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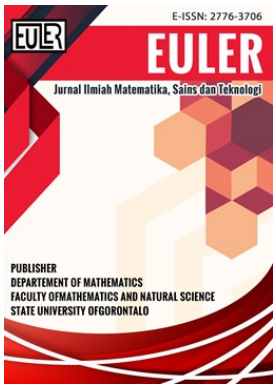

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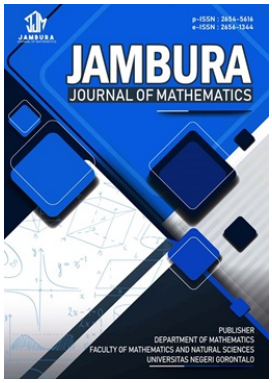

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Research Article

Fostering Inclusive Mathematics Learning: A Lesson Study Approach Integrating the Wordwall Digital Platform for Special Needs Students

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ABSTRACT. *This study investigated the integration of the Wordwall digital interactive learning platform into a Lesson Study framework to enhance mathematics instruction for students with special needs. Conducted at a Special Education School (SLB), the research explored digital tools and collaborative teacher development improved student engagement, conceptual understanding, and motivation in learning basic mathematical concepts. A group of mathematics teachers participated in lesson planning, classroom implementation, observation, and reflection, during which Wordwall was used to design interactive and accessible math activities tailored to students with diverse disabilities. Despite growing interest in inclusive education, few studies had examined how structured professional development models such as Lesson Study could be effectively integrated with digital platforms like Wordwall in special education contexts. This study addressed that gap by demonstrating that the strategic integration of these tools significantly enhanced students' active participation and conceptual comprehension. The interactive features of Wordwall supported multisensory engagement and differentiated instruction, while the Lesson Study process facilitated sustained collaboration and adaptive teaching among educators. The findings suggest that integrating technology-enhanced learning with professional learning communities not only improved students' outcomes, such as accuracy in basic computations, mathematical reasoning, and enthusiasm but also strengthened teachers' capacities in inclusive instructional design, reflective practice, and adaptive pedagogical strategies. These results showed insights for future research and practice, especially in developing inclusive models that digital technology and collaborative teaching to promote equity and quality in special education.*

1. Introduction

Inclusive mathematical education is still going through a tough time, especially for learners with special needs who often require more personalized and stimulating methods. In this study, we will explore how a mixture of immersive features provided through the Wordwall digital platform and collaborative reflection from lesson study can generate meaningful experiences. Working memory limitations are common among students with disabilities, which directly influences performance in math and problem-solving as well as long-term retention, rendering evidence-based strategies like both retrieval and interleaved practice, particularly when combined with technology support crucial for generating sustained learning benefits [1]. For visually impaired learners, multimodal and tactile-based tools, particularly when combined with audio feedback, have proven effective in fostering conceptual understanding and engagement [2]. The successful implementation of inclusive mathematics education depends greatly on teachers' competencies in adapting instruction, designing differentiated materials, integrating assistive technologies, managing diverse classrooms, and applying adaptive as-

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sessment methods, as demonstrated in Malaysian primary schools where such competencies have been linked to improved academic performance and greater classroom participation [3]. Recent studies underscore the significance of game-based learning in mathematics instruction, whether through digital platforms like Wordwall and Matific [4], innovative educational game development methodologies [5], or the integration of traditional cultural games [6], all of which aim to enhance student engagement, conceptual understanding, and positive learning attitudes.

By integrating technology and teacher collaboration, we aim to foster more equitable, engaging, and inclusive mathematics classrooms. Inclusive education has emerged as a global imperative aimed at ensuring that all students, regardless of their abilities or disabilities, receive equitable learning opportunities. Mathematics, as a foundational subject, poses unique challenges for students with special needs due to its abstract nature and often rigid instructional methods. Several studies highlight the effectiveness of game-based digital media in enhancing students' mathematical understanding and engagement. Integrating Project-Based Learning integrated with Science, Technology, Engineering, and Mathematics (PjBL-STEM) with online games improves critical thinking skills [7], while the benefits of Scratch-based interactive media in facilitating conceptual understanding [8]. Additionally, learning motivation through the application of game methods in primary mathematics education [9]. The integration of interactive media in mathematics learning has been further reinforced through the development of card-based educational tools that contextualize abstract mathematical concepts into tangible and engaging activities [10]. The effective implementation of such gamified strategies in the classroom, however, requires comprehensive teacher training that addresses the gap in technological pedagogy, ensuring that educators are equipped to adapt to curriculum reforms [11]. Aligning with the global agenda of Sustainable Development Goal 4, gamification and game-based learning have been recognized as innovative approaches to promote inclusive, equitable, and high-quality education by fostering student engagement and enhancing learning outcomes [12].

Inclusive game-based learning designs that incorporate multimodal sensory experiences, such as audio guidance and tactile materials have demonstrated promising results in engaging visually impaired learners in STEM education, ensuring that accessibility remains a core focus in educational innovation [2]. The positive influence of educational games on students' motivation and academic achievement has been consistently highlighted in studies where game-based learning is applied to simplify complex mathematical concepts and foster problem-solving skills through interactive and exploratory learning environments [13]. Despite the fact that conventional classroom strategies may not effectively satisfy the diverse cognitive, sensory, and behavioral requirements in special education situations, there is an emerging need for highly adaptable and inclusive pedagogical measures. Without further ado, here are the my take and the options for adapting mathematics instruction to a wider audience. Among them, there is an interactive digital platform such as Wordwall that helps to create multisensory learning experiences based on the profile of each student. What they fail to understand is that the effective integration of such tools in how we engage learners requires more than technical integration but needs pedagogically alignment and collaborative teacher development. Lesson study is a formalized, collaborative model of professional development that originated in Japan and involves designing, observing, delivering, and critiquing lesson plans as part of a community. Although shown to improve teaching in general education contexts, the use of lesson study in special education settings is limited and under-researched, including its combination with digital learning tools. This research will study how to integrate

Wordwall into the lesson so that it can support inclusive mathematics instruction in a Special Education School (SLB). In particular, it investigates the potential of these data to improve student participation in the learning process through digital interactivity but in conjunction with collaboration between teachers and students that take place on how to measure understanding or motivation for basic concepts in fraction base. Thus, this research is a step on the way to develop sustainable models of inclusion pedagogy in maths education that also addresses inclusive education and digital technology as well as professional learning communities.

