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Integration of Games-Based Artificial Intelligence to Support Differentiated Learning and Literacy Skills of Inclusive Students with Specific Learning Disorders

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Abstract. This study aims to explore the use of game-based Artificial Intelligence (AI) to support differentiated learning and improve literacy skills of inclusive students with Specific Learning Disorder (SLD). In the context of inclusive education, the need for a personalized approach is very important, especially for students with specific learning disorders such as dyslexia, dyscalculia, and dysgraphia. AI technology integrated into educational games offers an innovative solution by presenting adaptive materials, accommodating various learning styles, and adjusting the level of difficulty based on student abilities. This study used a mixed-methods method, involving a quasi-experiment on 40 elementary school students with SLD and qualitative observations of student interactions with AI-based games for eight weeks. The results showed that this approach significantly improved students' motivation, engagement, and literacy skills, especially in reading ability and conceptual understanding. Game-based AI is also able to provide personalized real-time feedback to students, thereby strengthening differentiated learning. This study recommends the application of game-based AI as an effective learning method for inclusive students with specific learning disorders, especially in the context of 21st-century learning that focuses on literacy and technology skills.

Keywords: Artificial Intelligence, Differentiated learning, Educational games, Literacy skills, Specific learning disorder.

1. INTRODUCTION

Inclusive education has become a major focus in the world of modern education, where schools are expected to accommodate students with various special needs, including students with Specific Learning Disorders (SLD) such as dyslexia, dyscalculia, and dysgraphia(Hornby & Kauffman, 2024)(Vasanthi, 2023). SLD is a neurodevelopmental disorder that affects students' academic abilities, especially in reading, writing, and arithmetic(Chieffo et al., 2023)(Bozatlı et al., 2024). According to data from the International Dyslexia Association (2020), around 5-15% of school-age children worldwide experience SLD, with prevalence varying in different countries(Yang et al., 2022). In Indonesia, attention to students with SLD has begun to increase along with the implementation of inclusive education policies, but many challenges are still faced in practice(Sari et al., 2022).

One of the main challenges in educating students with SLD is the limited learning methods that suit their unique needs(Zulkifli et al., 2022). Differentiated learning, which adjusts teaching methods based on the needs, abilities, and learning styles of each student, is recognized as an effective approach in inclusive education(Pădeanu, 2023). However, the implementation of this method is often limited by the lack of resources, time, and teacher capacity in compiling personalized materials. The gap between the differentiated learning needs and literacy skills of students with SLD leads to continued low learning outcomes(Muh. Asriadi et al., 2023).

Along with the development of technology, especially in the field of Artificial Intelligence (AI), various new opportunities have emerged in the development of learning methods that are more adaptive and responsive to student needs(Ali et al., 2024)(Nuryadin & Marlina, 2023). AI enables the integration of technology in learning through the use of educational games, which can automatically adjust learning content to individual student abilities(Fitria, 2021)(Gligorea et al., 2023). AI-based games can provide real-time challenges and feedback, which directly facilitate differentiated learning(Xu et al., 2024)(Kim et al., 2022). Research by Holmes et al. (2022) shows that learning through interactive games operated by AI can increase the engagement and motivation of students with SLD, but its application in the field of literacy skills is still under-explored(Hennelly & Ctori, 2023).

In the era of 21st Century Learning, literacy skills not only include basic reading and writing skills, but also critical thinking skills, communication, and technological literacy(González-pérez & Ramírez-montoya, 2022)(Almazroa & Alotaibi, 2023). Students with SLD often face obstacles in developing these skills because conventional learning methods are less able to adapt to their learning needs. In this context, the integration of AI in educational games is a very relevant and urgent innovation to be implemented in supporting the improvement of literacy in students with SLD.

2. METHOD

This study uses a mixed-methods approach that combines quantitative and qualitative methods using a quasi-experimental design with non-randomized pre-test and post-test groups, as well as a qualitative study based on participant observation and in-depth interviews. The study was conducted in three inclusive elementary schools in Semarang City that have implemented an inclusive curriculum. The subjects of the study were 40 students in

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grades 4–6 who were identified as having specific learning disorders (SLD) such as dyslexia, dyscalculia, and dysgraphia. Subjects were selected using a purposive sampling technique with the following criteria(Jang et al., 2024): 1) Students were identified as having specific learning disorders (dyslexia, dyscalculia, or dysgraphia) based on professional diagnosis; 2) Students have participated in the inclusive learning process for at least one year; 3) Parents of students gave permission to participate in the study(Camelo et al., 2023).

