionnaire Instrument

Problem-Solving Aspects	Observed Indicators
Understanding the Problem	Students understand the instructions and rules of the unplugged coding activity. Students are able to identify the objectives of the given task or game. Students can connect the problem to their prior experiences.
Devising a Plan	Students are able to determine strategies for solving the problem. Students demonstrate the ability to design logical steps to achieve the goal. Students consider several alternative ways to solve the problem.
Carrying Out the Plan	Students are able to carry out the planned steps consistently. Students show accuracy and persistence in completing the task. Students can adjust their strategies when encountering obstacles.
Looking Back	Students evaluate the results they have achieved. Students can identify and correct mistakes. Students are able to reflect on their own thinking processes and learn from them.

Table 2. Teacher Unplugged Coding Skills Questionnaire Instrument Based on Indicators by Demir (2021); Yilmaz & İzmirli (2023)

Aspects of Unplugged Coding Skills	Observed Indicators
Knowledge of basic coding and algorithm concepts	The teacher understands the fundamental principles of coding and algorithms conceptually. The teacher is able to apply algorithmic concepts in unplugged activities. The teacher recognizes the relevance of programming logic in learning.
Managerial ability and instructional adaptation	The teacher is able to adapt learning activities to students' characteristics.
Ability to motivate and provide positive support	The teacher is able to maintain students' motivation and engagement. The teacher fosters students' confidence and perseverance.
Creativity and pedagogical innovation in designing learning activities	The teacher offers a variety of relevant unplugged activities. The teacher is able to innovate and seek new instructional references. The teacher is creative in using simple and contextual learning materials.
Patience and interpersonal skills	The teacher is patient in guiding students and providing alternative explanations. The teacher builds a warm and collaborative learning climate.
Ability to observe and evaluate the learning process	The teacher uses observation and reflection to assess the process.
Commitment to professional development	The teacher has relevant professional experience in the field.

Data Analysis Technique

This study employed thematic analysis as its primary data analysis technique. Thematic analysis is used to identify, analyze, and interpret patterns or themes that emerge from qualitative data obtained through interviews, observations, and documentation. It serves as a foundational method in qualitative research. It is closely associated with grounded theory, involving key procedures such as coding, data categorization, and data grouping to produce detailed, in-depth findings. The main objective of thematic analysis is to identify patterns or determine themes within the collected data. The analysis process in this study followed the six-phase framework, beginning with data familiarization through

an in-depth review of interview transcripts, observation notes, and documents to understand the context and identify initial patterns related to the implementation of Unplugged Coding and students' problem-solving abilities. The next step involved generating initial codes by identifying relevant data segments and assigning codes that captured significant ideas. These codes were then organized during the theme-searching stage, in which related codes were grouped into potential themes and subthemes. The emerging themes were subsequently reviewed to ensure coherence and alignment with the entire dataset. Afterward, each verified theme was clearly defined and named to reflect its core meaning. The final stage involved interpreting and presenting the findings in a descriptive narrative supported by thematic tables, participants' direct quotes, and theory-based interpretations.

Result and Discussion

Students' Level of Understanding Before the Implementation of Unplugged Coding

The analysis shows a clear difference in problem-solving abilities between students at SDN 1 Glempang, who were implementing Unplugged Coding for the first time, and those at SDN 1 Tumiyang, who were already familiar with the approach. Prior to implementation, students at SDN 1 Glempang demonstrated confusion in solving problems, particularly in the *looking back* (reviewing) stage. Their unfamiliarity with Unplugged Coding activities and problem-solving tasks resulted in thinking processes that were not yet systematic. Interview data indicate that these students were generally at the initial stages of Polya's problem-solving framework, focusing primarily on Understanding the Problem and Devising a Plan, with early indications of reflective thinking emerging. In contrast, students at SDN 1 Tumiyang showed more advanced understanding. They were able to follow instructions in sequence and break problems into smaller components before addressing them in order of priority. Their familiarity with basic instructions and logical patterns enabled them to recognize problem structures more quickly. The comparison between the two student groups is analyzed using Polya's four phases of problem-solving.

Understanding the Problem

Students at SDN 1 Tumiyang demonstrated powerful initial motivation and a positive attitude toward learning. This constructive emotional stance is an important asset in understanding the problem. In addition, the students demonstrated good self-awareness, as evidenced by their ability to identify the specific difficulties they encountered. These pre-implementation conditions for Unplugged Coding indicate that the students already had strong motivational foundations and could understand the material's context. At this early stage, students at SDN 1 Glempang demonstrated adequate awareness of the problem's core. However, consistency of understanding remained a challenge. These pre-implementation findings indicate that although the students had basic abilities to identify the main problem, their understanding of more complex instructions or problems was still unstable.