Lesson Study has been globally recognized as a powerful approach for enhancing mathematics teachers' professional development, not only in Japan but also across various educational contexts, including Europe and Asia, by fostering collaborative lesson planning and reflective teaching practices [14]. The adaptation of Lesson Study into distance learning environments during the COVID-19 pandemic further demonstrated its flexibility and effectiveness in maintaining teacher collaboration and instructional improvement through digital platforms [15]. Moreover, integrating Lesson Study with Teaching Through Problem Solving (TTP) has been shown to significantly improve teachers' abilities to develop students' mathematical problem-solving skills, highlighting the synergistic potential of these two pedagogical models in promoting deep conceptual understanding and critical thinking [16].

Previous studies have shown that digital game-based platforms such as Wordwall can improve students' motivation and academic achievement in mathematics learning. Wordwall significantly enhanced students' learning motivation and mathematics achievement in regular classrooms [17]. The positive impact of digital game-based learning on mathematics education that can meet, particularly in improving students' motivation, engagement, and learning outcomes [18]. Digital games are also considered effective in creating interactive and student-centered learning environments that support cognitive and affective development in mathematics learning [19, 20]. According to systematic review studies, game-based learning has been regarded as one of the most popular method in mathematics education and it tends to have a positive impact on students' attitudes and achievement. But the majority of research is on general education students with infrequent discussion of its use in inclusion or special education contexts. Lesson Study is considered as an effective model for improving teachers' instructional practices widely, only a few studies have explored the utilization of Lesson Study with the aid of digital platforms in order to support inclusive mathematics learning experiences for the students who are identified with special needs. There is a research gap in identifying how this pedagogical tool can be implemented in Lesson Study ensuring inclusive mathematics classroom practices to special educators. The novelty of this research is to combine the Wordwall digital platform with the collaborative Lesson Study model as a form of mathematics learning support for students with special needs. Lesson Study acclaimed as a model of mathematics professional development, implemented in countries from Japan to numerous educational systems throughout Europe and Asia, promoting collaborative planning of lesson sequences followed by collective reflective discussions on teaching practices [14]. The adaptation of Lesson Study into distance learning environments during the COVID-19 pandemic further demonstrated its flexibility and effectiveness in maintaining teacher collaboration and instructional improvement through digital platforms [15]. Integrating Lesson Study with Teaching Through Problem Solving (TTP) has been shown to improve teachers' abilities to develop students' mathematical problem-solving skills [16].

Other studies emphasized the importance of Lesson Study in strengthening reflective teaching practices and collaborative lesson design across different educational contexts [21, 22]. In special education environments, collaborative lesson planning becomes particularly

important because teachers must design adaptive instruction that accommodates diverse learner needs [23]. Recent bibliometric analyses indicate that Lesson Study research continues to expand globally and has become an important framework for improving instructional quality in mathematics education [24, 25]. The novelty of this study lies in the use of the Wordwall digital interactive platform, the collaborative professional development model of Lesson Study, and the context of inclusive mathematics learning for students with special needs in special education schools. This study show an instructional approach that connects technology-enhanced learning with collaborative teacher reflection to improve both student engagement and instructional practices in inclusive classrooms. So based on it, this study aims to investigate how the integration of Wordwall within Lesson Study in inclusive mathematics classrooms.

2. Methods

2.1. Research Design

This study utilized a multiple embedded case study design within a collaborative Lesson Study context to explore the usage of Wordwall in inclusive mathematics instruction for students with special needs. Instead of cycles, the research was conceived as a single detailed look at two cases of teaching with an emphasis on collaborative planning, real-time doing and observing, and post-lesson reflection. This design enabled the researchers to investigate both inclusive teaching practices enriched by digital form of technology and that are situated in two different learning contexts.

2.2. Participants and Setting

The study was conducted at SLB D at East Java Indonesia involving one model teacher and five observing teachers who participated in the Lesson Study process. All teachers had experience teaching students with special needs. The student participants consisted of four students with intellectual disabilities, aged between 9 and 12 years. These students were grouped based on their functional academic abilities and received instruction in foundational mathematical concepts. The learning environment was designed to be inclusive and responsive to individual needs, with a focus on engagement through the use of the Wordwall digital platform.

2.3. Procedure

The research was conducted in three main stages: planning, implementation, and reflection. In the planning stage, the teaching team collaboratively designed two mathematics lessons suited to each group of students. Both lessons integrated the Wordwall platform, specifically utilizing the matching activity with quiz settings, where students matched questions to answers through interactive, game-like formats tailored to their cognitive and sensory profiles.

In the implementation stage, the model teachers delivered the lessons in their respective classrooms, while the observing teachers recorded student behavior, engagement, and interactions with the digital media. The focus was on how the Wordwall features supported understanding and participation. In the reflection stage, the teaching team held structured discussions to review student responses, identify instructional successes and challenges, and draw insights for future practice. Although not conducted in cycles, this reflective component retained the collaborative spirit of lesson study.

2.4. Instruments and Data Collection

Data were collected using instruments to ensure credibility and triangulation. Observations were conducted during each lesson implementation to document student behavior, engagement, and responses to Wordwall-based activities. Field notes were compiled throughout both the teaching and reflective sessions to capture classroom dynamics and instructional adaptations. Teacher reflective journals provided insights into pedagogical decisions, challenges encountered, and strategies for inclusive instruction. To assess students' learning outcomes, the researchers analyzed students' worksheets and scores from Wordwall activities, focusing on basic computational accuracy and conceptual understanding. These diverse data sources provided a comprehensive view of the teaching-learning process at Special Education School (SLB) D at East Java, Indonesia.

2.5. Data Analysis

Data were analyzed through Miles and Huberman's interactive model consisting of data reduction, data display, and conclusion drawing. Each of these was coded, analyzed, and interpreted according to categories that reflected the research questions, including patterns related to student engagement, instructional effectiveness, and teacher collaboration. Ethical approval was obtained from the school administration and teachers participating in the study provided informed consent. All participants were assured that their responses would remain anonymous and confidential throughout the research process.