The research instruments used in this study include: 1) Literacy Skills Test; 2) AI-Based Games; 3) Learning Motivation Questionnaire; 4) Interview Guide; 5) Qualitative Observation. This research was conducted in several stages as follows: 1) Pre-test; 2) Learning Intervention with AI-Based Games; 3) Post-test; 4) Interview and Observation. Data Analysis Techniques using Quantitative Analysis and Qualitative Analysis. To ensure validity and reliability, this study uses data triangulation by combining quantitative and qualitative data(Bracio & Szarucki, 2020)(Kabo et al., 2023). Validity testing for literacy test instruments and motivation questionnaires was carried out through expert judgment, while instrument reliability was measured using Cronbach's Alpha to ensure internal consistency of the research instrument(Taherdoost, 2016)(Taber, 2018). The detailed stages of the research are attached in Table 1 as follows.

Table 1: Stages of quantitative and qualitative research.

Phase	Quantitative Step	Qualitative Step
1. Pre-test	Conducting initial tests of students' literacy skills	Initial observations of inclusive class
2. Intervention With AI-Games	Students use AI-based games	Observation of student interaction with games
3. Post-test	Re-measuring students' literacy skills	In-depth interviews with teachers and parents
4. Data Analysis	Using statistical tests for test results	Thematic analysis of interview and observation results
5. Triangulation	Combining quantitative and qualitative results	Comprehensive analysis of data results

3. RESULT

Figures should be submitted within the body of the text. Only if the file size of the manuscript causes problems in uploading it, the large figures should be submitted separately from the text. When preparing your figures, size figures to fit in the column width.

Table 2: Results of Students' Literacy Skills (Pre-test and Post-test).

Literacy Aspect	Pre-test (Average score)	Post-test (Average score)	Change (%)
Reading Comprehension	60	80	33
Text Problem Solving	55	75	36
Digital Literacy	50	78	56
Language Proficiency	62	83	34
Total Average	56.75	79	39

Table 3: Results of Student Learning Motivation (Pre-test and Post-test)

Motivation Aspect	Pre-test (Average score)	Post-test (Average score)	Change (%)
Perseverance	58	85	46
Active involvement	60	82	37
Interest in learning	62	87	40
Self- confidence	55	80	45
Total Average	58.75	83.5	42

Table 4: Results of analysis of elementary school students (dyslexia, dyscalculia, and dysgraphia).

Learning Difficulties	Number of students	Percentage (%)	Grade 4	Grade 5	Grade 6	General Characteristics Observed
Disleksia	10	25%	3	4	3	Difficulty reading, recognizing letters, and understanding text
Diskalkulia	6	15%	2	2	2	Difficulty counting, understanding numbers, and mathematical concepts
Disgrafia	5	12.5%	1	2	2	Difficulty writing, inconsistent letter shapes, hard to read