Devising a Plan

Students at SDN 1 Tumiyang demonstrated a strong tendency toward flexible thinking. The students showed awareness of the cognitive attitudes required when developing strategies, such as the importance of "practicing focus." These findings indicate that before the implementation of Unplugged Coding, the students at SDN 1 Tumiyang already possessed cognitive assets (multiple-solution orientation) and an awareness of the importance of accuracy and focus when designing problem-solving steps. The planning stage was also a significant strength of the pre-implementation Unplugged Coding students at SDN 1 Glempang. This was evident from the high frequency of findings related to collaboration and creativity. The students were accustomed to working together, exchanging ideas, and freely expressing their thoughts during discussions. Thus, prior to the implementation of Unplugged Coding, students at SDN 1 Glempang already possessed substantial social capital, including collaborative skills, creativity in designing solutions, and mutual respect for ideas throughout the planning process.

Carrying Out the Plan

The quality of collaboration highly influences the execution stage of the plan, and students' level of understanding is affected by the social dynamics within their groups. Students at SDN 1 Tumiyang demonstrated active participation and high enthusiasm in teamwork, which served as their primary strategy for implementing the plan and solving problems. However, there were indications of vulnerability in the execution process, marked by observations of group members who were "not serious". This suggests that, before the implementation of Unplugged Coding, plan execution could be inconsistent due to differences in focus or unstable social dynamics. For students at SDN 1 Glempang, the ability to carry out the problem-solving steps was evident. However, the stability of execution had not yet fully developed prior to the Unplugged Coding intervention. Although the students understood

that Unplugged Coding activities require precision and patience, some still showed confusion or difficulty when faced with more complex tasks.

Looking Back

Students at SDN 1 Tumiyang demonstrated a strong tendency for self-evaluation and self-correction. They were accustomed to "repeating problems or calculations" when encountering errors, reflecting an early form of debugging and strategy review. This habit indicates a natural reflective initiative (self-correction) prior to the more systematic and structured implementation of Unplugged Coding, an important element in developing computational thinking. Students at SDN 1 Glempang also demonstrated strong reflective tendencies, as evidenced by their active monitoring of the problem-solving process. This was reflected in their efforts to revisit parts they did not understand, scrutinize errors, and correct answers deemed incorrect. These pre-implementation conditions suggest that the students already had a foundational capacity for reflection and self-improvement.

Teacher Strategies in Implementing Unplugged Coding

The strategies teachers adopted in implementing Unplugged Coding varied across schools. At SDN 1 Glempang, the teacher faced significant challenges, including limited time and low-quality worksheet completion. The teacher reported that the available time was insufficient to design practical worksheets, and students often completed tasks hastily, leading to deviations from the intended learning flow. This condition aligns with (Brackmann et al., 2017) findings, which highlight that the development of Computational Thinking activities in elementary schools is often hindered by limited planning time and material preparation. To address these constraints, the teacher employed independent strategies by preparing additional materials outside teaching hours and designing content relevant to children's daily lives, including examples and current news, to enhance student engagement. This approach reflects the characteristics of innovative teachers, as described by (Demir, 2021b); (Sbaragli & Panero, 2024), who can adapt materials to classroom learning needs.

Meanwhile, the teacher at SDN 1 Tumiyang faced different challenges because Unplugged Coding had already been implemented several times at the school. The challenges included the need for longer instructional time, varying student abilities, and a classroom environment that was sometimes unconducive during discussions. These findings are consistent with those of (Basister et al., 2025); (Li & Xue, 2023), who emphasize that time constraints and student heterogeneity are significant factors that affect the smooth implementation of activity-based learning and Computational Thinking in elementary schools. To address these issues, the teacher used more structured planning strategies, such as preparing tools and materials before class, establishing clear classroom rules, and assigning student roles systematically to support the smooth flow of activities. Additionally, the teacher encountered difficulties in maintaining students' focus, which were addressed through positive reinforcement, verbal praise, and increased active engagement. These strategies proved effective in enhancing students' motivation and their emotional and cognitive involvement throughout the learning process. The comparative analysis of teacher strategies at SDN 1 Tumiyang and SDN 1 Glempang reveals three fundamentally different approaches to teaching and computational thinking.

