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Research Article

The Effect of the AI-Based Intelligent Tutor System (ITS) on the Understanding of Mathematical Concepts in Grade V Students of SD Negeri 2 Badran, Temanggung

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Abstract: This study aims to analyze the effect of the implementation of the Intelligent Tutoring System (ITS) based on Artificial Intelligence (AI) on improving the understanding of mathematical concepts, especially in fractional and basic geometry materials, in Class V students of SD Negeri 2 Badran, Temanggung Regency. The research method used was a quasiexperimental experiment with a Non-equivalent Control Group Design. The research sample consisted of 48 students who were divided into two groups, namely the experimental group (n=24) who received learning with the help of AI-based ITS, and the control group (n=24) who received conventional learning with lecture methods and practice questions. The research instrument is in the form of a test of understanding of mathematical concepts that has been validated by experts and tested for reliability. Data were analyzed using parametric statistical tests of the Independent Sample t-test and N-Gain Score to measure the improvement. The results showed that there was a significant difference in understanding of mathematical concepts between the experimental group and the control group. The average post-test score of the experimental group (82.45) was significantly higher than that of the control group (70.12) with a p< value of 0.05. N-Gain analysis showed that the improvement in conceptual understanding in the experimental group was in the "moderate" category (g=0.56), while the control group was in the "low" category (g=0.32). These findings indicate that AI-based ITS is effective in improving students' understanding of mathematical concepts. The advantages of the system lie in its ability to provide instant feedback, personalize materials according to learning pace, and present interactive materials, thus helping to better construct students' conceptual understanding. It is recommended that schools consider the integration of ITS technology as a supplementary tool in mathematics learning at the elementary level.

Keywords: AI; Geometry; ITS; Mathematics; Quasi-experimental

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1. Introduction

Mathematics is a critical foundation in the development of logical thinking, problem-solving, and quantitative literacy skills from the elementary education level. In grade V of Elementary School (SD), students are introduced to more abstract and complex mathematical concepts, such as fractional operations, simple spatial geometry, and measurement. A deep conceptual understanding of these topics is essential as a prerequisite for learning mathematics at the next level. However, the reality in the field, including at SD Negeri 2 Badran, Temanggung, shows that many students still experience misconceptions and difficulties in understanding these core concepts. These difficulties often stem from conventional and teachercentered teaching methods, limited teachers' time in providing personalized attention and feedback to each student, and the lack of use of interactive and adaptive learning media.

The digital revolution and rapid advances in the field of Artificial Intelligence (AI) offer a new paradigm to address the classic challenges in education. One of the most promising innovations is the development of the Intelligent Tutoring System (ITS). AI-based ITS is a computational platform designed to mimic the pedagogical expertise of a human tutor, by providing a personalized learning experience, tailored instruction, and formative feedback in real-time without requiring constant direct intervention from teachers. This system is able to model student knowledge (student modeling), diagnose errors in depth, and adjust the learning path and speed according to individual needs (mastery learning).

Although many studies at the international level have proven the effectiveness of ITS in the context of secondary and higher education, exploration and empirical evidence regarding its implementation at the elementary school level, especially in Indonesia with a unique cultural and infrastructure context, is still very limited. SD Negeri 2 Badran, Temanggung, represents the context of elementary schools in semi-urban areas that already have the readiness of basic technology infrastructure, thus providing an ideal opportunity to test the application of this technology. Therefore, this study was conducted to investigate the influence of the implementation of AI-based Smart Tutor Systems on improving the understanding of mathematics concepts of grade V students.

2. Literature Review

The Concept of Understanding in Mathematics Learning

Conceptual understanding occupies a central position in the framework of mathematical competence. According to Kilpatrick, Swafford, & Findell (2001) in Adding It Up, conceptual comprehension is one of the five interconnected strands of mathematical ability, demonstrated by a student's ability to relate symbolic, graphic, and verbal representations to underlying mathematical ideas. In Bloom's taxonomy as revised by Anderson & Krathwohl (2001), understand is defined as the ability to construct meaning from learning material, which includes interpreting, modeling, classifying, summarizing, drawing inferences, comparing, and explaining. In the context of this study, indicators of understanding mathematical concepts in fractional and geometry materials are operationalized as the ability of students to: (1) restate a concept in their own language, (2) identify examples and non-examples of a concept, (3) classify objects based on conceptual properties, (4) convert a concept into various forms of representation (symbols, images, words), and (5) apply concepts to problem-solving situations new.

Intelligent Tutor Systems (ITS) and AI in Education

An Intelligent Tutor System is an advanced software system that integrates artificial intelligence to provide instructional guidance tailored to each learner's circumstances (Nkambou et al., 2010). The core architecture of a classic ITS consists of four model components:

a. Domain Model: Represents expert knowledge about the subject matter to be taught.
b. Student Model: Is at the heart of ITS, which diagnoses and tracks students' knowledge, skills, bugs, and sometimes affective states.
c. Tutoring Model: Contains pedagogical strategies that determine how and when to provide interventions, explanations, or new questions based on data from the Student Model.
d. User Interface Model: A module that governs the interaction between the system and the user (student).

