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Digital-Efficacy Design: A Deep Learning-Based Learning Model For Literacy And Numeracy In Inclusive Schools

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Abstract

Inclusive schools continue to strive to provide equitable education for all students, including those with disabilities. The Merdeka Curriculum emphasizes literacy and numeracy as core competencies but requires a more adaptive system to be effectively implemented in inclusive settings. This study develops and evaluates the Deep Learning-Based Digital Efficacy Design Model as an innovative approach to enhance literacy and numeracy learning for students with special needs. Using the Design and Development Research method by Richey and Klein, the research was conducted at SLBN 12 South Jakarta, involving 30 teachers and 30 students selected through cluster random sampling. Findings indicate a consistent increase in literacy and numeracy across all disability types and educational levels. These improvements demonstrate the model's effectiveness in strengthening students' comprehension and engagement with literacy and numeracy concepts. Additionally, the results show that the deep learning approach successfully accommodates the cognitive and sensory diversity of students, particularly those with hearing impairments and mild to moderate intellectual disabilities. Overall, the implementation of the Deep Learning-Based Digital Efficacy Design Model significantly enhanced literacy and numeracy performance in inclusive learning environments. Teachers should use adaptive digital tools and personalized feedback in daily lessons to help all students achieve literacy and numeracy.

Keywords: Deep Learning, Digital-efficacy model, Educational technology, Inclusive Education, Literacy and numeracy.

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INTRODUCTION

Literacy and numeracy skills are the main foundations in the learning process and development of student competencies at various levels of education (Ifrida, F., et al., 2023). Literacy not only includes the ability to read and write, but also understanding, analyzing, and critically utilizing information in various life contexts (Gea, E., et al., 2024). Meanwhile, numeracy refers to the ability to understand, interpret, and use basic mathematical concepts in everyday situations, including calculating, measuring, and analyzing data (Setyawati, R. D., et al., 2025). In the current educational context, mastery of literacy and numeracy is an important indicator in assessing the quality of learning and students' readiness to

face the challenges of the 21st century. These competencies are not only essential for academic success but also for shaping individuals who are able to think logically, make data-driven decisions, and participate actively and productively in society (Gea, E., et al., 2024).

Various studies have shown that low levels of literacy and numeracy limit access to further education, employment opportunities, and overall quality of life. Therefore, strengthening literacy and numeracy must be a primary focus in learning planning and implementation, both in formal and non-formal settings (Raini, A., et al., 2022). However, in the context of Special Schools (SLB), field observations indicate that conventional learning processes often fail to optimally enhance students' literacy and numeracy skills. Teacher-centered instructional methods, limited use of learning media, and the lack of differentiation in material delivery have caused students with special needs to struggle in understanding the basic concepts of reading, writing, and arithmetic. In addition, the scarcity of adaptive learning resources that align with each student's characteristics and abilities further hinders the development of their literacy and numeracy competencies. Consequently, the learning process becomes less meaningful and does not fully foster critical, logical, and contextual problem-solving skills in accordance with the needs of SLB students.

Ideally, inclusive schools are expected to provide equitable and meaningful educational services for all students, particularly those with special needs. However, there are still concerns that inclusive schools have not yet fully accommodated the diverse needs of students with disabilities. This is evident from the continued use of teacher-centered learning methods, as observed at SLBN 12 Jakarta, where approximately 80% of teachers still rely on conventional, teacher-dominated approaches. Within the framework of Indonesia's Merdeka Curriculum, inclusive learning is designed to support students in achieving the targeted learning outcomes (Harini et al., 2024). One of its main focuses is enhancing literacy and numeracy skills as a fundamental foundation for the development of student competencies. Although students in inclusive schools may have various limitations, the effort to educate them remains a responsibility and obligation of teachers in accordance with their professional duties. This is in line with the mandate of Article 31, Paragraph (1) of the 1945 Constitution of the Republic of Indonesia, which states that "Every citizen has the right to education." Therefore, students with special needs, without exception, are also entitled to receive quality educational services and to benefit from learning development in accordance with the current curriculum.