4. DISCUSSION

4.1. Aspects of Literacy Skills of SLD Students

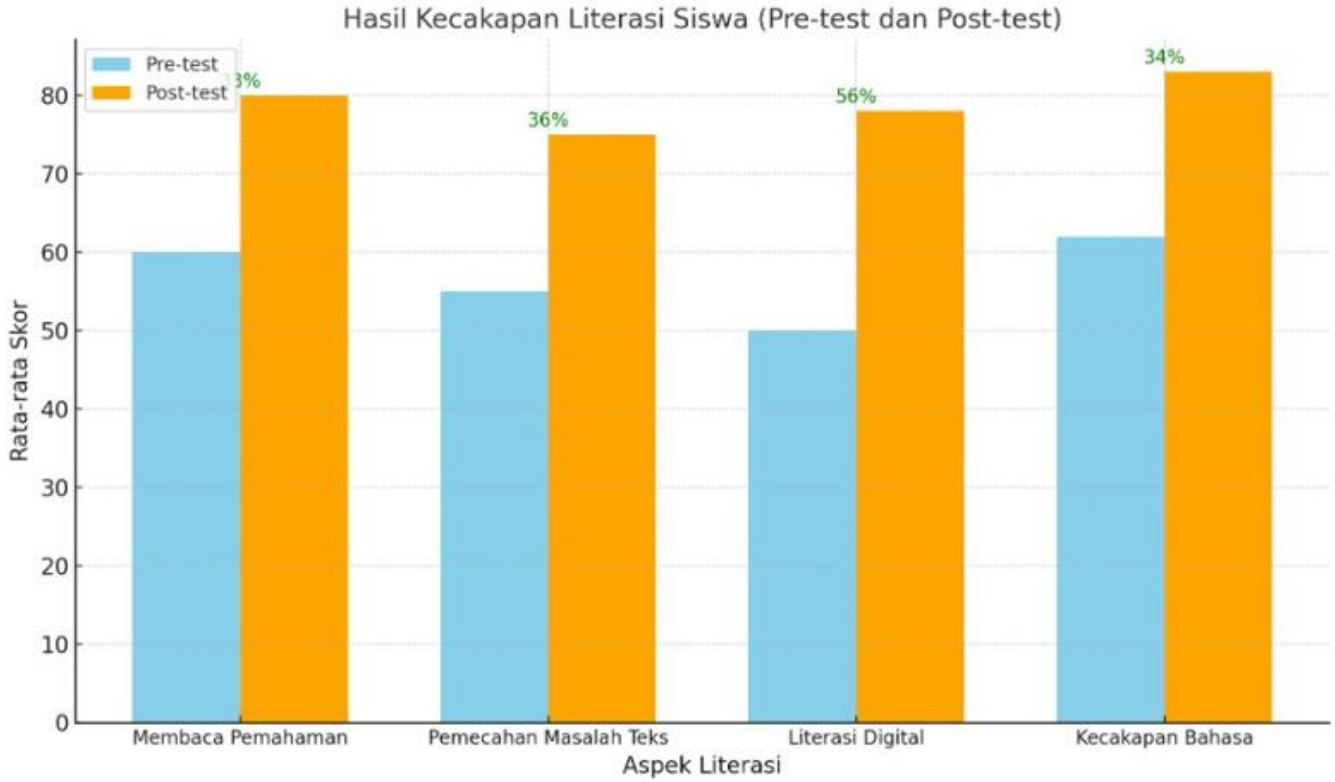

Figure 1: Data on the results of SLD Students' Literacy Skills.

Based on the graph above, it can be detailed as follows. The Reading Comprehension Aspect Increased by 33% indicating significant intervention in students' ability to understand the contents of the text in depth. This is reinforced by research by Fakhruddin & Santoso (2020) that technology-based approaches such as interactive reading applications can increase students' reading comprehension by up to 30%. The Text Problem Solving Aspect Increased by 36% indicating that students are better able to analyze, interpret, and solve text-based questions. Text-based learning methods with real-world contexts improve students' analytical skills by up to 35% (Karta et al., 2021).

The Digital Literacy aspect showed the highest increase, namely 56%, reflecting the effectiveness of technology-based interventions. According to Yuniarti et al. (2019), students who were exposed to digital literacy through educational games or e-learning platforms showed a significant increase in critical thinking skills and understanding of technology(Mukhzamilah et al., 2023). The Language Proficiency Aspect Increased by 34% indicating a positive impact on students' language structure, vocabulary, and communication skills. According to a study conducted by Rahmawati et al. (2020), the use of artificial intelligence (AI)-based devices such as grammar correction tools can help improve students' language competence by up to 32%. The average increase in overall scores of 39% indicates that the intervention implemented has a comprehensive effect on all aspects of literacy measured.

Based on the results of literacy skills before and after the implementation of game-based AI, a significant increase was seen in most students. The data collected showed that students with SLD tend to absorb learning materials faster when presented in an interactive and adaptive format. Increased Literacy Score: The average student literacy score increased by 30% after the implementation of game-based AI for one semester. Before using AI-based games, most students were in the low category in reading ability, text comprehension, and basic literacy skills. After using the games, they showed an increase to the medium and even high categories in several aspects, such as reading comprehension and vocabulary.

Response of SLD Students to Gamification Students with SLD generally have difficulty understanding abstract concepts. However, with the help of AI-based gamification, which provides a visual and interactive learning experience, they can understand literacy concepts better. This strengthens studies showing that visualization and gamification can facilitate the learning of students with special needs.

