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IMPROVING STATISTICS LEARNING OUTCOMES THROUGH DEEP LEARNING AND TARL APPROACHES IN GRADE X

Indah Susitya Sukmananda[1], Sunismi [*2,] Retno Trisniwati[3]
[1]Pendidikan Matematika, Universitas Islam Malang, Jawa Timur, Malang
[2]Pendidikan Matematika, Universitas Islam Malang, Jawa Timur, Malang
[3]Pendidikan Matematika, SMAN 3 Malang, Jawa Timur, Malang

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ABSTRACT

This study aims to improve students' learning outcomes in statistics using a digital-based approach. The approach integrates Deep Learning principles and the Teaching at the Right Level (TaRL) framework. The research was conducted as a Classroom Action Research (CAR) in two cycles involving Grade X students at SMAN 3 Malang. Data were collected using pre-tests and post-tests to measure changes in students' performance. The results showed an increase in students' average learning outcomes: from 35.15% in the initial condition to 54% in Cycle I, and further to 88.4% in Cycle II. These findings suggest that a digital-based Deep Learning and TaRL approach effectively enhances students' understanding and engagement in learning statistics.

Corresponding Author:

Sunismi,
Departement of Mathematics Education,
Universitas Islam Malang, Indonesia
Email: sunismi@unisma.ac.id
Phone Number : 081334764430

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1. INTRODUCTION

Mathematics is a fundamental science essential in solving real-life problems and supporting various fields, including technology and economics (Miftahul Jannah & Miftahul Hayati, 2024). In today's data-rich world, the ability to read, interpret, and analyze information has become a crucial skill. Initial assessments show that many students still lack the basic skills required to understand and analyze data effectively. Observations in Grade

X at SMAN 3 Malang indicate that many students struggle to grasp fundamental statistical concepts. Many students struggle to interpret tables and graphs or apply statistical formulas meaningfully in real-life contexts. When calculating measures such as the mean or standard deviation, students often follow procedures mechanically without understanding their real-world relevance. One of the main goals of teaching statistics in schools is to prepare students to critically engage with statistical information that increasingly influences modern life (Fitri et al., 2023).

1.1. Challenges in Learning Statistics

A study conducted by (Hana et al., 2023) revealed that one of the main reasons students struggle with solving hierarchical problems is their lack of understanding of the steps or procedures that need to be followed. Students often face various difficulties in learning mathematics, especially in statistical material (Anwar et al., 2024). One of the contributing factors to this low level of understanding is the use of conventional teaching methods. Students face challenges in statistics due to lack of procedural understanding and ineffective conventional teaching methods (Amanda et al., 2024). They are more often exposed to teacher-centered lectures or assigned practice questions without truly experiencing how data works in real-life situations. Even basic statistical material becomes challenging when presented through inappropriate instructional methods (Sukatin et al., 2022). To address this issue, a more innovative and strategic technology-based teaching approach in mathematics is needed (Sumandya et al., 2025). In response to this problem, the implementation of active learning models may offer a potential solution (Innawati., Muhajjir, N., 2014)

1.2. The Role of Deep Learning and Technology

Mathematical analysis of deep learning has evolved to address various important questions about why this technology is so powerful and effective in solving a wide range of modern learning challenges (Berner et al., 2022). In this study, deep learning refers to a pedagogical approach promoting meaningful, critical learning not artificial intelligence. Deep learning is a branch of machine learning that focuses on the use of artificial neural networks with deep layers to process, analyze, and understand complex data. In alignment with technological integration, the current Merdeka Curriculum. The curriculum in effect during this research was the Merdeka Curriculum. The Merdeka Curriculum, launched by the Ministry of Education, emphasizes that classroom learning activities should be student-centered (Maghfiroh, 2024). In this curriculum, active student engagement in the learning process is strongly emphasized in order to create purposeful and meaningful learning experiences (Takdirmin., Rischa, P., Siti, M., Nurul, M., 2025).