Teachers at SLBN 12 Jakarta face major challenges in delivering literacy and numeracy lessons that suit their students' diverse characteristics and abilities. Many students require more visual, concrete, and contextual learning approaches, yet limited access to disability-friendly media, learning resources, and technology often hinders this process. Meanwhile, advances in digital technology and artificial intelligence (AI) offer new opportunities for more personalized and adaptive learning. One promising solution is the use of Deep Learning models. By developing a Deep Learning based model that integrates digital technology with differentiated instruction, inclusive education can become more responsive to diverse learner needs. Teachers will act not only as facilitators but also as adaptive and innovative learning designers. Strengthening literacy and numeracy through

this approach is expected to nurture a generation of lifelong learners, individuals who communicate effectively, reason logically, and confidently solve real-world problems regardless of physical or cognitive limitations.

The deep learning approach in education refers to an in-depth learning process that emphasizes conceptual understanding, critical reflection, the integration of ideas, and the application of knowledge in real-life contexts (Sappaile, B. I., et al., 2025). All of these abilities are essential in learning mathematics. This approach is crucial to implement (Saputra, N., et al., 2025), because it encourages meaningful understanding by helping students interpret learning materials rather than merely memorizing them, ensuring that learning is not superficial but connected to prior experiences. This approach also fosters the development of 21st-century skills such as critical thinking, problem-solving, collaboration, and creativity, which are essential for real-life situations. In addition, deep learning enhances students' motivation and engagement since learning activities are designed to be relevant and meaningful, promoting both emotional and cognitive involvement (Sappaile, B. I., et al., 2025). This approach is highly suitable for inclusive education, as it allows flexibility and responsiveness in addressing the diverse needs of students, including those with disabilities.

Deep learning addresses the limitations of previous learning theories and practices (Prawiyogi & Rosalina, 2025). Unlike traditional approaches that focus on surface learning and content mastery, deep learning promotes conceptual understanding and knowledge transfer (Qohar & Widyaningrum, 2025). It bridges the gap between behaviorist and cognitive theories by integrating knowledge, practice, and personal values. Furthermore, it prepares students to face complex real-world problems through cross-disciplinary understanding, adaptability, and autonomous learning, shifting the focus from teacher-centered instruction to student-centered engagement.

Deep Learning is an advanced form of machine learning that is capable of processing large amounts of data and recognizing complex patterns (Bintang, Y. K., & Imaduddin, H., 2024). n the context of education, Deep Learning can be used to design digital systems that are able to adapt materials, provide automatic feedback, and map the abilities and learning progress of individual students, including those with learning disabilities (Fatmawati, I., 2025). However, the adoption of this technology in the context of inclusive schools cannot be done carelessly (Nadya, R., et al., 2025). Digital efficacy design is needed that not only relies on technological sophistication but also considers the principles of Universal Design for Learning, inclusive pedagogical approaches, and the specific needs of students with disabilities. Digital efficacy design models must be able to bridge the access gap between teachers and students, empower teachers to implement them in inclusive schools, and ultimately significantly improve student literacy and numeracy outcomes.

By integrating a technology-based adaptive approach that focuses on individual learner needs, such as the Digital-Efficacy Design learning model based on Deep Learning, students' literacy and numeracy skills are expected to improve significantly compared to previous conditions.

Based on this rationale, the present research aims to develop a Deep Learning-based Digital Efficacy design model as a strategic solution to support the enhancement of literacy and numeracy skills among students with special needs in

inclusive schools. This model is expected to serve as a prototype for inclusive, adaptive, and equitable digital learning, in line with the principles of education for all.

RESEARCH METHOD

The present study adopts a developmental perspective to bridge the gap between theory and practice, emphasizing iterative refinement and empirical testing of instructional products. This approach aligns with contemporary educational research that prioritizes design-based methodologies for generating sustainable and evidence-informed innovations.

