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Analyzing Students' Mathematical Conceptual Understanding Through Smart TV-Integrated Learning from the Perspective of Self-Regulated Learning

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Abstract

This study aims to describe the characteristics of students' Self-Regulated Learning (SRL) and analyze their mathematical conceptual understanding through Smart TV-integrated learning based on their level of SRL. This study employed a descriptive qualitative approach involving 24 eighth-grade students of SMP Negeri 1 Buntu Pepasan as research participants. The data were collected through a Self-Regulated Learning questionnaire, a mathematical conceptual understanding test on the Pythagorean Theorem, in-depth interviews, observations, and documentation. The data were analyzed using the Miles and Huberman interactive model, which consists of data reduction, data display, and conclusion drawing and verification. The validity of the data was established through technique triangulation. The findings revealed that 33.33% of the students were categorized as having high SRL, 45.83% had moderate SRL, and 20.84% had low SRL. The students demonstrated mathematical conceptual understanding across six indicators: stating concepts, identifying concepts, applying concepts, relating concepts, solving problems, and drawing conclusions. Students with high SRL demonstrated stronger conceptual understanding across the indicators, particularly in selecting appropriate strategies, relating mathematical concepts to real-life situations, and evaluating their solutions. Students with moderate SRL demonstrated adequate conceptual understanding but still required guidance in several aspects, while students with low SRL experienced greater difficulties, particularly in relating concepts and solving contextual problems. These findings suggest that Smart TV-integrated mathematics learning can provide meaningful support for students' conceptual understanding, particularly when accompanied by strong self-regulation skills. Therefore, integrating digital learning media with the development of students' self-regulated learning may provide a valuable approach to supporting meaningful mathematics learning.

Keywords: *Smart TV; Self-Regulated Learning; Mathematical Conceptual Understanding; Pythagorean Theorem; Mathematics Learning*

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INTRODUCTION

Mathematics is an essential component of school education because it contributes to the development of logical, analytical, critical, and problem-solving skills. However, learning mathematics should not be limited to the ability to perform calculations or memorize formulas. Students need to develop a meaningful understanding of mathematical concepts so that they can explain concepts in their own words, identify relationships among concepts, apply appropriate procedures, and use mathematical knowledge to solve problems in various contexts. Conceptual understanding therefore serves as an important foundation for students to develop more complex mathematical abilities.

Mathematical conceptual understanding refers to students' ability to comprehend mathematical ideas and establish meaningful relationships among concepts, procedures, and representations. Hiebert and Lefevre (1986) distinguish conceptual knowledge from procedural knowledge by emphasizing that conceptual knowledge involves understanding relationships within a network of knowledge rather than merely knowing isolated facts or procedures. Similarly, Kilpatrick et al. (2001) identify conceptual understanding as an important component of mathematical proficiency because students who understand mathematical concepts are better able to use knowledge flexibly and apply it to unfamiliar problems. Thus, mathematics instruction needs to provide learning experiences that encourage students to understand the meaning behind mathematical procedures rather than simply memorize formulas.

The importance of conceptual understanding is particularly evident in topics that require students to connect abstract mathematical concepts with visual and contextual representations. One such topic is the Pythagorean Theorem. Students are expected not only to remember the formula (a^2+b^2=c^2), but also to identify the hypotenuse and the legs of a right triangle, determine the appropriate relationship among the sides, apply the theorem correctly, and interpret the resulting solution in the context of a problem. Difficulties in these processes may occur when learning is predominantly procedural and does not provide sufficient opportunities for students to visualize and connect mathematical ideas.

The development of educational technology provides opportunities to create mathematics learning environments that are more visual, interactive, and engaging. Digital technologies can support the presentation of mathematical concepts through various forms of representation, including images, animations, videos, diagrams, and interactive materials. Schindler et al. (2017) highlight the potential of digital technologies to support mathematics learning by facilitating visualization, interaction, and access to mathematical representations. One form of digital technology that can be utilized in classroom instruction is a Smart TV. Through a large and accessible display, Smart TV can be used to present instructional videos, diagrams, animations, worked examples, and contextual problems, potentially helping students construct more concrete representations of abstract mathematical concepts.