Teaching at the Right Level (TaRL) learning approach can also be used to improve the effectiveness of learning, thereby increasing student learning outcomes. By facilitating the needs of secondary school students through personalized instruction, TaRL holds promise as a transformative approach to reduce achievement gaps and ensure equitable access to quality education (Ananda, I.I. Ulfa, J.F., & Yorianda, 2024a). The principles and practices of Teaching at the Right Level (TaRL) align with Indonesia's commitment to improving and enhancing the quality of the education system, including through the implementation of the Merdeka Curriculum and the Teacher Professional Education program. Both initiatives demonstrate a commitment to providing learning that is more relevant and responsive to the real needs of students (Ananda, I.I. Ulfa, J.F., & Yorianda, 2024b). The practice of Teaching at the Right Level (TaRL) in learning can be combined with various learning models, such as Problem Based Learning (PBL). This learning model has a positive impact on increasing students' average scores (Sumandya et al., 2025).

1.3. Integration of Digital Media in Mathematics Instruction

Research conducted by (Gultom, G. C., Hafiza, M., Rehana, R., Kaban, R. E. br, Ambarita, S. Y., Saragih, S. E. br, & Siregar, 2025) shows that the integration of technology in mathematics learning can enrich students' learning experiences, increase engagement, and support the development of better individual mathematical skills. Digital-based learning media have the potential to enhance student attention through the presentation of more interactive and dynamic materials, thereby creating a more conducive and engaging classroom atmosphere (Putu Rissa Putri Intari Dewi et al., 2022).

The use of technologies such as PhET Interactive Simulations, simulation report drafts, student worksheets (LKPD), interactive quiz assessments, or interactive data visualizations enables students to better understand how data works. This aligns with the findings of (Putra & Salsabila, 2021) who recommend the use of interactive media to increase student engagement. Students can directly observe how changes in data affect outcomes, try out different scenarios, and even analyze data from real-life contexts. When students actively connect new phenomena with their existing knowledge, they develop a deeper and more lasting understanding unlike rote learning, which tends to be superficial (Kholifah Al Marah Hafidzhoh et al., 2023). This practice embodies the core of deep learning, where students move beyond memorization toward conceptual understanding. Teaching and learning activities should be active and fully involve students in the process of scientific inquiry (Suheni et al., 2025). As recommended in the study by (Lena, R.P., Cici, O.L., Julica, H., Rinady, G.S., 2025), teachers are encouraged to continuously develop technology-based learning methods to improve the quality of education.

Based on these considerations, this study aims to implement digital-based learning using a Deep Learning approach to improve the statistics learning outcomes of Grade X students at SMAN 3 Malang. The research also seeks to explore how this method can help students become more data-literate, equipping them to face future challenges. Thus, integrating Deep Learning and TaRL within the Merdeka Curriculum enhances conceptual understanding, engagement, and statistical reasoning among students. This indicates that the learning approach has a positive impact on student achievement. In practice, teachers adapt the instruction to students' needs, including their level of understanding and learning styles. Deep Learning is inherently linked to the use of advanced technology in its process. Under the implementation of the *Merdeka Curriculum*, teachers have started to integrate technology in mathematics instruction as part of adapting to digital advancements an effort supported by the local government. This is done to reduce the abstractness of mathematics; with technology, teachers can visually demonstrate abstract concepts by linking them to real-life situations. The Deep Learning approach in education consists of three main pillars: understanding differentiated learning among students, encouraging critical thinking in problem-solving, and fostering joyful learning experiences to help students retain what they have learned (Hidayat, A. G. G., & Haryati, 2025).

Teachers apply various learning approaches such as differentiated instruction, deep learning, problem-based learning, and TaRL to develop students' critical thinking, problem-solving, and communication skills by providing opportunities for collaboration among students. Teachers do not limit themselves to textbooks but connect mathematics learning to students' everyday lives by linking abstract concepts with concrete real-life examples, supported by digital platforms such as PhET Interactive Simulations. This allows students to begin their conceptual understanding through direct engagement with digital simulation activities. Teachers use learning media, both manipulative tools and visual-based materials, in mathematics instruction, making students more active in the learning process. Deep Learning, according to Bloom's taxonomy, operates at the levels of creating, evaluating,

analyzing, and applying. Similarly, the *Merdeka Curriculum* emphasizes critical thinking in the learning process, which involves six aspects: interpretation, inference, explanation, analysis, evaluation, and self-regulation (Sulistyanto, H., Prayitno, H. J., Narimo, S., Anif, S., Sumardjoko, B., & Wardhani, 2024). In conclusion, the *Merdeka Curriculum* and Deep Learning both focus on developing critical thinking, communication, and collaboration skills, with character development also being an integral part of the learning process.