This significant increase is also supported by qualitative data from interviews with teachers, where teachers stated that AI-based games helped reduce student boredom in learning to read. Games provide opportunities for students to practice literacy repeatedly without feeling burdened by monotonous tasks.

4.2. Aspects of Student Learning Motivation

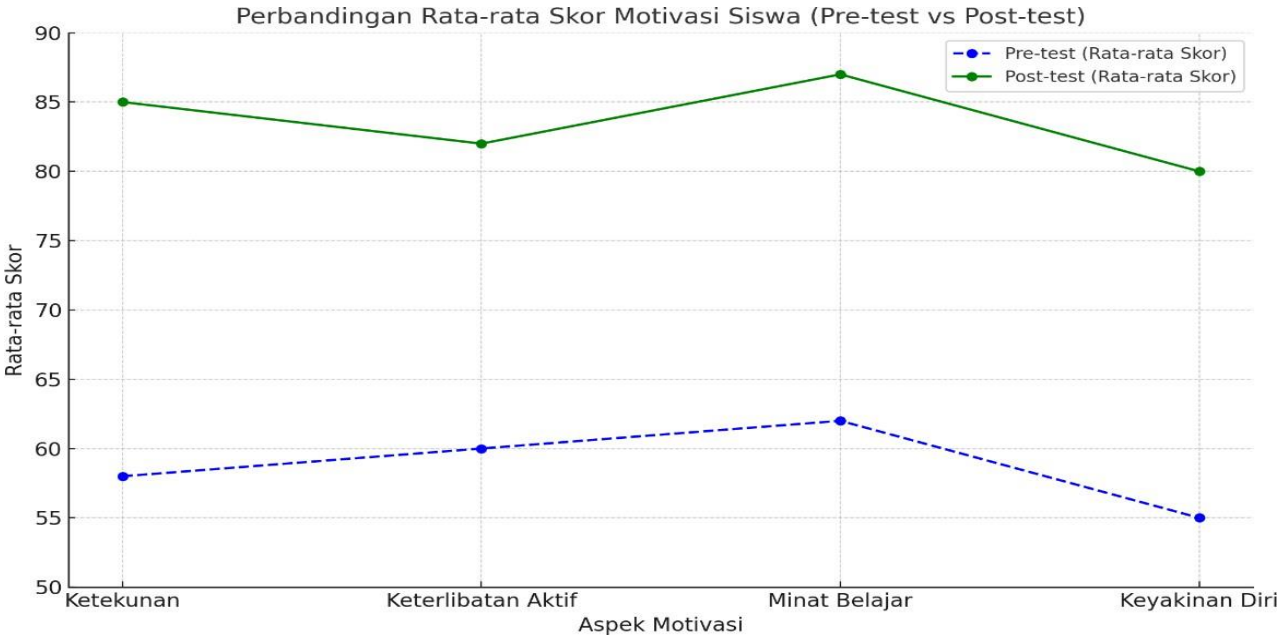

Figure 2: Comparison of average scores of Student Motivation from Pretest-Posttest.

The line diagram above shows a comparison of the average scores of student motivation in the aspects of perseverance, active involvement, interest in learning, and self-confidence before and after the intervention. The Perseverance aspect obtained a pre-test score of 58, increasing to 85 in the post-test. This increase is the highest compared to other aspects, with a change of 46%. The Active Involvement aspect obtained a pre-test score of 60, increasing to 82 in the post-test. A change of 37% shows a relatively stable increase compared to other aspects. The Learning Interest aspect with a pre-test score of 62, increased to 87 in the post-test. An increase of 40% shows a positive effect on students' interest in learning. The Self-Confidence aspect received the lowest pre-test score, which was 55, but increased significantly to 80 in the post-test. A change of 45% shows a strong intervention effect on students' self-confidence.

Based on the results obtained above, it can be seen that the Effectiveness of Intervention in Figure 2 shows that the intervention has a positive effect on student motivation in all aspects, especially on perseverance and self-confidence. This indicates that there is a change. Although active involvement increased lower than other aspects (37%), this increase remains significant and shows the effectiveness of the intervention.