Rationale for the Research Design

This study applies the Developmental Research Method (DDR) proposed by Richey and Klein (2014), which systematically designs, develops, and evaluates instructional products to enhance quality and effectiveness. Consistent with Gall, (Gall, et al., 2006), DDR provides an empirical foundation for developing and validating educational products, tools, and models.

The statement provides a clear conceptual framework for understanding the design and development approach in educational research. The stages of the DDR model by Ellis & Levy (2010).

Figure 1. DDR Research Design Stages by Ellis & Levy (2010)

Participants and Sampling Techniques

The research subjects consisted of teachers and students from SLBN 12 South Jakarta, selected using a cluster random sampling technique. The sample included 30 teachers and 30 students, representing each level and type of disability present in Table 1.

Table 1. Research Subject

Research Subject	Level	Type of Disability (person)			amount
		Deafness	Mild intellectual disability	Moderate intellectual disability	
Teacher	Elementary School	4	3	3	30
	Junior High School	3	4	3	
	Senior High School	3	4	3	
Student	Elementary School	3	4	3	30
	Junior High School	3	3	4	
	Senior High School	3	4	3	

The principal and class teachers are actively involved in the process of determining the research subjects, ensuring that the selected participants truly represent the study objectives. In addition, they collaborate in adjusting study schedules and

teaching loads for each teacher so that the research activities can be integrated smoothly into the school's routine. This collaborative effort is intended to maintain a balance between research implementation and regular teaching responsibilities, ensuring that the learning process for students continues without disruption.

Research Stages / Procedures

This study employed a Design-Based Research (DBR) approach as developed by Reeves (2006). This approach was chosen because it allows the iterative development of a model through direct engagement between researchers and users (teachers and students) and generates an empirically grounded instructional product. The research was conducted through five main stages, presented in Table 2:

Table 2. Research Stages / Procedures

DBR Stage (Reeves, 2006)	Digital-Efficacy Design learning model based on Deep Learning	Outputs
1. Analysis and Problem Identification	Conducting classroom observations and interviews to explore user needs, learning characteristics, materials, and students' literacy and numeracy skills.	Mapped learning needs and learner characteristics.
2. Development of Initial Solution	Designing the initial Digital-Efficacy model as a web-based learning prototype using a Deep Learning approach to enhance accessibility and effectiveness.	Prototype of the Digital-Efficacy Learning Model (Deep Learning-based software design).
3. Implementation and Validation	Validation of learning instruments and media by experts (software experts, instructional designers, and subject/literacy-numeracy experts). Limited trials conducted with 3 teachers and 3 students to evaluate usability and content clarity.	Expert validation data and functional performance results.
4. Reflection and Revision	The model was refined based on expert and user feedback, then tested extensively with 30 students and 30 teachers to ensure reliability and adaptability	Final version of an effective, adaptive, and user-friendly model.
5. Generalization and Dissemination	Preparing final development reports, publishing research results, and disseminating findings through seminars, workshops, and online platforms.	Scalable model ready for adoption in broader educational contexts.

Based on the stages presented in Table 2, the Design-Based Research (DBR) model proposed by Thomas C. Reeves (2006) is a systematic approach designed to bridge educational theory and practice through the development of empirically grounded instructional innovations. This model emphasizes the active involvement of researchers with users (teachers, practitioners, and students) in real learning contexts, thereby producing not only new educational products but also reinforcing

the underlying theoretical foundations. This research was carried out over a period of six months, from June to December 2024.