1.4. Learning Outcomes and Their Measurement

Mathematics learning outcomes reflect the level of mastery and skills that students possess in the subject. In reality, many students still experience difficulties in learning mathematics, which results in low learning outcomes (Fitrisyah et al., 2025). Learning outcomes are measured through tests that refer to the material that has been taught. According to research by (Afidah, N., Zuhri, M. S., Kristiawan, D., & Ariyanto, 2025). Learning Outcomes in the Merdeka Curriculum are also referred to as the National Curriculum Learning Outcomes, as the Merdeka Curriculum functions as a national curriculum. Within a particular stage, each Learning Outcome is further broken down into several Learning Objectives, which are then structured into a Learning Objectives Sequence (Magdalena et al., 2023). The Teaching at the Right Level (TaRL) approach is effective in improving students' mathematics learning outcomes.

Table 1. Indicators of Students' Understanding of Statistics

Content	Students Understanding Indicators
Statistics	• Determining measures of central tendency (mean, median, mode) • Determining data position measures (quartiles, deciles, percentiles) • Determining measures of data dispersion (standard deviation, mean deviation, variance)

2. METHOD

This study employs Classroom Action Research (CAR), aimed at enhancing the quality of teaching practices within the classroom setting. CAR is a reflective process conducted by teachers to improve their pedagogical competence and enhance the learning process (Sri Astutik et al., 2021). The study aims (1) to improve students' learning outcomes in statistics, and (2) to identify learning difficulties faced by students during the process. According to Kurt Lewin, the working procedure in classroom action research consists of four components: planning, acting, observing, and reflecting.

This study follows the CAR model developed by (Kemmis, S., & McTaggart, 1988), which involves four cyclical stages: planning, action, observation, and reflection. The cycle used follows the model proposed by (Arikunto, 2006). The stages of classroom action research can be seen in the figure 1.

The CAR model was chosen to allow for iterative improvement in instructional practices, particularly in teaching statistics (Kemmis, S., & McTaggart, 1988). This approach is chosen because it provides room for teachers and students to adapt to more effective strategies in understanding statistics. Data were analyzed using a quantitative approach by comparing pre-test and post-test results to measure students' improvement. This two-cycle process enables continuous refinement of instructional methods based on students' feedback and outcomes.

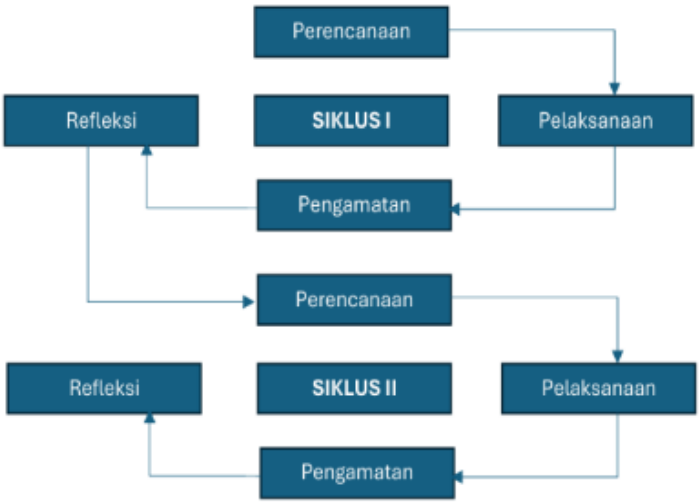

Figure 1. Classroom Action Research Scheme (Arikunto, 2006)

The research subjects were students of Class X-C at SMAN 3 Malang, who exhibited difficulties in understanding statistical concepts during preliminary observations. Many of them memorized formulas without truly understanding their meaning in everyday life. The aim is to foster conceptual understanding rather than rote memorization by applying a Deep Learning approach in digital-based instruction. To achieve this goal, a Deep Learning approach is applied in digital-based learning, where students are encouraged to think more deeply, connect concepts with real-life experiences, and develop critical thinking skills regarding the data they encounter.