3. Results and Discussion

This part has introduced the outcomes of Wordwall in an adapted Lesson Study framework, presented and critically analysed across two inclusive mathematics classrooms. The outcome was then aggregated by two instructional cases, Teacher Model A working with students with hearing disabilities and Teacher Model B working with students with intellectual disabilities. By combining classroom observations, Wordwall activity results, and teachers reflections, the study investigates how using interactive digital tools and collaborative pedagogical planning contributed to student engagement for learning, conceptual understanding on inclusion, and inclusive teaching practices. In support of the interpretability of findings for each model, visual data in classroom images and Wordwall performance scores were also provided.

3.1. Interactive Learning with Wordwall: Observations from Teacher Model A

Figure 1 shows a student with a hearing impairment completing a mathematics Wordwall-based task on a smartphone. The student focused on the screen with a quiz activity that was created by Wordwall. They may be solving problems in an interactive tool on the laptop, and saving answers to a printed worksheet with pencil or pen. Additionally, the student seems to be using sign language or gestural communication, which is an adaptive behavioral response that is leveraged in students who are hearing impaired. Wordwall is an example of a multisensory, low-tech way to engage students through embedded digital learning tools that prompt inclusive interaction and support students with special needs when they are seamlessly integrated into instructional practice. The way the student is sitting and using the device signals motivation, independence, and an active learning stance, vital signs of worthwhile engagement. Additionally, it illustrates how the Lesson Study framework allowed teachers to prepare instruction that uses technology to cross gaps in communication and cognition so that students are able to understand mathematics within inclusive classrooms. Having explained what

Wordwall is and listed some of its features, Figure 1 shows a student with hearing impairment actively participating in a Wordwall-based mathematics task using a smartphone during the activity.

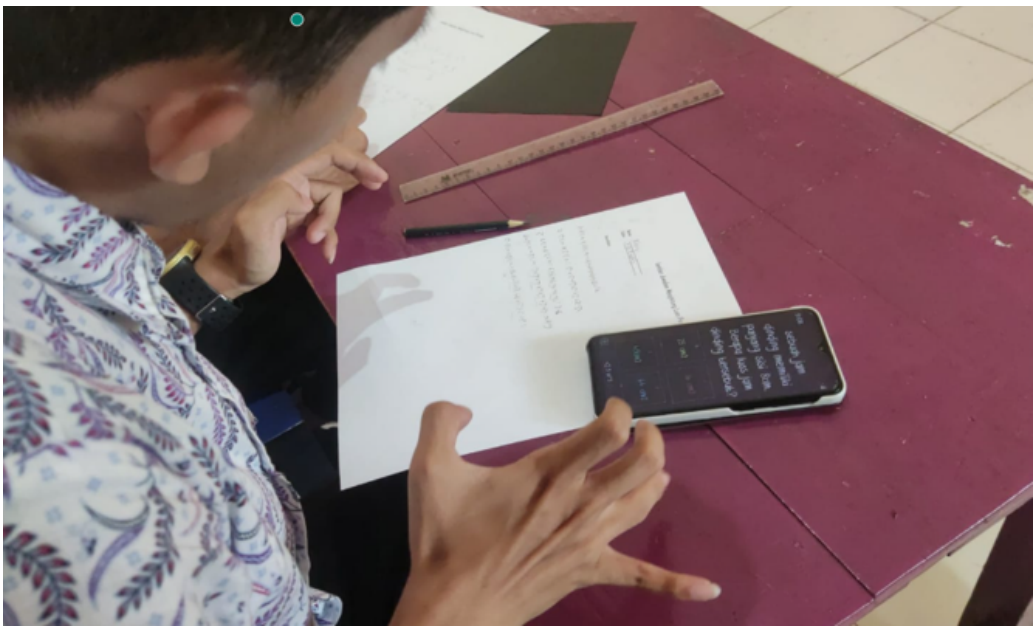

Figure 1. Student with hearing impairment engaging with a Wordwall activity using a smartphone during mathematics instruction

Figure 1 shows the student who has appeared in the system paying attention to the Wordwall interface, which represents active engagement with learning. Pairing visual information with audio. These figures show a student with hearing impairment using a Wordwall-based matching exercise on a smartphone. In the excerpt below (Figure 2), a student with hearing impairment uses gestural communication while working on a math task shown through the http://wordwall.net on a smartphone. The quiz on the phone is a matching activity, pairing students with math expressions and simple problems with their corresponding answers. This image shifts focus to the student at the center; their left hand is raised with fingers either outstretched in sign language or some expressive gesture. The phone and worksheet are placed in such a way that the student uses a dual-modality task: digital interaction with paper-based support. It shows how integrating technology can offer scaffolding for students who might struggle to navigate mathematical concepts independently due to communication challenges. Such practices are representative of one of the main findings from this study whereby, with appropriate lesson cohort structuring and thoughtful lesson planning in Lesson Study, digital platforms like Wordwall have the potential to offer valuable access, motivation, and conceptual understanding amongst learner populations exhibiting special needs, whether educational or physical; especially within inclusive environments where maximised development derived through verbal literacy instruction may not be feasible.

The interaction shown in Figure 2 also illustrates how the integration of digital platforms within the Lesson Study framework enables teachers to design learning activities that accommodate diverse communication needs, thereby promoting student engagement and conceptual understanding in inclusive mathematics classrooms. Figure 3 presents a student with hearing impairment solving multiplication problems on a worksheet after completing the Wordwall activity.