Learning Design: Systematic vs. Contextual

In terms of learning design, there are significant strategic differences between the two schools. The teacher at SDN 1 Tumiyang implemented a systematic and digital-based strategy, while the teacher at SDN 1 Glempang employed a contextual, analog, and experiential approach. The strategy used in Tumiyang relied on Unplugged Coding activities as a structured, systematic module to build students' logical foundation before transitioning to digital coding. This suggests that unplugged activities function as a structured preliminary step. In contrast, the approach at SDN 1 Glempang was more experiential and contextual. The school integrated unplugged coding into students' everyday life contexts and direct experiences, making Computational Thinking (CT) concepts, more closely connected to situations and games that were familiar to them.

Classroom Management and Differentiation: Structured vs. Flexible

In terms of classroom management, the teacher at SDN 1 Tumiyang applied a structured strategy with clearly defined roles. In contrast, the teacher at SDN 1 Glempang used a flexible approach supported by intensive interaction. The strategy in Tumiyang focused on ensuring that each student understood their specific role within the team, whereas the teacher in Glempang encouraged deeper discussion and more fluid collaborative experimentation. Regarding differentiation and motivation, the teacher at SDN 1 Tumiyang used a concept clarification and instruction-oriented approach, emphasizing the understanding of definitions and precise steps. In contrast, the teacher at SDN 1 Glempang applied scaffolding and analogy-

based strategies, using comparisons between Computational Thinking (CT) concepts and familiar real-life experiences.

Debugging Strategies: Linear vs. Reflective

The teacher at SDN 1 Tumiyang used a linear, procedural debugging strategy, while the teacher at SDN 1 Glempang used a reflective, pattern-based approach. At SDN 1 Tumiyang, the focus was on identifying which step in the sequence was incorrect. In contrast, at SDN 1 Glempang, students were encouraged to reflect on the cause of the error and to discover more effective solution patterns. These debugging strategies represent a core distinction in the development of Computational Thinking (CT). In Tumiyang, the teacher instructed students to check the instructions step by step, in a procedural manner. Conversely, in Glempang, the teacher analyze errors to identify problem patterns, and find more efficient and creative solutions.

The Effectiveness of Unplugged Coding in Improving Students' Problem-Solving Skills

The findings of this study indicate that Unplugged Coding is effective in enhancing students' problem-solving skills. This effectiveness is reflected in the consistent alignment between teacher and student interviews, as well as the observed development across all stages of problem-solving as outlined by Polya. Prior to implementation, students generally demonstrated only a superficial understanding of problems and were highly dependent on teacher instructions. After the activities were conducted routinely, students became more capable of identifying task objectives, linking problems to IPAS content and understanding the logical structure of the task. Students reported that this approach made it easier to understand problems because instructions were presented through concrete, visual, and structured steps. Thus, Unplugged Coding effectively deepens problem comprehension by transforming abstract concepts into tangible, accessible representations (P. Chen et al., 2023; Fanchamps et al., 2024).

Improvements were also evident in the second stage planning. Teachers noted that students became more capable of systematically designing strategies, recognizing multiple solution paths, and demonstrating greater accuracy, particularly after being introduced to the concept of looping. Student perspectives reinforced these findings: they began by "identifying the goal first," used everydays analogies, and showed increased patience and focus. These findings suggest that Unplugged Coding cultivates habits of planning through problem decomposition, which lies at the core of Polya's planning stage. In the execution stage, enhanced collaborative skills emerged as one of the most prominent outcomes. Teachers observed more active discussions, more effective role distribution, and improved student ability to choose the most logical ideas (Xiong, 2025; Subandiyah et al., 2025). Students also became increasingly independent in debugging correcting errors by revisiting initial steps, checking results individually, and integrating ideas within their groups. The game-like nature of the activities further increased their enthusiasm (Blair et al., 2024; Kerimbayev et al., 2023). These results show that Unplugged Coding not only strengthens students' ability to implement strategies logically and systematically but also improves the quality of collaboration that supports successful problem-solving.

The reflection stage also showed significant improvement. Teachers reported that students became more receptive to feedback and were able to identify errors by rereading steps or reviewing the sequence of actions. Students stated that they revised their answers by repeating steps or rereading instructions, and that they benefited from teacher and peer feedback. By offering opportunities for students to engage in debugging similar to programming processes, Unplugged Coding effectively fosters more concrete, thorough, and meaningful reflective skills. From the perspective of student motivation and engagement, Unplugged Coding proved effective, as students described the learning experience as enjoyable, and confidence-building particularly in expressing ideas, despite occasional confusion when instructions were incomplete. From the teacher's perspective, this approach also strengthened pedagogical competence by helping students recognize computational thinking patterns, providing clearer insights into their problem-solving abilities, encouraging teacher creativity in creating analogies and worksheets, and promoting a collaborative culture within the classroom. Notably, this effectiveness persisted even when the activities used simple, low-tech materials.