Data collection methods included pre- and post-tests, classroom observations, student perception questionnaires, and documentation of the learning process. Additionally, documentation was used to record the learning process, allowing for further analysis to identify aspects that need improvement.

3. RESULTS AND DISCUSSION

3.1. Results

This study was conducted in class X-C at SMAN 3 Malang to investigate the improvement in learning outcomes through the implementation of a Deep Learning approach in mathematics learning supported by digital-based worksheets (LKPD), the results show that this learning method effectively enhances students' learning outcomes. Quantitative descriptive techniques were used to analyze student learning activities based on observation data. based on the formula proposed by (Annadzili et al., 2024) as shown in Figure 2.

$$\boldsymbol{AP} = \frac{\sum \boldsymbol{P}}{\sum \boldsymbol{p}} \times \mathbf{100\%}$$

Keterangan

$AP = the\ percentage\ value\ being\ sought$

$\sum P = Total\ Student\ Learning\ Outcome$

$\sum p = Maximum\ Score$

Figure 2. Formula for Analyzing Observation Results

Based on the formula, the researcher conducted the study and obtained learning outcomes in accordance with the material taught. The following are the learning results obtained:

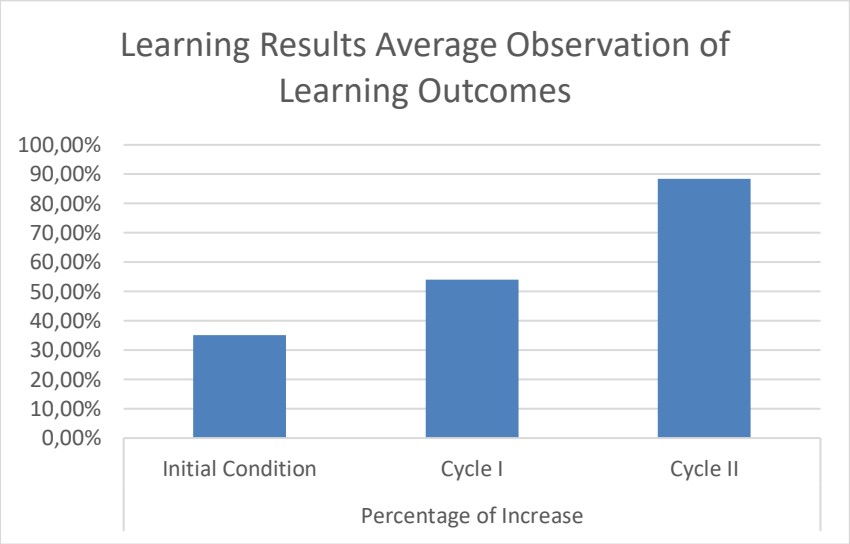

Figure 3. Average Percentage Diagram of Observation Results on Learning Outcome Improvement

The learning outcomes showed progressive improvement from the initial condition to Cycle I, and further to Cycle II. Detailed learning outcome data will be presented in table 2.

Table 2 Average Observation of Learning Outcomes

Variabel	Indicator	Percentage of Increase		
		Initial Condition	Cycle I	Cycle II
Learning Results	Average Observation of Learning Outcomes	35.15%	54%	88.4%

Figure 3 presents the increase in learning outcomes across two cycles, while Table 2 provides the detailed percentages. Based on the data above, there is a proven increase in the percentage from the observations conducted. This result indicates that the Deep Learning-based approach significantly improved students' understanding of statistical concepts. At the initial condition, before implementing the Deep Learning approach assisted by digital-based LKPD, the learning outcome percentage was 35.15%. In Cycle I, the average percentage increased to 54%, and in Cycle II, it further increased to 88.4%.