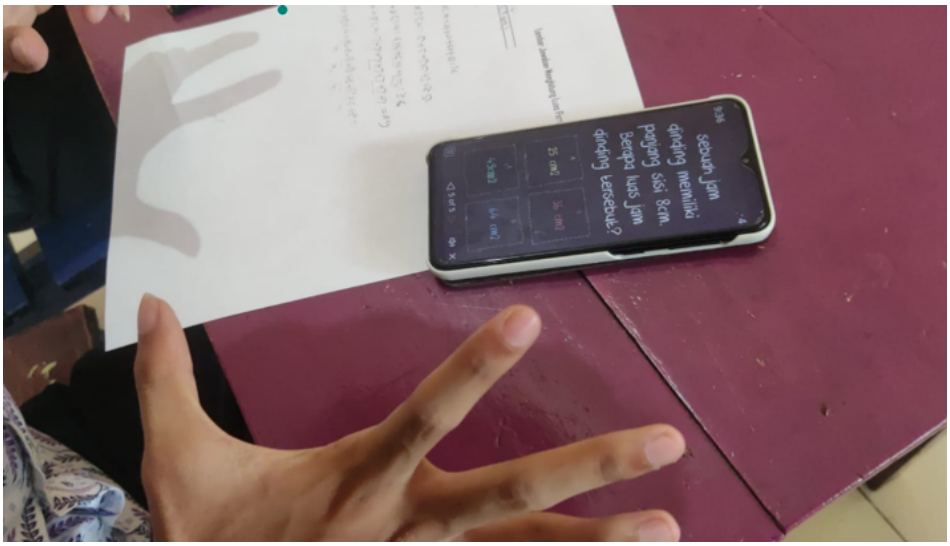

Figure 2. A student with hearing impairment interacting with a Wordwall-based matching activity using a smartphone

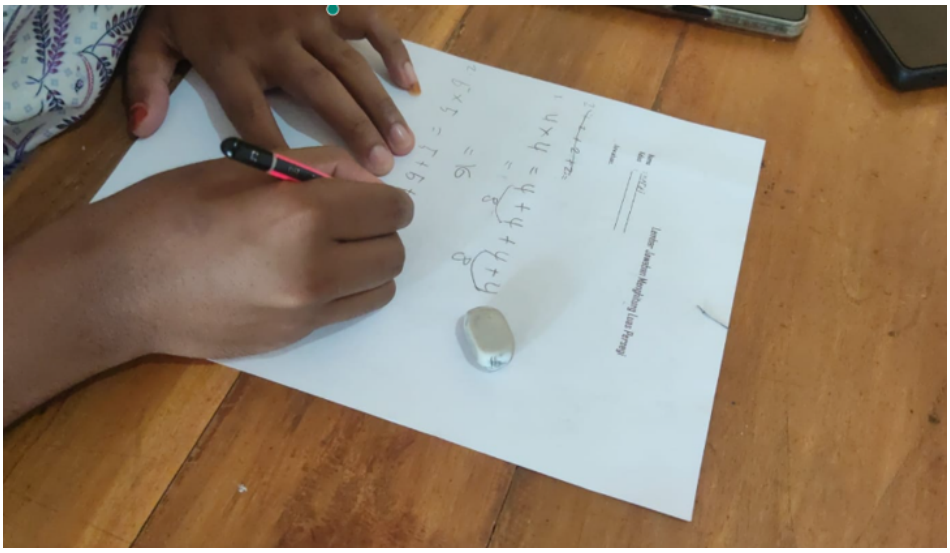

Figure 3. A student with hearing impairment solving multiplication problems on a worksheet following a Wordwall activity

Figure 3 shows a student with a hearing impairment independently solving basic multiplication problems on a worksheet. The structured layout of the student's work suggests the use of repetition and visual patterning, such as $4 + 4 + 4 = 12$, which aligns with strategies introduced through earlier interactive Wordwall activities. A pencil and eraser are visible, indicating traditional paper-based problem-solving, while a smartphone in the background suggests recent engagement with the digital platform. This behavior reflects the successful transfer of digital learning to conventional written tasks, especially important for students with hearing impairments who benefit from visual clarity, structured repetition, and self-paced instruction. The student's focus and independence demonstrate increased mathematical confidence, likely facilitated by the Lesson Study-informed instructional design that emphasized visual learning and multisensory engagement via Wordwall. The image exemplifies how combining technology-enhanced learning with carefully planned follow-up tasks can promote deep understanding and sustained engagement among students in inclusive mathematics settings.

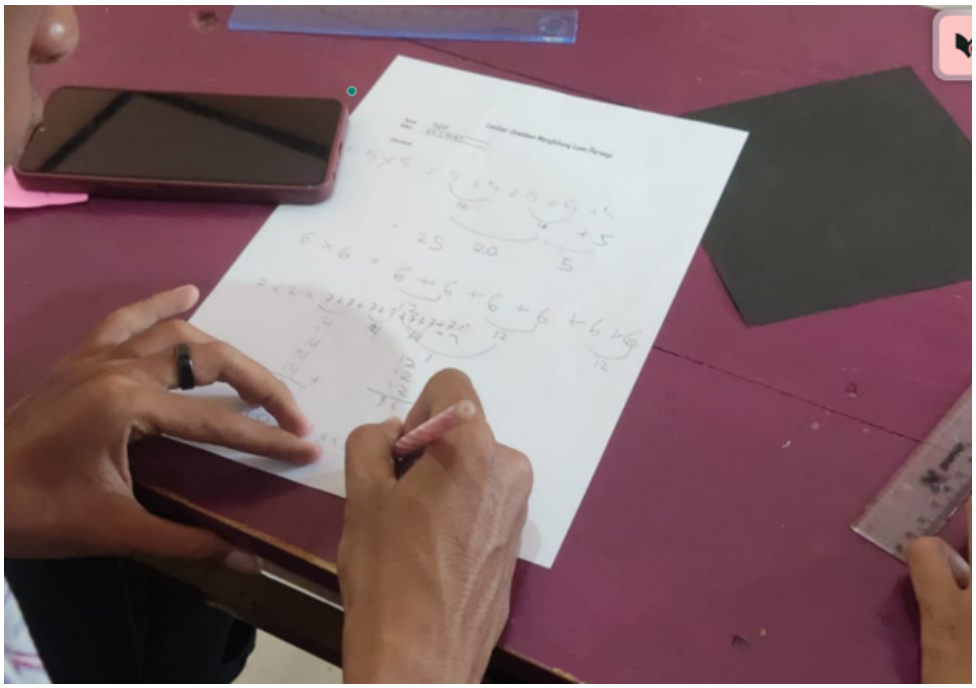

Figure 4. A student with hearing impairment performing multiplication exercises on a worksheet as a follow-up to a Wordwall activity