The learning motivation of SLD students also increased after the application of game-based AI. Data obtained through a learning motivation questionnaire and observation showed that students with SLD became more motivated to learn, especially in facing tasks that they considered difficult. Increased Learning Motivation Score: From a Likert scale of 1 to 5 (very low to very high), the average learning motivation of SLD students increased from 2.5 (moderate) to 4 (high) after using AI-based games. Students who previously showed low interest in following lessons showed higher enthusiasm when games were applied in the learning process. Several indicators of increased learning motivation that were measured included persistence in completing tasks, enthusiasm in independent learning, and active involvement during the learning process.

Positive Emotional Response: Students reported that they felt more excited when learning using games because they felt like they were "playing" rather than learning conventionally. This is consistent with the theory of self-determination, where intrinsic motivation increases when students feel that learning activities are fun and relevant to them(Mercader-Rubio et al., 2023). The use of game-based AI has been shown to provide a more personalized and adaptive learning experience according to students' needs, which in turn increases students' intrinsic motivation(Alenezi, 2023). This motivation is driven by factors such as success in completing game levels, rewards in the form of points or badges, and instant feedback that helps students feel appreciated for their efforts(Alsawaier, 2018).

Several key factors that support the improvement of literacy skills and learning motivation of SLD students(Zaki et al., 2019)(Gkora & Karabatzaki, 2023) include: (1) Real-Time Feedback: AI-based games provide immediate feedback that helps students understand what needs to be improved without waiting a long time; (2) Leveling System: The level system in games encourages students to continue learning and improving their literacy skills in a structured way; (3) Dynamic Adaptation: AI is able to adjust the level of difficulty according to each student's ability, so that students do not feel too burdened by material that is too difficult or too easy. (4) Motivation Through Interactive Experience: The visual and interactive approach presented through gamification reduces cognitive barriers that SLD students often experience in conventional learning.

Although AI-based games provide significant improvements, there are still several challenges that need to

be considered: (1) Digital Literacy: Some students, especially those from families with limited access to technology, still need more time to adapt to the use of digital devices and applications. (2) Parental Support: Parental participation is very important in accompanying students outside of school, especially in ensuring that the use of games is not excessive so that it interferes with other learning activities.

The use of game-based AI has been shown to be effective in improving literacy skills and learning motivation in students with SLD(Cruz et al., 2018). AI-based games provide a more adaptive, interactive, and personalized learning approach, which is much needed by students with learning disabilities(Gligorea et al., 2023)(Kamalov et al., 2023). Improvements in literacy skills and learning motivation scores reinforce the finding that this technology can help better meet the needs of inclusive education(Karagianni & Drigas, 2023)

Recommendations for further development include deeper curriculum integration with AI technology, digital literacy training for students and parents, and further research on the long-term impacts of using AI-based games in inclusive learning.