The use of multimedia in learning is also supported by Mayer's (2009) Multimedia Learning Theory, which explains that learners can construct knowledge more effectively when information is presented through appropriately integrated verbal and visual representations. In mathematics education, the combination of visual and verbal information can help students recognize relationships among mathematical objects and procedures. Therefore, integrating Smart TV into mathematics instruction may provide students with richer opportunities to observe, discuss, and connect mathematical representations, particularly when learning concepts such as the Pythagorean Theorem.

Nevertheless, the availability of learning media alone does not guarantee that all students will achieve the same level of understanding. Students differ in their ability to regulate their own learning processes. One important individual factor is Self-Regulated Learning (SRL). SRL refers to students' ability to actively manage their learning through processes such as planning learning activities, monitoring their understanding, controlling learning strategies, maintaining motivation, and evaluating learning outcomes. Zimmerman (2002) describes self-regulated learners as active participants who regulate their cognition, motivation, behavior, and learning environment to achieve their learning goals. Similarly, Pintrich and De Groot (1990) emphasize the relationship between motivational beliefs, self-regulation, and academic performance.

Students with strong SRL are generally more capable of setting learning goals, selecting appropriate strategies, monitoring their progress, and reflecting on the results of their learning. These characteristics may influence how effectively students utilize digital learning media. In a Smart TV-integrated mathematics classroom, students with higher levels of SRL may be more actively involved in observing learning materials, identifying relevant information, asking questions, applying strategies, and evaluating their solutions. In contrast, students with lower levels of SRL may require greater guidance to engage with the learning materials and regulate their learning processes effectively. Broadbent and Poon (2015) also emphasize the importance of self-regulated learning strategies in supporting students' academic achievement.

The relationship between SRL and mathematical conceptual understanding is particularly important because conceptual learning requires students to actively construct and reorganize their knowledge. Understanding a mathematical concept involves more than receiving information from the teacher or digital media; students need to process information, make connections, apply concepts, and reflect on their solutions. Consequently, students' ability to regulate their learning may influence the extent to which they benefit from technology-supported mathematics instruction.

Previous studies have examined the role of digital technology in mathematics education and the contribution of self-regulated learning to students' academic achievement. However, there remains a need to examine how students' mathematical conceptual understanding is characterized when Smart TV is integrated into mathematics learning and viewed from different levels of SRL. In particular, research that describes students' performance across specific indicators of conceptual understanding—such as stating, identifying, applying, relating, solving problems, and drawing conclusions—is still important for providing a more detailed picture of the learning process.

Based on this background, this study aims to describe the characteristics of students' Self-Regulated Learning and analyze their mathematical conceptual understanding through Smart TV-integrated mathematics learning from the perspective of their SRL levels. The study focuses on eighth-grade students learning the

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Pythagorean Theorem and examines their conceptual understanding across six indicators: stating concepts, identifying concepts, applying concepts, relating concepts, solving problems, and drawing conclusions. The findings are expected to provide insights for mathematics teachers regarding the integration of digital learning media and the development of students' self-regulated learning to support meaningful mathematical conceptual understanding.

Methode

Research Design

This study employed a descriptive qualitative research approach. The qualitative approach was selected because the study aimed to describe students' Self-Regulated Learning (SRL) characteristics and analyze their mathematical conceptual understanding in depth through Smart TV-integrated mathematics learning. The study focused on describing students' understanding of the Pythagorean Theorem based on their respective levels of SRL rather than measuring the effectiveness of Smart TV through experimental procedures.

Research Participants and Setting

The research was conducted at SMP Negeri 1 Buntu Pepasan. The participants consisted of 24 eighth-grade students who participated in mathematics learning on the Pythagorean Theorem using Smart TV as an integrated learning medium. The students completed an SRL questionnaire to determine their level of self-regulation in learning. Based on the questionnaire results, the students were classified into three SRL categories: high, moderate, and low.

The classification was used as the basis for analyzing differences in students' mathematical conceptual understanding. Students from each SRL category were then examined based on their responses to the conceptual understanding test, interview results, and observations during the learning process.