Figure 4 shows a student with hearing impairment completing multiplication exercises on a worksheet as a follow-up activity to the Wordwall-based learning session. The student applied repeated addition and grouping strategies when solving the problems. As illustrated in Figure 4, the integration of digital activities with written practice reinforced mathematical understanding and supported conceptual learning through multiple modalities. The image depicts a student with a hearing impairment deeply engaged in solving multiplication problems on a printed worksheet. The student applies structured repetition and grouping strategies evident from the use of repeated addition (e.g., $5 + 5 + 5 = 15$) and decompositions such as $6 \times 6 = 36$, suggesting a visual and conceptual understanding of multiplication. A smartphone placed nearby indicates that the worksheet was likely a follow-up to a Wordwall digital activity, which previously introduced or reinforced the concepts in an interactive format. This behavior demonstrates the effective transfer of knowledge from digital to analog tasks, highlighting the importance of multimodal instruction in inclusive settings. The student's ability to organize work spatially on paper also reflects the benefit of prior visual scaffolding offered by Wordwall's interactive design. Moreover, the quiet, focused posture and independence in problem-solving align with key indicators of student engagement and self-efficacy, outcomes targeted in the collaborative lesson planning phase of the Lesson Study model. This example underscores how combining digital interactivity with structured written practice can strengthen mathematical reasoning and foster inclusive, differentiated learning pathways for students with hearing impairments. Table 1 presents the student-level analysis for Teacher Model A, including Wordwall scores, engagement behavior, worksheet performance, and levels of learning independence among students with hearing impairments.

Results. As highlighted in Table 1, students with hearing impairments exhibited a clear level of engagement and independence throughout the Wordwall-based learning activities. Most students scored between 80% and 90% in Wordwall, showing that the interactive digital tasks were accessible and understandable for them. Students A1 and A4 performed with

Table 1. Student with Hearing Impairments Level Analysis with Teacher Model A

Student	Wordwall Score (%)	Engagement Behavior	Worksheet Performance	Independence Level	Notes
A1	90	Focused, used visual scanning and gestures	Completed 100% of multiplication tasks	High	Demonstrated self-paced problem solving and accurate match
A2	85	Actively engaged, frequent gestural communication	Minor calculation errors, but completed tasks	High	Asked clarifying gestures, confident in transitioning to paper
A3	80	Calm and focused, maintained attention	Needed verification for 1–2 answers	Moderate to high	Occasionally looked at peer's screen, but worked mostly alone
A4	88	Smiling, used sign gestures when unsure	Completed most tasks independently	High	Demonstrated positive attitude and improved time on task

the most independence, completing the majority of tasks on the worksheet correctly while also displaying strong self-paced problem-solving ability. Students A2 and A3, on the other hand, still needed minor adjustments to reach closure; however, they were ultimately able to carry out the tasks given in class independently. The behaviors of student engagement demonstrated in this table indicate that visual interaction and gestural communication facilitated students' participation. The participants' use of visual scanning, sign gestures, and focused attention when using the Wordwall platform also indicates that it accommodates the communication characteristics of students with hearing impairments. The results in Table 1 indicate that the combination of interactive digital schoolwork and more traditional structured worksheets can enhance independent learning, student engagement, and conceptual understanding within inclusive contexts for mathematics education.

3.2. Interactive Learning with Wordwall: Observations from Teacher Model B

The second instructional case involved students with intellectual disabilities, facilitated by Teacher Model B. This group of students required highly structured, repetitive, and visually supported instruction to understand fundamental mathematical concepts. The use of the Wordwall platform, particularly its matching quiz format, proved effective in capturing students' attention and guiding them through multiplication tasks with visual reinforcement and gamified elements. Teacher Model B implemented step-by-step demonstrations and allowed extended response times to accommodate the students' cognitive processing needs. Observational data and student worksheets indicated that students were able to apply repeated addition strategies and showed increased independence in completing written exercises following the digital activity. The integration of Wordwall not only enhanced engagement but also supported concrete conceptual understanding, making abstract arithmetic more accessible for students with intellectual disabilities. Figure 5 illustrates how the technology-supported lesson helped increase motivation, accuracy, and focus among the participants.

Figure 5 illustrates that collaborative interaction and teacher support have aided students in actively staying on task with the Wordwall-based mathematics tasks. In Figure 5, we see two female students with intellectual disabilities interacting with a Wordwall activity on a smartphone and laptop. They appear engaged and positive, reflecting a sense of enjoyment when presented with the digital educational material. The teacher or facilitator is very present, providing supportive supervision and encouragement as shown by her positive ex-

Figure 5. Students with intellectual disabilities engaging collaboratively with Wordwall activities on a smartphone and laptop under teacher guidance

pression and body language. This case is an example of how digital interaction can promote understanding and social skills, which are two important pillars for students with intellectual disabilities. This indicates how flexible and adaptive this system is; students were able to engage with the content using whichever device they felt most comfortable with (laptop, mobile). Figure 5 further supports the study's findings, indicating that technology can augment inclusive mathematics instruction when such use is underpinned by appropriate pedagogical considerations and planning, considerably increasing student participation levels, enjoyment, and learning outcomes for all students, especially those who thrive on visual, repetitive, and interactive modalities.

Figure 6. Students with intellectual disabilities collaboratively engaging with a Wordwall quiz on a smartphone

Figure 6 depicts two female students with intellectual disabilities working together on a Wordwall-based quiz shown on a smartphone. In this learning activity, the students are

looking at the screen, providing evidence of joint attention and shared problem-solving. The presence of a measuring tape on the table indicates that the learning activity may include contextual tasks related to mathematical concepts (in this case, measurement or estimation) or hands-on activities to better understand these concepts. This behavior suggests that peer-assisted learning with the support of digital tools can promote cooperation, engagement, and mutual support for children with special needs. The simplicity and clarity of the Wordwall interface, as well as its immediate feedback features, kept both students focused and engaged with the task at hand. Figure 6 supports the study's findings that interactive and visual digital platforms such as Wordwall can effectively scaffold student-centered learning experiences for diverse learning needs when integrated into collaborative learning strategies within an inclusive classroom environment. In Figure 6, two students with intellectual disabilities are collaboratively working on a Wordwall quiz accessed on a smartphone.

As shown in Figure 6, two students with intellectual disabilities were observed collaboratively engaging with a Wordwall-based quiz displayed on a smartphone. The students appeared to focus their attention on the digital interface while attempting to match mathematical problems with their corresponding answers. Their close interaction with the device suggests joint attention and cooperative engagement during the learning activity. This collaborative interaction indicates that the use of gamified digital tools such as Wordwall can support peer-assisted learning in inclusive mathematics classrooms. The visual interface and interactive features of the platform allowed students to participate actively in the task while receiving immediate feedback. Such interaction helped maintain students' motivation and encouraged them to explore mathematical concepts in a more engaging and accessible manner. The behavior observed in Figure 6 suggests that digital game-based learning environments can facilitate social interaction, engagement, and conceptual understanding among students with intellectual disabilities.