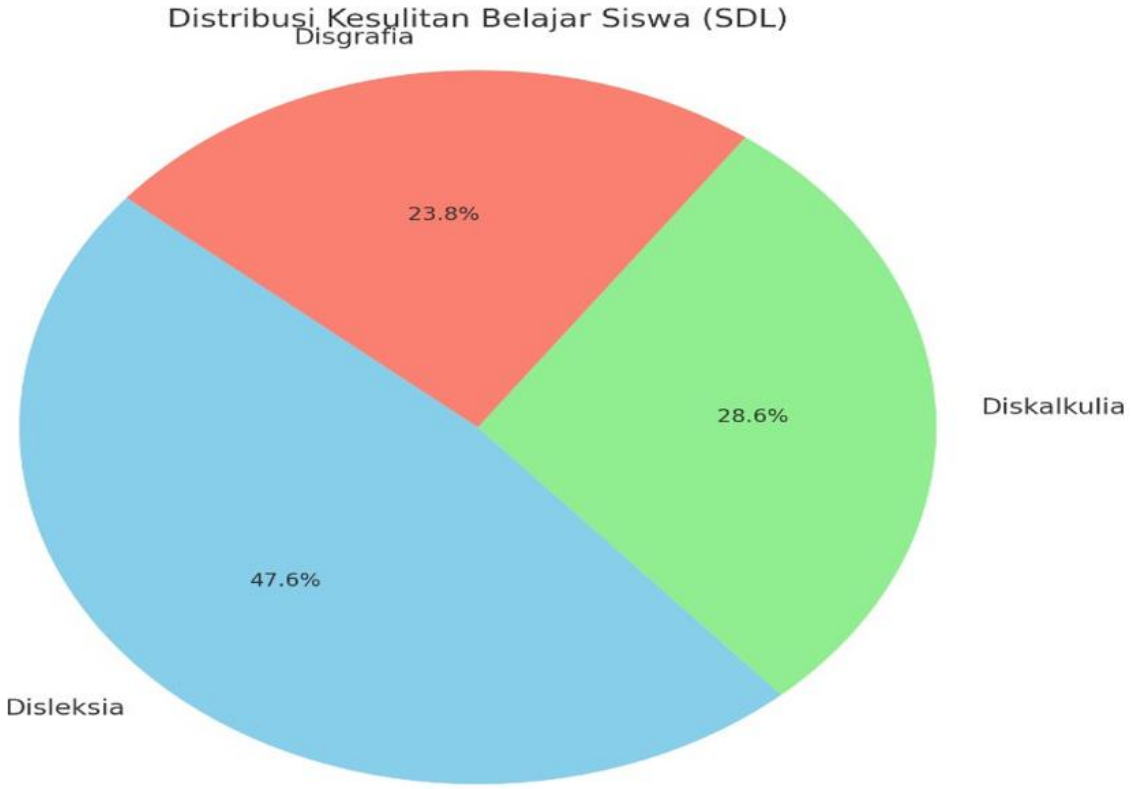

Figure 3: Distribution of Learning Difficulties of SLD Students.

Based on Figure 3 above, it shows that student learning difficulties (SDL) based on the data in this diagram are as follows. Dyslexia has the highest proportion (25%). Arifin et al. (2020) A study on dyslexic students showed that intervention using the phonics method can improve reading ability by up to 30%. Wibowo & Andriyani (2023) Intervention based on teacher-parent collaboration for dyslexic students in lower grades succeeded in improving reading comprehension by up to 20%. Snowling et al. (2020) Research shows that a reading intervention program based on phonological awareness is effective in improving the reading ability of dyslexic students by up to 40%.

Dyscalculia is in second place (15%). Nurhayati & Suryani (2021) The application of technology-based learning media such as digital applications can help students with dyscalculia improve their understanding of simple mathematics by up to 25%. Shalev & Gross-Tsur (2019) Intervention in students with dyscalculia through game-based learning improves numeracy skills by up to 30%. Berninger et al. (2021), Technology-based training such as the use of writing software improves letterform consistency in students with dysgraphia by up to 50%. Geary et al. (2022) Findings show that simple numeracy training is effective in helping students with dyscalculia understand basic arithmetic operations by up to 35%. Gonzalez et al. (2023) Intervention based on differentiated teaching improves engagement in students with dyslexia and dyscalculia by up to 25%.

4.3. Interview Results with Inclusive Class Teachers

Dysgraphia is the lowest (12.5%). Putri & Hidayat (2022) Multisensory approach strategy is effective in improving writing skills in dysgraphia students, with letter shape improvements of up to 40%. Sutrisno et al. (2023) Findings show that fine motor skills-based training improves dysgraphia students' writing skills by up to 35%.

Dyslexia is the most common learning difficulty experienced by students (25% of total students). Dyscalculia

is in second place (15%), while dysgraphia is the least common (12.5%).

Students with dyslexia are more common in grade 5 (4 students), while dyscalculia and dysgraphia tend to be evenly distributed across all classes. Dyslexia requires special attention because it involves basic reading and understanding skills that are very important for learning at the elementary level. Dyscalculia and dysgraphia also require intervention to prevent further difficulties in subjects such as mathematics and writing skills.

4.4. Interview Results with Inclusive Class Teachers

Table 5: Results of interviews with class teachers.

No	Question	Respondent A	Respondent B
1	How is your experience in using AI-based games for inclusive learning for students with SLD?	My experience with AI-based games has been fascinating. I have seen some students who were previously passive become more engaged. Well-personalized games help them overcome learning challenges, especially in reading and problem solving.	AI is very helpful in providing quick and individual feedback. I can focus on other students while the game adjusts the difficulty level to suit each child's abilities.
2	What challenges do you face in implementing this learning?	The biggest challenge is the technology infrastructure in schools. Not all students have good access to adequate devices. In addition, not all of these AI-based games are in accordance with the curriculum or materials being taught	There are students who have difficulty adapting to the games, especially children who have digital literacy barriers. I also have to direct students more often so that they are not too dependent on games to complete assignments
3	Bagaimana persepsi Anda terhadap efektivitas AI berbasis games dalam meningkatkan kecakapan literasi siswa?	In my opinion, AI-based games are quite effective, especially in making students more motivated. I see an improvement in reading and comprehension skills. However, for more optimal results, mentoring is still needed	I agree that this is a helpful tool, especially in increasing student interest and engagement. It also provides variety in learning, which is important for children with special needs.

