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Application of the Discovery Learning Model to Improve Mathematical Activities and Conceptual Understanding

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Abstract

The learning process in higher education, particularly in education study programs, is not only oriented towards knowledge transfer, but rather emphasizes the development of prospective teachers' pedagogical capacity in designing and delivering contextual learning materials. The main challenge that often arises, especially among first-semester students, is the low level of active engagement in the learning process due to the still dominant one-way learning approach. Through mixed methods research (qualitative-quantitative) that combines observation, interviews, document analysis, and comprehension tests, it was found that the implementation of Discovery Learning succeeded in significantly increasing both student engagement and their conceptual understanding. Quantitative data showed an average post-test score of 93.13, while qualitative findings revealed the development of students' creative pedagogical abilities in designing innovative learning strategies such as educational songs, puzzle games for Roman numerals, and origami media for fractions. These results prove that the student-centered approach through Discovery Learning not only addresses engagement issues but also builds a more meaningful and applicable understanding of mathematics for prospective teachers and elementary school students.

Keyword: *Discovery Learning, Mathematical Activities, Conceptual Understanding, Instructional Strategies*

Introduction

The learning process in higher education is not only oriented towards knowledge transfer, but more towards developing the pedagogical capacity of prospective teachers in designing and delivering contextual learning materials (Barkley et al., 2014). The main challenge that often arises, especially for first semester students, is the low level of active involvement in the learning process due to the dominance of a one-way learning approach (Theobald et al., 2020). Students tend to be passive recipients of information delivered by lecturers, without sufficient opportunities to explore, ask questions, and build knowledge independently (Fadila & Hariyati, 2019).

Second-semester students are the group that begins to be introduced to the foundations of teaching science, including mastery of teaching materials and how to convey them to students. This momentum is crucial for beginning to instill pedagogical skills and reflective thinking as they prepare to become professional educators in the future (Brown et al., 2022). One learning approach that can support this goal is Discovery Learning (Bruner, 1971).

Discovery Learning is a learning model that encourages students to be actively involved in the thinking process, exploring information, asking questions, testing ideas, and drawing conclusions through direct experience (Wicaksono, 2022). In this approach, the lecturer acts as a facilitator who guides students to discover concepts or principles independently through certain stages. (Naibaho, 2018). This model is believed to be able to improve students' critical thinking skills, creativity, and learning independence (Haeruman et al., 2017).

This research was conducted in the context of the Elementary Mathematics course, a foundation course for prospective elementary school teachers. In this course, students are not only required to understand mathematical concepts but also to be able to develop appropriate learning strategies for elementary school students. Therefore, the Application of Discovery Learning explores the process of students designing an approach appropriate to the developmental level of elementary school students to convey mathematics material through simplification and participatory explanation.

This the problem limitation in this study lies in the exploratory process of second-semester students in understanding and designing a teaching approach to basic mathematical concepts for elementary school level through the Discovery Learning model. It is hoped that this learning will not only improve students' conceptual understanding of mathematical material but also train their pedagogical skills in communicating ideas appropriately to students with different developmental characteristics.

Methods

This study uses a mix method approach, qualitative data is explained descriptively with the aim of describing in depth the process of implementing the Discovery Learning model in Basic Mathematics learning for 2nd semester students of the Elementary School Teacher Education (PGSD) study program and quantitative data will describe the extent to which they understand the material (Creswell & Creswell, 2017). This approach was chosen because it allows researchers to explore students' responses, activities, and understanding outcomes comprehensively in the natural context of learning (Waruwu, 2024).

The study was conducted on second-semester students taking Basic Mathematics at a university in Indonesia. The study involved 32 students enrolled in one regular class. The course lasted one semester, with 14 face-to-face meetings. Discovery Learning was implemented specifically during the fourth and fifth meetings, which focused on Roman

numerals and fractions. Learning is designed using the Discovery Learning model which consists of six main stages (Prasetyo & Abduh, 2021); stimulation, problem statement, data collection, data processing, verification, and generalization. Lecturers act as facilitators, presenting contextual problems related to mathematical concepts commonly taught in elementary schools. They then guide students in exploring solutions and strategies for delivering them to elementary school students. Students work individually and in groups to design learning models and conduct simple simulations to explain the material.