Data Collection Techniques

Data were collected using several complementary techniques, namely an SRL questionnaire, a mathematical conceptual understanding test, in-depth interviews, observations, and documentation.

The SRL questionnaire was administered to identify students' levels of self-regulated learning. The questionnaire focused on students' ability to manage and regulate their learning activities, including planning, monitoring, controlling, and evaluating their learning processes.

A mathematical conceptual understanding test was administered after the Smart TV-integrated learning activities. The test focused on the Pythagorean Theorem and was designed to examine six indicators of mathematical conceptual understanding: (1) stating concepts, (2) identifying concepts, (3) applying concepts, (4) relating concepts, (5) solving problems, and (6) drawing conclusions.

In-depth interviews were conducted to obtain more detailed information about students' reasoning, learning strategies, difficulties, and experiences when solving mathematical problems. Observations were used to identify students' participation and learning behaviors during the Smart TV-integrated learning process. Documentation was used to complement the data obtained from the questionnaire, test, interviews, and observations.

Data Analysis

The data were analyzed using the interactive model of Miles and Huberman, which consists of data reduction, data display, and conclusion drawing and verification. During data reduction, the researcher selected, organized, and summarized relevant information obtained from the SRL questionnaire, conceptual understanding test, interviews, observations, and documentation.

The reduced data were then displayed in descriptive and comparative forms to identify patterns in students' mathematical conceptual understanding across the three SRL categories. The analysis focused on the six indicators of conceptual understanding and the characteristics demonstrated by students with high, moderate, and low SRL.

The final stage involved drawing and verifying conclusions. The researcher compared information obtained from different data collection techniques to identify consistent findings regarding the relationship between students' SRL characteristics and their mathematical conceptual understanding.

Data Validity

The validity of the research data was established through technique triangulation. Data obtained from the mathematical conceptual understanding test were compared with information from interviews, observations, and documentation. This process was conducted to ensure that the findings concerning students' conceptual understanding and SRL characteristics were supported by information from multiple data sources and not based solely on a single instrument.

RESULTS AND DISCUSSION

Results

1. Characteristics of Students' Self-Regulated Learning

The results of the Self-Regulated Learning (SRL) questionnaire revealed that the 24 eighth-grade students were distributed across three levels of SRL: high, moderate, and low. The distribution of students is presented in Table 1.

SRL Category	**Number of Students**	**Percentage**
High	8	33.33%
Moderate	11	45.83%
Low	5	20.84%
Total	**24**	**100%**

Table 1 shows that the largest proportion of students belonged to the moderate SRL category, consisting of 11 students (45.83%). Eight students (33.33%) were categorized as having high SRL, while five students (20.84%) were categorized as having low SRL.

Students with high SRL demonstrated stronger characteristics in managing their learning processes. They were able to plan learning activities, monitor their understanding, regulate their learning strategies, and reflect on the results of their learning. In contrast, students with low SRL tended to require greater guidance from the teacher in managing their learning activities independently.

These findings indicate that students differed in their ability to regulate their own learning. Such differences are important because

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the ability to plan, monitor, and evaluate learning activities may influence how students respond to learning tasks and utilize the learning media provided by the teacher.

2. Students' Mathematical Conceptual Understanding

The results of the mathematical conceptual understanding test showed that Smart TV-integrated mathematics learning supported students' understanding of the Pythagorean Theorem. Students' conceptual understanding was analyzed based on six indicators: (1) stating concepts, (2) identifying concepts, (3) applying concepts, (4) relating concepts, (5) solving problems, and (6) drawing conclusions.

2.1. Stating Mathematical Concepts

The results showed that most students were able to explain the concept of the Pythagorean Theorem. Through the visual presentation provided by the Smart TV, students were exposed to diagrams, illustrations, and learning materials that helped them recognize the relationship between the sides of a right triangle.

Students were able to describe the basic idea of the Pythagorean Theorem and recognize that the theorem relates the lengths of the sides of a right triangle. This indicates that the visual representation provided during learning helped students develop an initial conceptual understanding rather than merely memorizing the formula.

2.2 Identifying Mathematical Concepts

Most students were also able to identify the hypotenuse and the legs of a right triangle correctly. The use of visual representations through Smart TV helped students distinguish the different sides of a right triangle based on their positions and relationships.