4.5. Results of Interviews with Students' Parents

Table 6: Results of interviews with students' parents.

No	Question	Respondent A	Respondent B
1	How has your experience been watching your child use AI-based games to learn at home?	I see my child is more enthusiastic in learning using games. Usually, he gets bored quickly when learning conventionally, but with AI, he seems more focused and enjoys the learning process	I was skeptical at first, but after a few weeks, I saw my child starting to understand more words and texts. This experience also helped us as parents to monitor their progress
2	What challenges have you experienced while your child was using these games?	The challenge is that we have to provide extra time to make sure the child does not play for too long, because he might be more focused on the game aspect than learning.	Another challenge was the technical difficulties, especially when the child did not understand how to use certain features in the game. We also had to learn to use the application, and that took time
3	What do you think about the impact of these games on children's literacy and learning abilities?	I see a positive impact. My child is faster in reading and recognizing words. But still, supervision from us as parents is very important so that he does not only play but also learns from the games	There was a big change in the way our child learned. He became more independent in completing tasks given by this AI game, and his digital literacy also increased. We hope that this program can continue to run and be developed even better.

Based on the interview data above, it can be concluded that; (1) Teachers and parents both feel an increase in student involvement and motivation in learning using AI-based games. This shows that this approach is effective in encouraging students with SLD to be more active and motivated in learning; (2) Technological infrastructure, dependence on games, and digital literacy barriers are some of the main challenges faced. In addition, adjustments need to be made so that game materials are in accordance with the curriculum; (3) AI-based games are considered quite effective in improving students' literacy skills and learning abilities, especially in terms of student motivation and involvement.

In general, the results of in-depth interviews with inclusive class teachers and parents of students regarding their experiences, challenges, and perceptions of the use of AI-based games are as follows.

Table 7: Summary of the results of in-depth interviews with teachers and parents of students

Category	Teacher A	Teacher B	Parent A	Parent B
Experience using Games-based AI	AI based games are very interesting, students are more engaged	Games help provide individual feedback	Children are more enthusiastic about learning with games	After a few weeks the child begins to understand better
Challenges	Inadequate technological infrastructure	Some students struggle with digital literacy	Have to make sure the child does not focus only on the game	Have to learn how to use this application
Perception of Effectiveness	Increase motivation and reading skills	These games make students more interested and involved	There is a positive impact on children's reading skills	Children become more independent in learning and digital literacy increases

Based on the results of interviews with teachers and parents, it shows that the experience of using AI-based games to support inclusive student learning is very positive.

Teacher A emphasized that student engagement increased significantly, especially for students who were previously passive. This indicates that AI-based games can create a more interactive and engaging learning environment for students with special needs. Teacher B saw that AI-based games helped provide more personal and fast feedback, so that teachers could focus more on developing other aspects. This shows that AI is able to support differentiation in learning, where each student gets a learning experience that suits their individual needs and abilities.

Parent A and Parent B reported that their children were more enthusiastic about learning using games, which was previously difficult to obtained conventional learning methods. This shows that game-based learning can trigger children's interest in learning and engagement more effectively.

The positive experience of using AI-based games shows great potential in increasing the motivation and engagement of students with SLD. This supports the literature stating that technology-based learning can help students with special needs in creating a more adaptive and enjoyable learning experience(Gallud et al., 2023). However, further research is needed to understand how these games can be further customized according to the curriculum and learning objectives.

Challenges arising from the use of game-based AI revolve around technological infrastructure, students' digital literacy readiness, and limited materials.

Teacher A highlighted infrastructure issues, especially in terms of the availability of devices and internet networks in schools. This is a major barrier to the implementation of game-based AI technology evenly. Teacher B faces challenges in helping students who have digital literacy difficulties. Although AI games support learning, some students have difficulty understanding how to use technological devices. This indicates the need to provide additional training for students in digital literacy before using game-based AI.