Research Instrument

The instruments used to collect data from teachers, students, experts/specialists, regarding the needs, responses, and assessments of the developed product were: (1) Questionnaires, (2) Observation formats, (3) Tests, (4) Interviews, (5) and documentation. The experts involved in this research were software experts, instructional design experts, and educators as material experts and literacy & numeracy skills. The assessment criteria adopt the scoring by Purwanto (2009) presented in the Table 3:

Table 3. Research Criteria by Purwanto (2009)

Score	Criteria	Percentage
5	very good	$81\% \leq x \leq 100\%$
4	Good	$61\% \leq x < 80\%$
3	sufficient	$41\% \leq x < 60\%$
2	not good	$21\% \leq x < 40\%$
1	very not good	$0\% \leq x < 20\%$

Data Analysis

A qualitative analysis was conducted to examine the implementation of the Digital Efficacy Learning Design Model at SLBN 12 and its impact on students' literacy and numeracy. The process involved data collection, reduction, presentation, and conclusion drawing. Triangulation from teachers, students, and experts through interviews, observations, and questionnaires ensured reliability, while expert validation confirmed the model's consistency and effectiveness in enhancing digital learning in inclusive settings.

RESULTS AND DISCUSSION

Results

The validation of the learning media design was conducted in two stages: limited trials and extensive trials. The evaluation covered five indicators: (1) content quality, (2) visual design, (3) interactivity, (4) menu completeness, and (5) navigation or ease of access. Each aspect was rated on a four-point scale (4 = very good, 3 = good, 2 = fair, 1 = poor). However, the validation team recommended several improvements, including adjustments to font style and size, image clarity, and color composition on the homepage of the e-learning platform. The results of the validation of digital learning media efficacy based on deep learning are shown in Table 4.

Table 4. Validation Results of Learning Media (LM) for the Digital Efficacy Design Model

Rated Aspect	Assessment Score (average)			
	IT Experts	LM Expert	Teacher	Criteria
Content quality	4	4	4	very good
Design and visual appearance	4	3,5	3	good
Interactivity	3	3	3,5	good
Menu completeness	4	4	3	good
Navigation and ease of use	4	4	4	very good

The figure below shows the homepage interface of the digital efficacy learning model application after the refinement process.

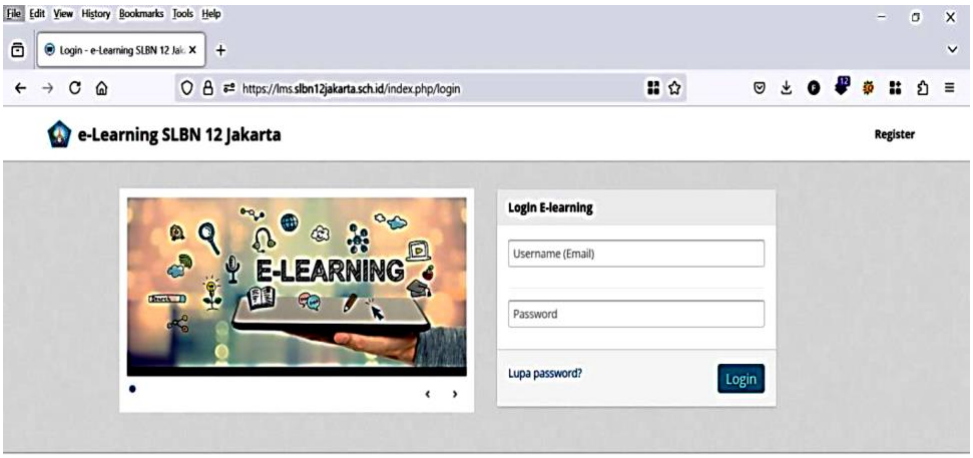

Figure 2. E-learning homepage view after the refinement process

Based on the observation results regarding the ability to use the learning media developed through the deep learning-based digital efficacy design model, the following data were obtained:

Table 5. Observation Results on the Use of Learning Media with the Efficacy Design Model

Type/class of Disability	The Efficacy Design Model Application Usage Ability (Teacher)		The Efficacy Design Model Application Usage Ability (Students)	
	Pre (%)	Post (%)	Pre (%)	Post (%)
Deafness	67	82	59	83
Mild intellectual disability	80	94	80	90
Moderate intellectual disability	75	89	72	83

The data presented in Table 5, it is clearly demonstrated that both teachers and students with various types and levels of disabilities showed significant improvement in their ability to use the Digital Efficacy Design Model application

after the training and implementation process (from pre-test to post-test).