This ability is important because identifying the hypotenuse and the legs is a prerequisite for applying the Pythagorean Theorem correctly. Students who are unable to identify these elements may select an inappropriate mathematical relationship when solving problems.

2.3 Applying Mathematical Concepts

At the application stage, students were able to use the Pythagorean formula to solve mathematical problems. The visual presentation of examples and explanations through Smart TV provided students with opportunities to observe how the formula could be applied in different situations.

The findings suggest that students were not only able to recognize the formula but also use it to obtain solutions. However, the ability to apply a formula should be accompanied by an understanding of when and why the formula is appropriate. Therefore, contextual and visual learning activities remain important in helping students connect procedures with mathematical concepts.

2.4 Relating Mathematical Concepts to Everyday Situations

The results also showed that students were able to relate the Pythagorean Theorem to situations encountered in everyday life. This ability demonstrates that students could recognize the relevance of mathematical concepts beyond the classroom.

Smart TV-supported learning provided opportunities to present mathematical situations through visual examples, making it easier for students to connect the concept with real-world contexts. Such connections are important because mathematical conceptual understanding involves not only knowing a mathematical rule but also recognizing its application in meaningful situations.

2.5 Solving Mathematical Problems

Most students were able to solve contextual problems systematically. Students were able to identify the information provided, determine the appropriate mathematical procedure, apply the Pythagorean Theorem, and obtain a solution.

Nevertheless, students' ability to solve problems was related to their level of SRL. Students with stronger self-regulation tended to demonstrate greater independence when selecting strategies and completing problem-solving tasks. Students with lower SRL required more guidance, particularly when dealing with contextual problems that demanded several stages of reasoning.

2.6 Drawing Conclusions

The majority of students were able to draw conclusions based on the mathematical concepts they had used. Students could interpret the results of their calculations and formulate conclusions related to the problems being solved.

This finding indicates that conceptual understanding extended beyond calculation. Students were able to connect the results of their mathematical procedures with the context of the problem. The ability to draw conclusions is important because it demonstrates that students understand the meaning of the solution rather than simply producing a numerical answer.

3. Mathematical Conceptual Understanding Based on Students' Self-Regulated Learning

The analysis of students' conceptual understanding based on their SRL levels showed differences among students with high, moderate, and low SRL.

Students with high SRL demonstrated better conceptual understanding across the six indicators. They were able to understand mathematical concepts more deeply, select appropriate solution strategies, relate mathematical concepts to real-life situations, and evaluate their answers independently.

Students with moderate SRL demonstrated relatively good conceptual understanding but still required teacher guidance in several aspects of learning. They were generally able to understand and apply mathematical concepts but were less consistent in independently selecting strategies and evaluating their solutions.

Meanwhile, students with low SRL experienced greater difficulties, particularly in relating mathematical concepts to contextual situations and solving contextual problems. These students tended to require more direct assistance from the teacher during the learning process.

The findings suggest that students' SRL characteristics are closely associated with their ability to engage with mathematical concepts. Students who were better able to regulate their learning also tended to demonstrate stronger conceptual understanding.

Discussion

The findings indicate that students demonstrated different levels of Self-Regulated Learning, with the majority of students belonging to the moderate SRL category. Specifically, 33.33% of the students were categorized as having high SRL, 45.83% as having moderate SRL, and 20.84% as having low SRL. This distribution suggests

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that students possessed different capacities to manage and regulate their learning activities. Students with high SRL tended to demonstrate stronger learning management, including planning learning activities, monitoring their understanding, and reflecting on their learning outcomes. In contrast, students with low SRL required greater assistance in managing their learning independently.

These findings are consistent with the view of Zimmerman (2002), who describes self-regulated learning as an active process in which students regulate their cognition, motivation, behavior, and learning environment to achieve learning goals. Students who are able to regulate these aspects effectively are more likely to remain actively engaged in learning and monitor their progress. Pintrich and De Groot (1990) similarly emphasize the importance of motivational and self-regulatory components in students' academic performance. Thus, differences in SRL may help explain variations in students' responses to mathematics learning activities.