With the advancement of machine learning (especially deep learning), student modeling has become more dynamic and accurate. Modern ITS can analyze response patterns, processing time, and even cursor movements to infer a student's level of understanding, confusion, or confidence. Meta analysis research by Ma et al. (2014) and Pane et al. (2017) consistently shows that ITS has a medium to large effect on improving learning outcomes compared to traditional teaching or non-adaptive computer-based learning.

Related Research in the Indonesian Context

Research on ITS in Indonesia is starting to develop, but the majority is still in the development stage or applied at the secondary and higher education levels. Arifin & Zulkardi (2020) successfully developed an ITS prototype for fractional materials in elementary school, showing good potential in limited tests. A study by Nurhayati & Mulyati (2018) found a positive effect on the use of simple smart tutor modules on mathematics learning outcomes in grade IV of elementary school. Evaluative research by Purnamasari & Hidayat (2022) in Central Java revealed that the main challenge in the implementation of ITS in elementary schools is the limitations of teacher training and uneven infrastructure. Meanwhile, a study from Wijaya & Dewi (2022) emphasizes the importance of ITS design that is contextual and in accordance with the pedagogical needs of elementary school students in the region. This study seeks to go further than previous studies by conducting a strict controlled experiment to isolate the influence of more sophisticated AI-based ITS on the construct of concept understanding (not just learning outcomes) in a real elementary school setting.

3. Research Method

This study uses a quantitative approach with a quasi-experimental design method. The design applied is Non-equivalent Control Group Design. The choice of this design was due to the natural conditions in the school where the researcher could not randomize individual assignments to students, so experimental and control groups were formed based on existing classes.

Algorithm of Research Implementation

The methodological flow of this research is illustrated in the following algorithm:

1. BEGIN (Start Research)
2. Population = All 5th Grade Students at SDN 2 Badran (N=48)
3. Sample Selection: Purposive Sampling
   3.1. Class V-A (n=24) → Assigned as Experimental Group (E)
   3.2. Class V-B (n=24) → Assigned as Control Group (C) // Basis: Similar prior math achievement & teacher recommendation
4. Pre-Test Phase:
   4.1. Administer Conceptual Understanding Test (T1) to both Group E and C.
   4.2. Validate data normality (Kolmogorov-Smirnov) and homogeneity (Levene's Test).
5. Intervention Phase (Duration: 8 meetings):
   5.1. FOR Group E:
      5.1.1. Learning using "MathWhiz AI Tutor" ITS.
      5.1.2. Process: Diagnostic pre-test → Adaptive content delivery → Interactive exercises → AI-driven feedback & hints → Mastery check → Progression.
   5.2. FOR Group C:
      5.2.1. Conventional learning (lecture, Q&A, group worksheets).
      5.2.2. Process: Teacher explanation → Class discussion → Solving uniform problems → Teacher-led review.
6. Post-Test Phase:
   6.1. Administer Conceptual Understanding Test (T2) to both Group E and C.
7. Data Analysis Phase:
   7.1. IF (Data is Normal AND Homogeneous)
      7.1.1. Perform Independent Samples t-test on Post-Test Scores (T2).
      7.1.2. Calculate Normalized Gain (N-Gain) for both groups.
      ELSE
         Perform Mann-Whitney U Test.
8. Interpretation & Discussion of Results.
9. END

Figure 1. Algorithm

Instrumentation and Data Collection

The main instrument is the Mathematical Concept Comprehension Test in the form of descriptions (10 questions). The questions refer to indicators of concept understanding and are validated by two mathematics education experts. Reliability was tested with Cronbach's Alpha ($\alpha = 0.81$). The supporting instruments are activity observation sheets and semi-structured interview guidelines.

Formatting of Mathematical Components

In ITS learning materials and tests, mathematical notation is clearly presented. Example of a fraction concept problem: Concept Understanding Questions (Example):

The N-Gain analysis is calculated using the formula of Hake (1998):

$$\langle g \rangle = \frac{\text{Post-test Score} - \text{Pre-test Score}}{\text{Maximum Score} - \text{Pre-test Score}}$$

Kategori: $\langle g \rangle > 0.7$ (Tinggi), $0.3 \leq \langle g \rangle \leq 0.7$ (Sedang), $\langle g \rangle < 0.3$ (Rendah).

4. Results and Discussion

Results

The results of the analysis prerequisite test showed normal and homogeneous distribution data ($p > 0.05$). The data on pre-test, post-test, and N-Gain results are presented in Table 1.