Numeracy literacy skills were observed only in students with special needs, specifically those with deafness, mild intellectual disabilities, and moderate intellectual disabilities at each educational level. Data were obtained at Table 6:

Table 6. Recapitulation of Student Literacy and Numeracy Skills Data

Type/class of Disability	Level	Literacy Ability (%)		Numeracy Ability (%)	
		Pre	Post	Pre	Post
Deafness	Elementary (SD)	43	66	55	74
Mild intellectual disability		48	71	59	73
Moderate intellectual disability		37	65	51	70
Deafness	Junior High School (SMP)	53	72	61	77
Mild intellectual disability		51	72	59	76
Moderate intellectual disability		49	68	51	67
Deafness	High school (SMA)	73	82	78	81
Mild intellectual disability		61	77	69	76
Moderate intellectual disability		59	69	61	74

Data on Table 6, showed significant improvements in the literacy and numeracy skills of students with special needs at all levels, both for students with hearing impairments and those with mild and moderate intellectual disabilities.

Discussion

The study confirms that the Deep Learning-based Digital Efficacy Learning Design Model effectively improves digital accessibility, literacy, and numeracy in inclusive education. The iterative Design-Based Research (DBR) process was crucial for aligning theory with classroom practice (Reeves, 2006).

Strengthening Accessibility and Inclusivity

The findings show that the Deep Learning-based Digital Efficacy Design Model enhances inclusivity, accessibility, and literacy-numeracy skills in inclusive classrooms. Integrating Universal Design for Learning principles with deep learning technology fostered adaptive, independent learning for students with mild intellectual disabilities (Habib, H., et al., 2022).

The revised Digital Efficacy Design e-learning menu (Figure 3) is intentionally structured to promote reading habits and strengthen literacy skills among users. Unlike conventional platforms where information is immediately visible to actively select and open learning materials, assignments, and schedules. This interactive process encourages them to read, comprehend, and make decisions independently. Built upon deep learning principles, the design fosters flexibility, autonomy, and active engagement, transforming learning from a passive experience into an exploratory and self-directed process.

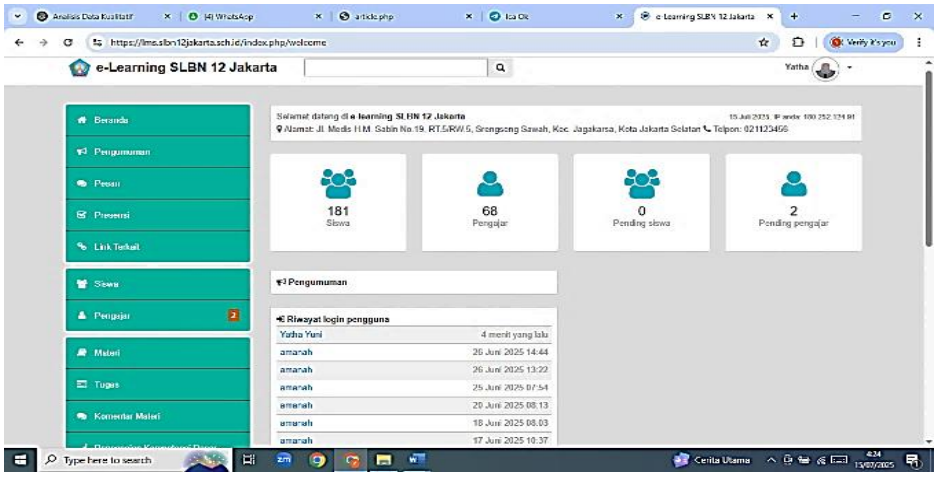

Figure 3. Digital-Efficacy Design Application Menu Display

By encouraging students to read before acting, the application fosters self-directed learning an essential 21st-century skill (Syihada, G. N., Sugilar, H., & Ihsan, M., 2025). This approach helps students independently understand information and make decisions while promoting shared involvement from parents at home, thereby strengthening collaboration between schools, technology, and families in supporting inclusive education.