Smart TV-Integrated Learning and Mathematical Conceptual Understanding

The findings show that students demonstrated conceptual understanding across six indicators: stating concepts, identifying concepts, applying concepts, relating concepts, solving problems, and drawing conclusions. The use of Smart TV provided visual and multimedia representations that could support students in understanding the Pythagorean Theorem. Learning materials presented through videos, illustrations, animations, and examples enabled students to observe mathematical relationships in a more concrete and accessible form.

This finding is relevant to Mayer's (2009) Multimedia Learning Theory, which emphasizes that learning can be supported when information is presented through appropriately integrated verbal and visual representations. In the context of the Pythagorean Theorem, visual representations can help students recognize the relationship among the sides of a right triangle and connect symbolic formulas with geometric representations. Consequently, Smart TV can function as a supporting medium that enriches the representation of mathematical concepts during classroom instruction.

The findings also support the broader argument that digital technologies can provide opportunities for visualization and interaction in mathematics learning. Schindler et al. (2017) explain that digital technologies can contribute to mathematics education by providing students with opportunities to interact with mathematical representations and explore concepts in different forms. However, the contribution of Smart TV should not be viewed independently of the instructional process. The quality of teacher guidance, learning activities, and students' active engagement remains important in determining how effectively the technology is utilized.

Mathematical Conceptual Understanding Based on SRL Levels

Differences in conceptual understanding were particularly apparent when the findings were examined according to students' SRL levels. Students with high SRL demonstrated stronger performance across the six indicators. They were generally able to explain concepts, identify relevant mathematical information, select appropriate procedures, relate mathematical concepts to real-life situations, solve contextual problems, and formulate conclusions based on their solutions.

The stronger performance of students with high SRL may be associated with their ability to regulate the learning process. When solving a mathematical problem, students need to understand what is known and what is being asked, select an appropriate strategy, carry out the procedure, monitor the solution, and evaluate whether the answer is reasonable. These processes require students to actively monitor their own thinking. Students with stronger SRL are more likely to engage in such monitoring and evaluation.

The findings are consistent with Broadbent and Poon (2015), who emphasize the contribution of self-regulated learning strategies to students' academic achievement. Self-regulation enables learners to manage learning strategies, monitor progress, and adjust their approaches when difficulties arise. In mathematics, these abilities are particularly relevant because solving problems often requires students to identify errors, reconsider procedures, and determine whether a solution is consistent with the problem context.

Students with moderate SRL demonstrated adequate conceptual understanding but still experienced difficulties in several aspects. They were generally able to identify and apply the Pythagorean Theorem, but some required teacher guidance when selecting strategies, relating concepts to contextual situations, or evaluating their solutions. This suggests that students with moderate SRL may possess sufficient mathematical knowledge but do not always regulate the use of that knowledge independently.

Students with low SRL experienced greater difficulties, particularly in relating mathematical concepts to real-life situations and solving contextual problems. Their difficulties were not necessarily limited to knowing the formula but also involved determining how and when the formula should be applied. Some students tended to focus on obtaining numerical answers without sufficiently examining the meaning of the solution within the context of the problem.

This finding is important because mathematical conceptual understanding involves more than procedural knowledge. Hiebert and Lefevre (1986) explain that conceptual knowledge concerns relationships among pieces of knowledge, whereas procedural knowledge concerns knowledge of procedures or steps. A student may remember the Pythagorean formula but still experience difficulty applying it appropriately if the student does not understand the relationships represented by the formula. Therefore, the differences observed across SRL categories indicate that self-regulation may be particularly relevant when students are required to connect mathematical knowledge, select strategies, and evaluate solutions.

The Role of Self-Regulation in Technology-Supported Mathematics Learning

The findings further suggest that the availability of Smart TV does not automatically result in the same learning outcomes for all students. Students' ability to regulate their own learning appears to influence how they engage with and benefit from technology-supported instruction. Students with high SRL tended to be more active in processing the information presented through Smart TV and more capable of connecting the information with mathematical problem-solving activities.