Figure 7 presents a student with an intellectual disability participating in a mathematics lesson supported by digital technology. The student was seated facing a projected Wordwall activity displayed on the classroom screen. As shown in Figure 7, the use of visual digital media helped maintain the student's attention and supported the understanding of mathematical concepts through structured and interactive instructional materials.

Figure 7. A student with an intellectual disability participating in an inclusive mathematics lesson supported by digital technology

Figure 7 captures a student with an intellectual disability actively engaged in a classroom setting during a mathematics lesson. Facing a digital projector screen displaying a Wordwall-based instructional slide, the student is seated attentively, wearing a scout uniform commonly used in Indonesian schools. The classroom environment reflects an inclusive and supportive atmosphere, with neatly arranged desks and visible visual learning aids on the walls. The projected slide demonstrates the integration of the Wordwall digital platform into mathematics instruction. This setup exemplifies how technology-enhanced teaching, when planned collaboratively through a Lesson Study approach, can provide accessible and engaging learning experiences for students with special needs. The student's forward-facing posture indicates focus and participation, highlighting the impact of multisensory digital tools in fostering meaningful conceptual understanding in inclusive educational settings.

Figure 8 below shows inclusive mathematics instruction facilitated through the integration of the Wordwall platform within a Lesson Study framework. The teacher explained the learning material displayed on the projector while students engaged with the same activity using digital devices. As illustrated in Figure 8, the integration of interactive digital media and collaborative lesson planning created a structured learning environment that promoted student engagement and conceptual understanding.

Figure 8. Inclusive mathematics instruction using the Wordwall platform facilitated through Lesson Study collaboration

Figure 8 shows a mathematics teacher delivering an interactive lesson to students with special needs in a structured classroom environment. The teacher stands at the front of the room, explaining a concept displayed on the projector screen, which features a colorful slide from the Wordwall digital platform. The content appears to be a gamified mathematics activity designed to foster student engagement through visual and interactive elements. In the foreground, two female students with intellectual disabilities are seated at a desk, actively participating in the lesson. One of them is using a laptop that displays the same Wordwall activity shown on the projector, indicating synchronized digital engagement. The student holds a stylus or pointing tool, suggesting direct interaction with the platform. Educational materials and teacher notes are visible on the desk, reinforcing the structured and well-planned nature of the lesson. Figure 8 reflects the core principles of the study, namely the integration

of interactive digital tools like Wordwall with collaborative lesson planning, as facilitated by the Lesson Study model. Figure 8 shows that inclusive learning environments can be improved through technology and professional collaboration to support motivation, engagement, and conceptual understanding among students with special needs.

Figure 9 presents the reflection phase of the Lesson Study conducted after the implementation of the mathematics lesson. Teachers gathered to discuss observations of student responses, learning difficulties, and instructional strategies used during the lesson. As shown in Figure 9, collaborative reflection enabled teachers to evaluate the effectiveness of their teaching practices and refine future lesson designs to better support inclusive learning.

Figure 9. Reflection phase (See Phase) of the Lesson Study conducted after inclusive mathematics instruction

As shown in Figure 9, it captures a post-lesson reflection session involving a group of teachers after conducting an inclusive mathematics lesson supported by the Wordwall digital platform. Seated in a classroom, the teachers are seen discussing their observations of student responses and instructional strategies used during the implementation phase. One teacher gestures while speaking, indicating active engagement in evaluating the effectiveness of the learning activities. This reflective dialogue centers on the students' engagement with digital tools, their ability to understand basic mathematical concepts such as multiplication through visual and interactive formats, and the challenges encountered during instruction. The presence of a laptop and a projector on the desk suggests that teaching materials or student activity outcomes may have been reviewed during the discussion to support evidence-based analysis. The See Phase allowed the educators to critically examine how the integration of Wordwall influenced students with special needs, particularly regarding their motivation, focus, and conceptual understanding. Through this collaborative reflection, the teachers identified instructional successes, such as increased student participation and independence, as well as areas for refinement in future lesson designs. This moment highlights the core principle of Lesson Study: continuous, collaborative improvement of teaching practice through structured reflection based on real classroom experiences in inclusive settings.

Figure 10 captures a learning class of inclusive teaching in which a teacher is actively assisting two female students with intellectual disabilities during a mathematics lesson utilizing the Wordwall digital platform. The students are seated at a desk, closely engaging with a laptop, smiling and showing clear signs of enjoyment and focus as they complete a digital task. The teacher stands beside them, attentively observing and offering guidance in a sup-

portive and encouraging manner. This close interaction reflects a personalized instructional approach where the teacher ensures that each student receives the help they need to participate meaningfully in the lesson. The teaching process shown here emphasizes the importance of proximity, empathy, and responsiveness in supporting students with special needs. By integrating technology such as Wordwall in a collaborative setting, the teacher fosters a dynamic and inclusive learning environment that not only promotes cognitive engagement but also social-emotional development. The presence of printed materials on the desk indicates that digital tasks are complemented by written or tactile resources, allowing students to access mathematical content through multiple modalities. Through this approach, we illustrate the enriching effect of sound instructional design, enhanced through the Lesson Study model, on student motivation, participation, and understanding in inclusive mathematics education.

Figure 10. Teacher facilitating inclusive mathematics learning through digital engagement

As shown in Figure 10, the teacher actively facilitated inclusive mathematics learning by guiding students as they interacted with a Wordwall-based activity using a digital device. The students appeared engaged and motivated while working collaboratively, while the teacher provided immediate support and feedback during the task. This interaction illustrates the important role of teacher facilitation in ensuring that digital learning tools are used effectively to support students with special needs. The learning situation presented in Figure 10 also reflects how the integration of digital platforms within a Lesson Study framework can create a supportive and interactive learning environment. Through teacher guidance and collaborative engagement, students were able to participate more confidently in mathematical tasks. This suggests that combining digital learning tools with responsive teacher facilitation can enhance student participation, motivation, and understanding in inclusive mathematics classrooms.