The habit of learning by utilizing digital learning media is an effective strategy to motivate students to be more diligent in reading and exploring the various menus available in the application (Auliakhasanah, S., et al., 2023). Each menu is designed to present not only written information but also interactive links that direct students to additional materials, such as instructional videos. This integration creates a more engaging, varied, and easy-to-understand learning experience.

Learning in a fun and curious atmosphere has a positive impact on the development of students' literacy skills (Sari, M. K., Rulviana, V., 2021). For students with disability at SLBN 12 Jakarta, this learning approach helps them access information in a way that better suits their individual needs, while also enhancing their learning independence. Thus, the use of digital efficacy learning media serves not only as a means of delivering material but also as a tool to foster reading interest, active engagement, and improved literacy skills.

The effort to improve numeracy skills through digital efficacy-based learning media focuses on strengthening students' understanding of numerical concepts linked to real-life contexts. Mathematics plays a central role by emphasizing basic operations, measurement, fractions, and data interpretation. Through interactive and accessible digital media, students are expected to master core math skills, build confidence, and develop problem-solving abilities essential for lifelong learning.

The application's content menu is designed to help students understand numerical concepts gradually and contextually. The material is presented visually and interactively, complete with simple problems that students can access independently. Furthermore, some content is linked to explanatory videos and interactive simulations, making it easier for students to learn through engaging audiovisual media. For students with special needs, this approach provides a more flexible and understandable learning experience, as they can repeat the material at their own pace. Thus, the content menu in digital efficacy serves not only as a

source of information but also as a medium that encourages numeracy reinforcement in a fun and adaptive way. The display for inputting learning materials on Figure 4.

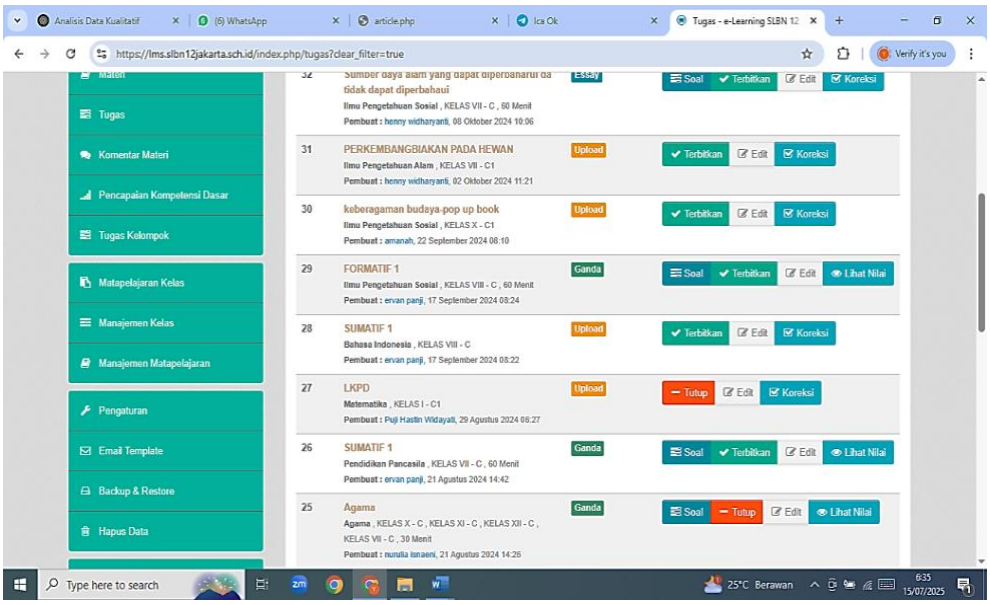

Figure 4. View the lesson material menu

In addition to mathematics, students are also accustomed to performing simple arithmetic activities in their academic life through the application, such as calculating the remaining time for assignment submissions. Each assignment has a specific deadline, and the system will automatically close access after the deadline. Thus, students are indirectly trained to understand the concepts of time, deadlines, and task management-all of which are part of functional numeracy skills that are essential in everyday life.