In contrast, students with low SRL may require additional scaffolding and teacher support even when attractive and interactive digital media are available. This indicates that technology should be positioned as a learning support rather than a

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substitute for pedagogical guidance. Smart TV can provide richer representations of mathematical concepts, but students still need to actively process the information, formulate relationships, apply mathematical procedures, and reflect on their solutions.

Therefore, mathematics teachers should consider integrating digital media with activities that explicitly promote self-regulated learning. For example, teachers can encourage students to set learning goals before beginning an activity, monitor their understanding while solving problems, discuss alternative strategies, check their solutions, and reflect on the strategies they have used. Such activities can help students develop both conceptual understanding and self-regulation.

Overall, the findings indicate that Smart TV-integrated mathematics learning provides meaningful support for students' conceptual understanding, while the level of Self-Regulated Learning is an important characteristic associated with differences in students' learning processes and outcomes. The combination of appropriate digital media, teacher guidance, active student engagement, and self-regulated learning strategies may therefore create a more supportive environment for meaningful mathematics learning.

CONCLUSION

Based on the findings and discussion, it can be concluded that the students of SMP Negeri 1 Buntu Pepasan demonstrated different levels of Self-Regulated Learning (SRL), with the majority of students belonging to the moderate category. Students with high SRL demonstrated stronger abilities to manage their learning processes, including planning, monitoring, and evaluating their learning activities.

The implementation of mathematics learning integrated with Smart TV provided meaningful support for students' mathematical conceptual understanding of the Pythagorean Theorem. Students demonstrated conceptual understanding across six indicators, namely stating concepts, identifying concepts, applying concepts, relating concepts, solving problems, and drawing conclusions. The visual and multimedia representations provided through Smart TV helped students engage with mathematical concepts in a more concrete and contextual manner.

Students with high SRL demonstrated better conceptual understanding across the identified indicators. They were more capable of selecting appropriate strategies, applying mathematical concepts, relating concepts to real-life situations, and evaluating their solutions. Students with moderate SRL demonstrated adequate conceptual understanding but still required guidance in several aspects, while students with low SRL experienced greater difficulties, particularly in relating concepts and solving contextual problems.

These findings suggest that the use of digital learning media such as Smart TV can support mathematics learning when it is accompanied by appropriate instructional guidance and students' active engagement. In addition, the development of Self-Regulated Learning is important to help students make effective use of learning media and develop deeper mathematical conceptual understanding. Therefore, mathematics instruction should integrate innovative digital media with activities that encourage students to plan, monitor, and evaluate their own learning processes.

APPENDIX

Appendix 1. Self-Regulated Learning Questionnaire

The Self-Regulated Learning questionnaire was administered to 24 eighth-grade students to identify their level of self-regulated learning. The questionnaire focused on students' ability to plan, monitor, control, and evaluate their learning activities.

SRL Category	Number of Students	Percentage
High	8	33.33%
Moderate	11	45.83%
Low	5	20.84%
Total	**24**	**100%**

Appendix 2. Mathematical Conceptual Understanding Test

The mathematical conceptual understanding test focused on the Pythagorean Theorem. The test was developed to examine six indicators of students' conceptual understanding:

1. Stating mathematical concepts.
2. Identifying mathematical concepts.
3. Applying mathematical concepts.
4. Relating mathematical concepts to real-life situations.
5. Solving mathematical problems.
6. Drawing conclusions based on mathematical solutions.

Appendix 3. Interview Guidelines

The semi-structured interview was conducted to obtain deeper information about students' understanding and learning processes. The interview focused on:

1. Students' understanding of the Pythagorean Theorem.
2. Strategies used when solving mathematical problems.
3. Students' ability to explain the reasoning behind their answers.
4. Students' difficulties in applying the Pythagorean Theorem.
5. Students' ability to relate mathematical concepts to everyday situations.
6. Students' experiences when learning mathematics using Smart TV.
7. Students' strategies for monitoring and evaluating their own learning.

Appendix 4. Observation and Documentation

Observations were conducted during the Smart TV-integrated mathematics learning process. The observations focused on students' participation, attention, interaction, use of learning materials, problem-solving activities, and learning behaviors related to Self-Regulated Learning.

Documentation included photographs of learning activities, students' work, learning materials presented through Smart TV, and other relevant research documents used to support the findings.

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