To better understand how students with intellectual disabilities responded to the Wordwall-based learning activities, a detailed analysis of individual student engagement and performance was conducted. The analysis included Wordwall scores, observed engagement behaviors, worksheet completion, and levels of learning independence during the lesson. Table 2 presents the student-level analysis for Teacher Model B, providing a detailed overview of how the students interacted with the digital learning platform and completed the assigned mathematical tasks.

As shown in Table 2, a visual representation of Wordwall activity scores for Teacher Model A and Teacher Model B's students was developed. The bar chart below illustrates the dis-

Table 2. Student with Intellectual Disability Level Analysis Teacher Model B

Student	Wordwall Score (%)	Engagement Behavior	Worksheet Performance	Independence Level	Notes
B1	75	Enthusiastic, needed visual prompting	Completed with teacher assistance	Moderate	Responded well to gamified format but required reminders
B2	65	Easily distracted, re-engaged with peer support	Completed 60% of tasks with guidance	Low to Moderate	Relied on repetition and peer scaffolding
B3	70	Enjoyed the activity, smiled frequently	Attempted all problems with several errors	Moderate	Required verbal repetition and modeling
B4	60	Hesitant at first, gained confidence	Partial completion, strong visual reliance	Low	Needed constant support, benefited from teacher proximity

tribution of scores, highlighting differences in accuracy and engagement patterns between students with hearing impairments (Teacher Model A) and those with intellectual disabilities (Teacher Model B). This visual data complements the qualitative observations by offering a concise depiction of how the integration of interactive digital tools and structured lesson planning impacted student outcomes in both groups.

To provide a clearer comparison of student performance across the two instructional models, a visual representation of Wordwall activity scores was developed. Figure 11 illustrates the distribution of Wordwall scores among students from Teacher Model A and Teacher Model B.

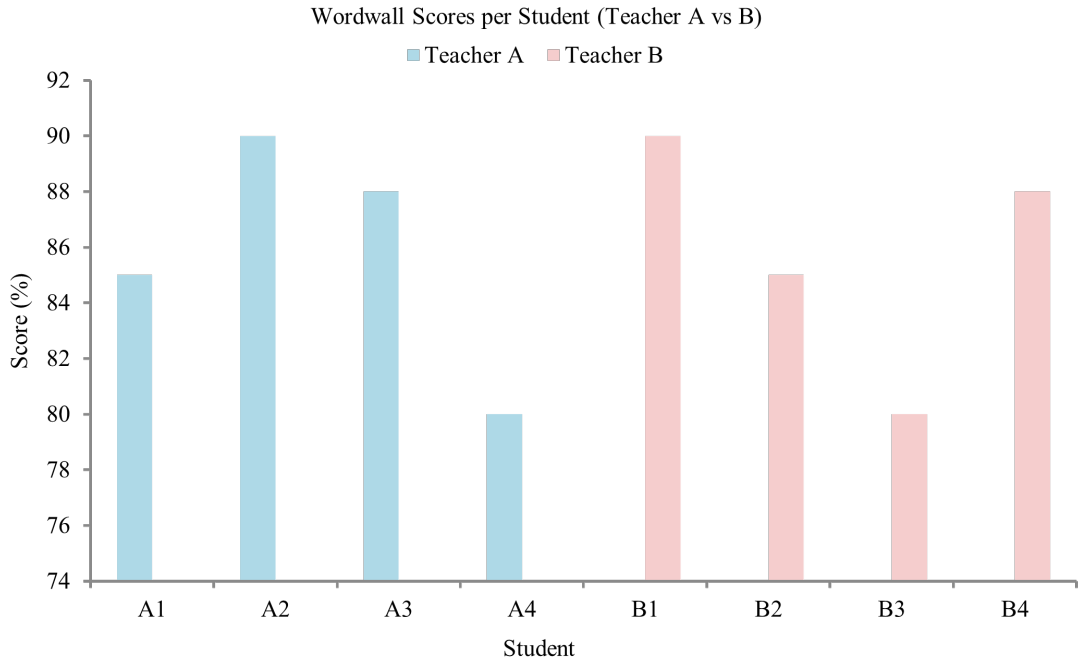

Figure 11. Wordwall activity scores per student for Teacher A and Teacher B

As shown in Figure 11, it provides a comparative visualization of individual student performance across two instructional models. Students A1 through A4, facilitated by Teacher A, represent learners with hearing impairments, while students B1 through B4, guided by Teacher B, consist of students with intellectual disabilities. The chart reveals a consistently higher score distribution among Teacher A's students, with scores ranging from 80% to 90%.

In contrast, Teacher B's students exhibit a wider score variance, ranging from 60% to 75%. This data pattern indicates that students with hearing impairments, when provided with multisensory and interactive digital tasks through Wordwall, were able to engage more independently and accurately in completing the activities. Their performance reflects the efficacy of visual and gesture-supported learning strategies, as reinforced by the Lesson Study-informed lesson design. Conversely, students with intellectual disabilities, although displaying visible enthusiasm and engagement during the Wordwall sessions, required more guided facilitation and support throughout the task completion process, which is reflected in their lower score range.

The chart in Figure 11 emphasizes how differentiated instructional strategies, tailored to specific cognitive and sensory profiles, are critical in inclusive mathematics instruction. It illustrates that while digital platforms like Wordwall offer engaging and accessible learning environments for diverse learners, the level of teacher scaffolding and adaptive instructional approaches significantly influences student performance outcomes. The visual comparison reinforces the study's findings that effective integration of technology must be complemented by responsive and individualized pedagogical practices to maximize learning gains in inclusive classrooms.

3.3. Discussion

The findings of this study indicate that integrating the Wordwall digital platform within a Lesson Study framework can support inclusive mathematics learning for students with special needs. The interactive features of Wordwall encouraged students to participate actively in learning activities and helped maintain their attention during the lesson, indicating increased student engagement. The visual and interactive design of the platform also enabled students to connect digital learning experiences with written mathematical tasks, supporting their conceptual understanding of mathematical concepts. Students with hearing impairments benefited from the visual clarity and interactive nature of the platform, which facilitated focused attention and independent task completion. These students were able to transition from digital activities to worksheet-based exercises, suggesting that the digital tasks supported their conceptual retention. In contrast, students with intellectual disabilities required more guided interaction during the learning process. However, the repetitive structure and immediate feedback provided by Wordwall helped them understand mathematical concepts such as multiplication and repeated addition. The visual scaffolding embedded in the platform, combined with teacher guidance, supported their cognitive processing and gradually encouraged independent problem-solving.