Table 1. Summary of Descriptive Statistics and N-Gain Results

Group	N	Pre-test Mean (SD)	Post-test Mean (SD)	N-Gain Mean	N-Gain Category
Eksperimen (ITS)	24	52.33 (7.89)	82.45 (6.78)	0.56	Medium
Control	24	54.17 (8.12)	70.12 (8.45)	0.32	Low

The results of the Independent Samples t-test at the post-test value showed a very significant difference: t (46) = 5.678, p = 0.000 ($p < 0.01$). A p-value of less than 0.05 indicates that the Null Hypothesis (H0) is rejected. Thus, there was a significant difference in understanding of mathematical concepts between the group that learned using AI-based ITS and the group that learned conventionally.

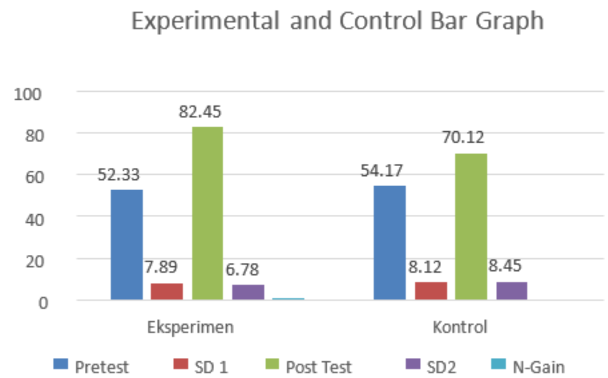

Figure 2. Comparison of Average Pre-test and Post-test Scores of the Experimental and Control Groups (The double bar image shows a sharper improvement in the experimental group)

Discussion

These findings confirm the effectiveness of AI-based ITS in facilitating deeper conceptual understanding. Several key mechanisms identified through observation and interviews support these quantitative results:

a. Adaptive Scaffolding: ITS provides scaffolding that is timely and in accordance with the student's specific fault pattern. If students make a mistake in equalizing denominators, the system not only corrects them, but displays interactive visualizations of equal partitioning, which is a fundamental concept of fractions.

b. Cognitive Feedback: Feedback from the system is designed to guide the thought process ("Try to pay more attention to the relationship between the numerator and the denominator") rather than just telling the correct answer. It encourages metacognition.

c. Minimization of Cognitive Load: The gradual presentation of material and the elimination of irrelevant elements (extraneous load) by ITS allows students' cognitive resources to be focused on understanding core concepts.

d. Motivation and Agency: Students in the experimental group reported feeling in control of their learning. The ability to repeat explanations and move forward after a thorough understanding increases intrinsic motivation and confidence.

These results are in line with the research of Arifin & Zulkardi (2020) and are consistent with the theory of constructivism and the principle of mastery learning. ITS acts as a "private tutor" that allows each student to build his or her conceptual understanding in their respective zones of proximal development.

5. Comparison

Table 2. Comparison of Findings with Previous Research in Indonesia

Aspects	This Research (SDN 2 Badran)	Nurhayati & Mulyati (2018)	Purnamasari & Hidayat (2022)
Focus	Understanding of Mathematical Concepts (Class V)	Mathematics Learning Outcomes (Class IV)	Evaluation of the Implementation of ITS (Multi-Grade Elementary School)
Types of ITS	Web-based AI platform with high adaptability	Standalone Computer-Based Smart Tutor Module	Diverse (Most simple applications)
Design	QuasiExperimental (Pretest/Posttest Control Group)	Quasi-Experimental	Evaluative Descriptive Studies
Key Findings	Significant improvement in concept comprehension (moderate NGain)	Significant improvement in learning outcomes	Great potential, but constrained by teacher training & infrastructure
Location Context	Semi-Urban Elementary School, Temanggung	Urban Elementary School (non-specific)	Some elementary schools in Central Java (varied)

The comparison shows that this study makes a specific contribution by: (1) focusing on measuring deeper understanding of concepts than just learning outcomes, (2) the use of more advanced and adaptive AI-based ITS platforms, and (3) its application in the context of semi-urban elementary schools that receive less attention. The findings of "moderate" N-Gain in the experimental group were stronger than the general findings of improved learning outcomes in similar studies, indicating that ITS not only helped students answer questions correctly, but also built a stronger conceptual foundation.

6. Conclusion

Based on the data analysis and discussion, it can be concluded that the implementation of the AI-based Smart Tutor System (ITS) has a statistically significant positive impact on improving the understanding of mathematical concepts among Class V students of SD Negeri 2 Badran, Temanggung. The experimental group using ITS achieved significantly higher post-test scores and N-Gain scores compared to the control group. The key advantage of the AI-based ITS lies in its ability to offer a personalized learning environment, provide timely cognitive feedback, and reduce unnecessary cognitive load, which enables students to focus more effectively on building conceptual understanding.

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