3.2. Discussion

Before conducting mathematics learning related to statistics material in class X-C SMAN 3 Malang, the researcher administered a diagnostic test using Quizizz on statistics. The average learning outcome from the diagnostic test was 35.15%. This indicates the need for in-depth learning of statistical concepts to improve student outcomes. The results of this diagnostic test also served as a reference for the researcher in implementing learning with the Teaching at the Right Level (TaRL) approach, where students are divided into three categories (low, medium, high) based on cognitive ability levels.

In the first learning cycle, the researcher utilized Augmented Reality (AR) media through the Phet Interactive Simulations platform to provide in-depth learning, particularly in studying the concept of the mean. The researcher provided worksheets for students to complete while conducting simulations using PhET Interactive Simulations. Afterward, the researcher assigned additional worksheets on central tendency data (mean, median, mode) for students to work on. The learning outcome in cycle I reached 54%, showing an improvement compared to the initial condition.

In the second learning cycle, the researcher used interactive worksheets (LKPD) completed by students through Live Worksheet. This step was taken to make the process of completing and streamline the assessment process, allowing the researcher more time for classroom discussions about the meaningfulness and key points related to the learning and statistics material. The learning outcome in cycle II reached 88.4%, showing an improvement compared to both the initial condition and cycle I.

Student engagement increased significantly through the use of digital simulations using PhET Interactive Simulations. With this method, students are not only encouraged to memorize formulas or procedures but also to gain a conceptual understanding of statistical measures such as mean, median, and data distribution. The use of digital platforms allows students to explore independently, observe patterns, and draw evidence-based conclusions, thereby strengthening their critical thinking skills. (Cariana et al., 2025) support this finding, stating that which shows that the implementation of interactive media is significantly more effective in improving learning outcomes compared to conventional learning media.

Another advantage of implementing this method is the creation of a more dynamic classroom atmosphere. Students no longer act as passive recipients. They become active participants who engage in discussions, collaboration, and reflection on their own learning processes. Furthermore, by applying the principles of Teaching at the Right Level (TaRL) and differentiated instruction, teachers can tailor their approaches to the needs, comprehension levels, and learning styles of each student, providing a more personal and meaningful growth space for every child. The Teaching at the Right Level (TaRL) learning method offers all students the opportunity to develop according to their abilities while building skills relevant to modern life (Mubarokah, 2022).

Despite its advantages, the implementation of this approach presents several challenges. One of them is the readiness of teachers and students to use technology. Not all students are familiar with digital platforms, requiring a period of adaptation. Another challenge lies in time management; deep learning-based instruction requires teachers to provide broader exploration opportunities, which may demand additional learning time compared to conventional methods. The varying levels of student understanding also need to be considered, so teachers must design flexible activities and guidance to ensure every student has the optimal opportunity to learn. The progressive increase from 35.15% to 88.4% demonstrates the effectiveness of the digital and differentiated instruction approach.

4. CONCLUSION

The research conducted in class X-C at SMAN 3 Malang demonstrates that the mathematics learning approach based on Deep Learning, supported by digital worksheets (LKPD), can bring about significant positive changes. Starting from an initial average learning outcome of only 35.15%, it increased to 54% in Cycle I, and finally reached 88.4% in Cycle II. These percentages reflect the students' learning progress in understanding statistical concepts but reflect the students' learning journey, showing their growing confidence in understanding statistical material.

This approach fosters an active and participatory classroom environment: students do not merely sit and listen but actively engage in discussions, experiments, exploration, and understanding concepts through real-life experiences. By utilizing technology such as PhET Interactive Simulations, students are encouraged to connect abstract mathematical concepts with real-life contexts.

Through the application of Deep Learning principles, Teaching at the Right Level (TaRL), and differentiated instruction, each student is supported to develop according to their individual capabilities. This aligns with the Merdeka Curriculum's focus on student-centered learning and 21st-century skills development such as critical thinking, communication, collaboration, and creativity.

However, several challenges remain, particularly in technology adaptation and resource limitations. Adapting to the use of technology and limited facilities remain real obstacles in the field. However, these challenges open up opportunities to continuously learn, grow, and innovate, ensuring that every child receives the best possible learning experience they need. Ultimately, this study reinforces the importance of designing learning that connects concepts to real-life experiences. It highlights how such designs foster improved outcomes, curiosity, and lifelong learning motivation.

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