Teacher Competence in Implementing Unplugged Coding

Based on the findings, teachers at SDN 1 Glempang and SDN 1 Tumiyang demonstrated many of the characteristics of effective educators as described by Yilmaz & İzmirli (2023). Both teachers displayed several key competencies, including understanding basic algorithmic concepts, providing scaffolding, using concrete learning media, managing collaborative classrooms, and employing positive communication to foster a growth mindset among students. However, the findings also indicate that each teacher still has several competencies that have not yet developed optimally in accordance with theoretical expectations. Although the

teacher at SDN 1 Glempang demonstrated many characteristics of a responsive educator, several areas still require further strengthening. These include technical competence in designing more complex algorithmic activities, limited mastery of core Computational Thinking (CT) concepts, and an instructional materials planning process that has not yet been systematic. The teacher prepares learning materials independently outside instructional hours; however, a structured planning framework, as recommended in effective educator models, has not yet been fully implemented. In addition, continuous professional Development remains an area of concern. Although the teacher has shown initiative in seeking references, participation in formal training on CT or coding remains limited. This condition underscores the need for stronger institutional support to promote sustained and systematic professional Development.

The teacher at SDN 1 Tumiyang demonstrates greater competence through repeated experience implementing Unplugged Coding. However, several abilities still need improvement to align with theoretical standards: Managing differentiated instruction for students with diverse abilities; The teacher has implemented role distribution and provided support; challenges remain in addressing the heterogeneity of student abilities. C.-Y. Chen et al. (2023); Zahid & Nawab (2025), emphasize the need for deeper differentiation strategies; Time management in computational activities; The teacher noted that Unplugged Coding requires more time, whereas (Rincon-Flores et al., 2024; Van Sluijs & Matzat, 2024), stresses that effective educators should balance time between exploration, discussion, and reflection; Using more standardized formative assessments; The teacher conducts process-based observations but has not yet used comprehensive CT assessment instruments aligned with modern CT assessment models.

Overall, both teachers possess a strong foundation in pedagogical, interpersonal, creative, and motivational competencies for implementing Unplugged Coding. However, consistent with (Adeniran et al., 2025); (Fernandes et al., 2024), the teacher at SDN 1 Glempang still needs improvement in technical competence, systematic planning, and professional development, while the teacher at SDN 1 Tumiyang requires stronger differentiation strategies, better time management, and more in-depth CT assessment practices.

Conclusion

This study aims to analyze students' initial understanding before the implementation of Unplugged Coding, describe teachers' strategies for its application, and evaluate its effectiveness in improving elementary students' problem-solving skills. The findings indicate that Unplugged Coding is effective in strengthening problem-solving abilities across all stages outlined by Polya. Students demonstrated substantial improvement in understanding problems, devising plans, executing strategies, and engaging in reflection and debugging. Consistent implementation encouraged students to think more systematically, collaboratively, and critically through visual representations and concrete activities that facilitated their understanding of computational concepts. Adaptive teacher strategies ranging from material preparation and instructional planning to classroom management also played an essential role in supporting successful implementation. Theoretically, this study contributes to activity-based, non-digital learning by demonstrating that Unplugged Coding can serve as a practical approach for developing elementary students' thinking and problem-solving skills, particularly in contexts with limited technological resources. Practically, the findings offer important implications for teachers and schools, showing that Unplugged Coding can be integrated as an innovative instructional alternative that fosters a collaborative learning culture while enhancing students' basic digital literacy and readiness for the demands of 21st-century learning. This study has several limitations, including its narrow school coverage, a relatively small sample size, and variations in implementation across teachers that may limit the generalizability of the results. Therefore, future research is recommended to involve more schools with diverse characteristics, to combine unplugged and digital approaches, and to employ more standardized instruments to measure problem-solving skills. Further studies are also needed to explore the long-term impact of Unplugged Coding on students' digital literacy, creativity, and preparedness for technology-based learning.

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Author Contributions

A graduate student in the Elementary Education Study Program at the Graduate School of Muhammadiyah University Purwokerto (UMP): A. A. R. His research interests include elementary education and teaching. A. A. R; W. K contributed to the development of the main conceptual ideas, the writing of the theoretical analysis, the collection and analysis of secondary data, and the proofreading of the manuscript.

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The researchers funded this research independently.

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