Data collection was carried out using several techniques (Saefuddin et al., 2023); Observation carried out to record student activities during the learning process using an active involvement observation sheet. Interviews conducted with several students purposively to explore their perceptions of the learning process and understanding of concepts. Documentation: in the form of notes on student work and learning plans. Tests: in the form of questions to assess student understanding.

The collected data was analyzed qualitatively through the stages of data reduction, data presentation, and conclusion drawing. Student activities were analyzed based on indicators of active learning and critical thinking. (Yuliani, 2018). Meanwhile, the results of students' work and reflections are analyzed to reveal the extent to which they understand the material and are able to design appropriate learning strategies for elementary school students.

Result

The research showed that students successfully explored various creative approaches to presenting Roman numerals and fractions to elementary school students. For the Roman numerals topic, students successfully explored three creative approaches based on educational media that were fun and easily understood by students: educational songs, interactive puzzle games, and mnemonic acronyms. For the fractions topic, students were able to use the provided materials, namely origami paper, to explain the fractions topic. The following is an analysis and interpretation of the research results.

The multisensory approach in teaching Roman numerals reveals that students intuitively adopt visual, auditory, and kinesthetic learning methods. They utilize songs to stimulate auditory memory through rhythm and rhyme, card puzzles to engage visual-spatial intelligence, and mnemonic acronyms using associative stories to enhance linguistic stimulation. These strategies align with M. Arsyad's (2021) theory of multisensory learning and Firdaus' (2020) insights on linguistic stimulation, emphasizing the importance of accommodating diverse learning styles among elementary school students.

Meanwhile, the use of mathematical manipulatives such as origami in teaching fractions serves as an effective bridge between concrete experiences and abstract concepts. This method is consistent with the cognitive developmental stage described by Jean Piaget, particularly the concrete operational stage (ages 7–11), in which children can perform logical operations only when dealing with tangible, real-world situations (Juwantara, 2019). By folding paper into parts like ½, ¼, or ⅛, students experience firsthand the process of dividing a whole into fractional parts. This physical activity facilitates a natural transition from concrete manipulation to abstract mathematical understanding. As noted by Purwadi (2019) and Indriani et al. (2024), using concrete media to illustrate abstract concepts positively impacts students' conceptual comprehension and their ability to represent mathematical ideas, particularly in the topic of fractions.

An analysis of students' pedagogical processes shows progressive development in teaching skills through three main stages: imitation (mimicking the lecturer's method),

adaptation (modifying strategies), and creation (designing original approaches). This pattern reflects Shulman's (1987) theory of Pedagogical Content Knowledge (PCK), where knowledge is transformed and internalized to enable meaningful instructional delivery. However, in practice, students encounter challenges in implementing differentiated instruction, particularly in adjusting language to suit varying cognitive levels and managing time effectively when producing learning media. These difficulties support Tomlinson's (2001) findings on the complexity of applying differentiated instruction in real classroom settings, where sensitivity to student diversity is crucial.

Table 1. Comparative Analysis of Learning Materials

Aspect	Roman Numerals	Fractions
Dominant Modalities	Auditory-linguistic	Visual-kinesthetic
Level of Abstraction	Symbolic	Semi-concrete
Main Difficulty	Conversion logic	Representation of parts
Effective Strategy	Mnemonics	Physical manipulatives

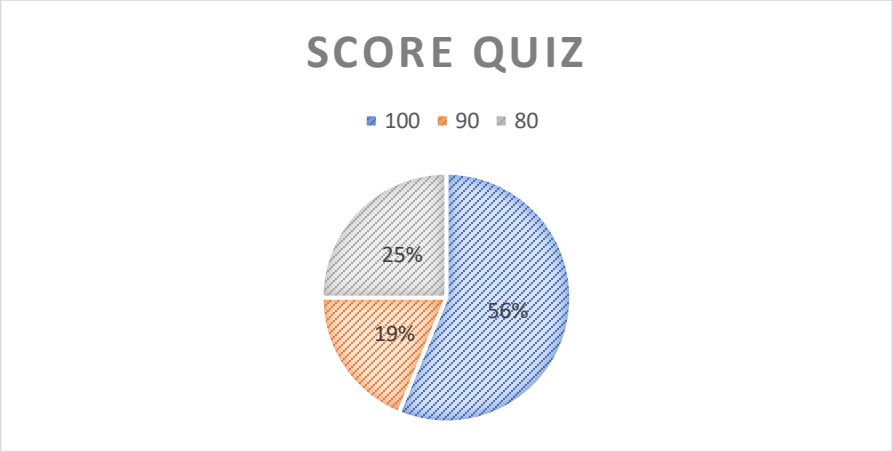

Figure 1. Student College Quiz Scores

The analysis of quiz results conducted after the learning activity revealed highly positive outcomes. The majority of students—more than half—achieved the maximum score, indicating excellent mastery of the material. The average score was also notably high at 93.13, reflecting a strong overall understanding of the quiz content. Furthermore, no student scored below 80, suggesting that none experienced significant difficulty in comprehending the material. These findings highlight the effectiveness of the teaching approach and the clarity of material delivery during the lesson.