The present findings align with previous research that underscores the significance of integrating Lesson Study with arts-based methodologies to foster reflective teaching practices and enhance pre-service teachers' sensitivity to human rights education [26]. The iterative process of collaborative lesson planning and feedback refinement, particularly through the role of Koshi as knowledgeable others, has been shown to be instrumental in bridging theoretical frameworks with classroom practices, ensuring a more contextualized approach to pedagogical improvement [21, 23, 27]. The evolving landscape of Lesson Study research also highlights a notable geographical diversification, where recent bibliometric analyses reveal a substantial growth of scholarly contributions from Europe and other regions, indicating a global adaptation of Lesson Study practices beyond its Japanese origins [24]. Furthermore, the integration of emerging technologies such as Generative AI within Lesson Study cycles has demonstrated a promising avenue for enhancing teachers' instructional design and fostering agency in utilizing AI-driven tools for innovative classroom practices [25].

The game-based characteristics of Wordwall also contributed to improving students' learning motivation. The interactive tasks and immediate feedback encouraged students to participate more confidently and complete the assigned activities with greater interest. The findings of this study further reinforce the growing body of literature highlighting the pedagogical potential of gamification in enhancing student engagement and learning outcomes. Gamified quizzes, for example, have been shown to significantly improve students' recall, motivation, and overall learning performance by integrating game mechanics into assessment activities [28]. A recent bibliometric analysis also revealed a rapid growth of research on gamification in education, indicating both increasing scholarly interest and a diversification of its applications across disciplines and educational levels [29]. In addition, gamification has been found to foster self-directed learning skills, as it encourages students to take greater ownership of their learning process and engage in goal-oriented activities within a playful yet structured environment [30]. Beyond traditional classroom subjects, gamification has also been effectively implemented in domains such as entrepreneurship education, where tools like Kahoot! have demonstrated the capacity to stimulate competition, enhance participation, and improve knowledge retention [31].

Gamification has also been identified as an effective pedagogical approach for sustaining student motivation and improving academic performance in higher education, particularly during the challenges posed by the COVID-19 pandemic, where it provided both engagement and continuity in remote learning contexts [32]. Within STEM-related fields, gamification has been systematically reviewed as a promising strategy to enhance programming and problem-solving skills while maintaining learner interest over time [33]. Student acceptance of gamification in higher education has been linked to factors such as perceived enjoyment, ease of use, and relevance to learning objectives, reinforcing the need for thoughtful integration of game elements into course design [34]. Beyond general education, gamification has been effectively adapted to inclusive and special education contexts worldwide, with evidence showing its potential to improve access, participation, and learning outcomes for students with disabilities across diverse cultural settings, including the Middle East, Europe, and Africa [35–37]. Moreover, systematic reviews have highlighted the success of gamifying peer review activities to foster critical thinking and constructive feedback in educational settings [38], while immersive approaches to integrating gaming concepts into lessons have been found to improve engagement and cognitive immersion [39].

In the context of primary mathematics education, gamification has shown promise in making learning more interactive and relatable for young learners, especially when combined with personalized and adaptive strategies that cater to individual learning needs [40, 41]. Importantly, serious game prototypes have also been developed for children with special needs, demonstrating that game-based learning can be a valuable tool for promoting inclusivity and providing differentiated learning experiences that align with diverse abilities [42]. Collectively, these findings support the view that gamification, when intentionally designed with accessibility and learner diversity in mind, can serve as a powerful enabler of both academic achievement and equitable educational participation. The success of this instructional approach is closely related to the collaborative nature of the Lesson Study framework. Through collaborative lesson planning, classroom observation, and reflective discussions, teachers were able to analyze students' responses and refine their instructional strategies. This reflective process enabled teachers to design learning activities that were better aligned with students' cognitive and sensory characteristics, thereby strengthening inclusive instructional practices. The contrasting responses between the two groups of learners also underscore the

importance of differentiated instruction in inclusive settings. While students with hearing impairments displayed greater autonomy in transferring knowledge across modalities, those with intellectual disabilities required more explicit modeling and support. These differences highlight the need for teachers to employ flexible strategies that consider the unique cognitive and sensory profiles of their students.

In conclusion, the combination of digital innovation and collaborative teacher development has proven to be a promising approach for fostering inclusive mathematics learning. The results suggest that when digital platforms like Wordwall are thoughtfully integrated into professional learning communities, they can enhance both student learning outcomes and teacher instructional competence. This study contributes to the growing discourse on inclusive education by offering a model that is not only effective but also scalable, adaptable, and rooted in reflective, data-informed practice. The current study's findings resonate with prior research emphasizing the importance of preparing prospective mathematics teachers (PMTs) to critically evaluate and integrate historical elements into lesson plans, fostering students' deeper conceptual understanding of mathematics through historical contexts [43]. Moreover, embedding design-based learning strategies within a lesson study framework has been shown to enhance teachers' spatial pedagogical content knowledge and foster innovative practices in early childhood STEM education [44]. These results reaffirm the potential of lesson study as a dynamic professional development model that bridges theoretical constructs with practical instructional strategies, allowing teachers to collaboratively refine their approaches in alignment with students' learning needs.

4. Conclusion

The integration of the Wordwall platform within a lesson study framework was effective in supporting inclusive mathematics instruction for students with diverse special needs. The use of the Wordwall platform through a lesson study process was beneficial in supporting its inclusive teaching and learning approach for students with various special needs. The study showed that using Wordwall's matching activity in quiz mode led to higher engagement and promoted conceptual understanding in students with intellectual disabilities as well as hearing impairments. The digital platform allowed differentiated and multisensory learning experiences to be implemented, and the collaborative lesson study process deepened teachers' reflective practices and instructional strategies. The findings highlight the effectiveness of technology-enhanced learning coupled with structured professional development to facilitate equity and quality in special education settings. Future research is suggested to investigate longitudinal impacts of digital-supported collaborative instruction across different contexts of inclusive education.

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