Effectiveness of Deep Learning Integration

The data presented in Table 5 show a consistent improvement in both teachers' and students' abilities to use the Digital Efficacy Design Model application across different disability categories after the implementation of the deep learning–based media. This finding reflects the model's success in providing accessible, adaptive, and inclusive digital learning experiences.

For teachers, the increase in usage ability, ranging from 67% to 94% across disability types, demonstrates enhanced confidence and digital competence in managing inclusive learning environments. This aligns with the study by Charles-Zalakoro, J. L. (2025), which highlights that professional engagement with adaptive learning technologies strengthens teachers' pedagogical efficacy and readiness for inclusive education. The interactive design and user-friendly interface of the model likely reduced teachers' cognitive load, enabling them to focus more effectively on instructional adaptation.

For students, the improvement in usage ability from 59% to 90%, suggests that the integration of deep learning algorithms successfully supported learners with varied disabilities in navigating and interacting with digital content. The adaptive system generated by deep learning allowed the platform to provide differentiated support and feedback according to individual performance. This supports the

findings of Andika, A. W., et al. (2025), who argue that machine learning, driven personalization enhances students' engagement and comprehension, particularly in literacy and numeracy learning. The significant progress observed among students with deafness and intellectual disabilities further reinforces the importance of combining universal design for learning with artificial intelligence.

These results are also consistent with Rahma et al. (2024), who reported that integrating digital media in adaptive classrooms increased students' motivation and understanding due to the transition from teacher-centered to technology-supported learning environments. Similarly, the current findings suggest that the use of tablets and laptops through the Digital Efficacy Design Model created a more interactive and stimulating learning atmosphere, allowing students to learn autonomously and meaningfully.

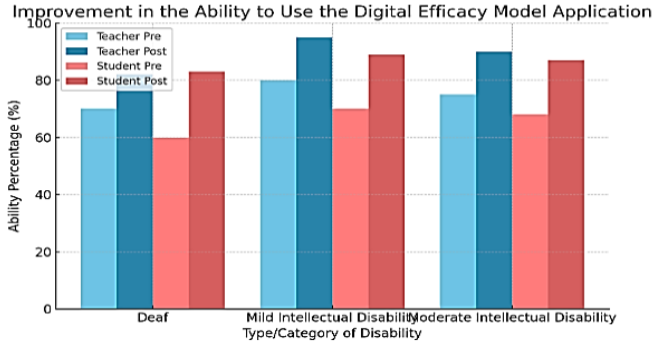

Figure 5. Graph of Increase in Use of Digital Efficacy Applications

Overall, the improvements observed across all types of disabilities, as presented in Figure 5, indicate that the digital efficacy design model effectively bridges the gap between technological innovation and inclusive pedagogy. The model contributes to a more equitable digital learning ecosystem, empowering both teachers and students to participate actively in inclusive education.

Improvement in Literacy and Numeracy Skills

The data presented in Table 6 and Figure 6 show a significant improvement in literacy skills among students with different disabilities after implementing the Deep Learning-based Digital Efficacy Design Model, confirming its effectiveness in fostering inclusive digital learning across all educational levels (Sholihah, et al., 2025).