Discussion

This study demonstrates that the students were able to explore and apply various creative approaches in delivering mathematics content to elementary school students, particularly on the topics of Roman numerals and fractions. These results reflect the students' understanding of the importance of using contextual, engaging, and developmentally appropriate media and instructional methods tailored to the cognitive stages of learners.

For the Roman numerals topic, the students developed three complementary strategies. First, through an educational song adapted from a familiar children's tune ("Balonku Ada Lima"), they successfully embedded Roman numeral content into the lyrics, allowing students to memorize the symbols through repetitive and enjoyable singing. Second, using an interactive puzzle game, the students designed an activity in which learners match Roman numeral symbols with their standard numeric equivalents, engaging both their cognitive and kinesthetic skills. Third, the use of a mnemonic acronym such as "Ibu Vina Xena Lagi Cari Durian Manis" (a playfully constructed Indonesian phrase) accompanied by an imaginative story provided strong verbal memory cues that were easy for students to remember.

Meanwhile, for the topic of fractions, the students utilized concrete materials in the form of origami paper to visually and tactilely explain the concept of parts of a whole. Through the process of folding, dividing, and observing the sections of paper, students were able to gradually build conceptual understanding of fractions—starting from concrete experiences, moving to visual representations, and eventually grasping the symbolic form of fractions. This approach aligns with the principles of the Concrete–Pictorial–Abstract (CPA) learning model and is consistent with the concrete operational stage in Piaget's theory of cognitive development, which emphasizes the need for direct, hands-on experiences in helping elementary school children understand abstract concepts.

Overall, the students' success in exploring these creative approaches indicates that they not only mastered the subject matter but also demonstrated the ability to design learning experiences that are aligned with the characteristics and needs of young learners. This highlights the importance of integrating pedagogical and content knowledge (PCK) in the training process of future teachers.

Conclusion

The findings indicate that the students successfully utilized various creative strategies to teach Roman numerals and fractions to elementary learners. The strategies employed were not only visually engaging and enjoyable but also provided opportunities for students to think actively and participate directly in the learning process. The use of media such as educational songs, interactive puzzle games, and mnemonic acronyms for Roman numerals, along with origami paper to explain fractions, reflects the students' efforts to connect abstract mathematical concepts with concrete experiences that are familiar and relevant to the learners' world. This approach aligns with the principles of discovery learning, in which students are encouraged to construct their own understanding through exploration, experimentation, and gradual concept discovery. In this context, the students assumed the role not just of content deliverers, but as facilitators who designed meaningful and stimulating learning experiences. Through this student-centered strategy, mathematical concepts were not merely presented but actively uncovered by the learners themselves, resulting in deeper, longer-lasting, and more applicable understanding.

Declarations

Author contribution statement
Specifies the exact contributions of each author in a narrative form.

Funding statement
The funding agency should be written out in full and include the grant number, which can be included in brackets. The funding agency needs to be listing in the "Organization Name." If there is only one funding agency, the Organization Name [grant number xxxxxx] supported this research. If there are multiple agencies or grant numbers, then it should be formatted as such: This research was supported by the Organization Name [grant numbers xxxxxx]; the Organization Name [grant number xxxxxx]; and the Organization Name [grant number xxxxxx]. If there is no funding information, they should state: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. If an organization providing not monetary support (maybe they provided facilities, survey samples, etc.), please mention that that organization supported the research.

Data availability statement

Data availability statements provide a statement about where data supporting the results reported in a published article can be found - including, where applicable, hyperlinks to publicly archived datasets analyzed or generated during the study.

Declaration of interests statement
The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper. Alternatively, The authors declare the following financial interests/personal relationships, which may be considered as potential competing interests.

Additional information
Additional information in a narrative form.

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