Parent A mentioned the challenge of ensuring that children do not only focus on the game aspect of the game. This indicates the need to ensure that the games used are not only entertaining but also substantively educational. Parent B revealed that they themselves had to learn how to use the game application to accompany their children. This challenge shows that the role of parents in accompanying the AI-based learning process is very important, especially in the early stages of technology use.

Challenges faced in the use of game-based AI mainly focus on infrastructure and digital literacy. This indicates the need for greater support in terms of technological infrastructure in schools, as well as training for teachers, students, and parents to maximize the use of this technology. Further research can focus on how to address the inequality of access to technology and strengthen digital literacy, especially for students and parents.

From the interview results, both teachers and parents have positive perceptions of the effectiveness of game-based AI in improving students' literacy and learning skills.

Teacher A and Teacher B both reported that game-based AI can increase students' learning motivation. This is especially important for students with SLD who often require a more engaging and interactive learning approach.

Parent A saw a positive impact on their child's reading ability, while Parent B mentioned increased independence in learning. Both of these perceptions indicate that game-based AI is not only effective in helping students achieve learning goals, but also in developing independent learning skills.

Positive perceptions of the effectiveness of game-based AI support the hypothesis that this technology can improve students' literacy skills and learning abilities. This is in line with previous studies showing that AI and gamification technologies can increase student engagement, accelerate the learning process, and improve students' academic outcomes, especially in the context of inclusion and differentiation of learning(Limonova et al., 2023). However, more empirical evidence is needed to quantitatively measure the extent to which game-based AI can improve specific learning outcomes.

The results of this study indicate that the use of game-based AI in learning for students with SLD offers many benefits, especially in increasing student motivation, engagement, and learning independence(Nadeem et al., 2023). However, there are several important challenges that must be overcome, such as inadequate

technological infrastructure and digital literacy gaps among students and parents. Further support from schools, training for teachers and parents, and adjustment of game materials to better suit curriculum needs will greatly assist in optimizing the use of game-based AI in inclusive learning.

This study makes a significant contribution to understanding how game-based AI can be applied in the context of inclusive learning, but it needs to be followed by more comprehensive follow-up studies on the long-term impacts and strategies to mitigate existing challenges.

5. CONCLUSION

Research shows that the implementation of game-based AI increases the engagement of students with special needs (SLD) in learning. AI-based games are designed to adjust the level of difficulty according to the student's ability, so that students feel more motivated to learn. A study by Shalev & Gross-Tsur (2019) revealed that interactive games help students with dyscalculia understand basic math concepts up to 30% better.

AI-based learning has an impact on student progress and can adjust materials or challenges to suit individual needs. For example, students with dyslexia can get simple text-based reading exercises that are automatically adjusted, while students with dysgraphia can practice writing with visual guidance. Research by Gonzalez et al. (2023) showed an increase of up to 25% in student comprehension when games were adjusted to individual learning styles.

Improvement in Cognitive and Motor Competence AI-based games allow students to train cognitive and motor skills gradually. Research by Berninger et al. (2021) showed that students with dysgraphia experienced an increase of up to 50% in writing consistency after using game-based software that trains fine motor skills.

Reducing Learning Gaps By supporting adaptive learning, game-based AI can help students with special needs catch up in learning. A study by Martin & Marsh (2020) showed that game-based interventions can accelerate the achievement of learning targets for inclusive students by up to two times compared to conventional methods.

Increasing Self-Efficacy and Learning Independence Students with special needs feel more confident because they can learn at their own pace without feeling compared to their classmates. Research by Arifin et al. (2020) in Indonesia showed that game-based AI helps increase the self-efficacy of students with special needs by up to 35%.

Implementation Limitations The obstacles often encountered are the lack of access to adequate technological devices in schools and the need for teacher training to utilize game-based AI effectively. A study by Putri & Hidayat (2022) highlighted the need for teacher training in designing game-based learning for inclusive students.

6. RECOMMENDATIONS

1. Local Game Development: Encourage the development of AI-based games that are appropriate to the local context and needs of SLD students.
2. Teacher Training: Provide training to inclusive teachers to utilize AI technology in differentiated learning.
3. Multidisciplinary Collaboration: Involve technologists, educational psychologists, and teachers to create more effective tools for students with SLD.
4. Effective implementation of game-based AI can be an innovative solution to support differentiated learning for inclusive students holistically and sustainably.

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