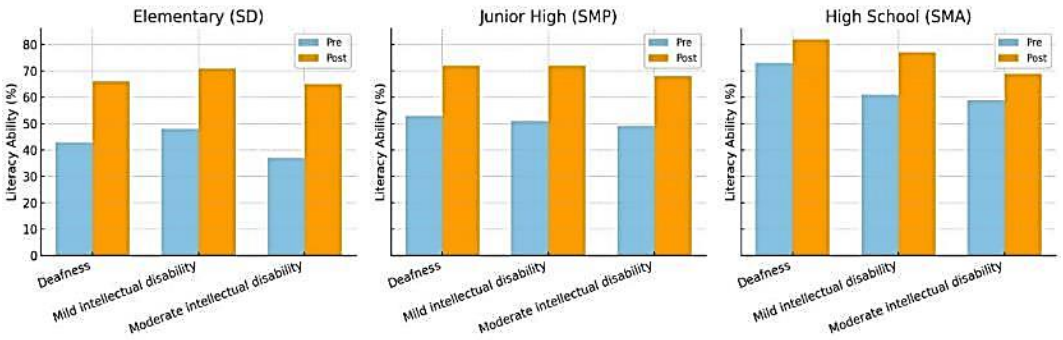

Figure 6. Graph of Improvement in Student's Literacy Skills

Improvements also occurred in students' numeracy skills across all types of disabilities. Adaptive deep learning allows for personalized adjustments in pace and feedback, helping students with disabilities understand mathematical concepts more effectively (Supriyatmoko, S., et al., 2025).

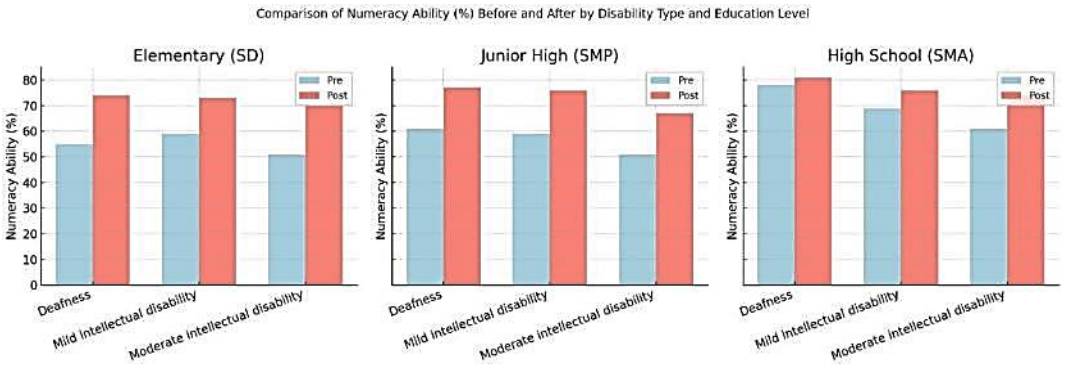

Figure 7. Graph of Improvement in Student's Numeracy Skills

Impact Across Educational Levels

The results reveal that literacy and numeracy improvements were more pronounced at the elementary and junior high levels, while progress at the high school level was moderate but stable. This suggests that early exposure to adaptive digital tools can provide a stronger foundation for literacy and numeracy development among students with disabilities. Such findings resonate with Rahma, et al., (2024) and Rohyana, H., et al., (2025), who reported that integrating digital media in early inclusive classrooms fosters motivation, engagement, and sustained learning outcomes.

Pedagogical and Practical Implications

The findings confirm that the Deep Learning–based Digital Efficacy Design Model effectively integrates technological innovation with inclusive pedagogy. By using Deep Learning algorithms aligned with universal design for learning principles, the model personalizes instruction to meet diverse cognitive and sensory needs (Devitt, A., et al., 2025). Its multimodal features text, visuals, and interactive simulations, encourage active engagement and foster greater independence in literacy and numeracy learning. Overall, this model enhances accessibility, adaptability, and equity in inclusive education, as reflected in the consistent improvement across disability types and educational levels shown in Figure 6.

CONCLUSION

This study concludes that the Deep Learning-based Digital Efficacy Design model is essential in overcoming the limitations of traditional methods that focus on memorization and one-way instruction, making it highly relevant in today's digital and inclusive era. The integration of digital learning tools has been proven to enhance learning performance, self-confidence, and student engagement in inclusive schools, thereby assisting teachers in effectively improving literacy and

numeracy skills. Future research is recommended to extend the implementation of this model to inclusive schools that serve students with visual impairments.

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