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Learning Obstacles and Students' Difficulties in Solving the Problem of Pythagorean Theorem: A Systematic Literature Review

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Abstract: Pythagorean's theorem is a fundamental concept in mathematics that is widely used in various fields, including geometry, physics, and engineering. The ability to understand and apply these theorems is important in solving geometric problems and calculating distances or angles in real contexts. However, there are learning obstacles and difficulties for students in solving the problems of the Pythagorean theorem. This study aims to describe the learning obstacles and difficulties of students in solving Pythagorean theorem material through Systemic Literature Review (SLR). The article search strategy applies inclusion and exclusion criteria. The selection process was 19 selected articles using CASP checklist with articles coming from Google Scholar, Scopus, Springer Link, IEEE Explore, and PubMed databases. Based on the results of the study, it was obtained that students' learning obstacles came from epistemological obstacles, ontogenic obstacles, and didactical obstacles. The students' difficulties are dominated by conceptual difficulties. Learning obstacles cause learning difficulties. Studying students' learning obstacles and difficulties can assist a teacher identify student learning problems.

Keywords: learning difficulties, learning obstacles, pythagorean theorem, systematic literature review.

▪ INTRODUCTION

Pythagorean theorem is a fundamental concept in mathematics that is widely used in various fields, including geometry, physics, and engineering. The ability to understand and apply these theorems is important in solving geometric problems and calculating distances or angles in real contexts. The principles of the Pythagorean theorem have been applied to calculate the circumference of Mama Bhagne, one of the ancient geomorphocytes in West Bengal that has specific and unique geomorphic characteristics than the surrounding area (Datta & Sarkar, 2019). Since about 2010 the GML has been combined with the Gielis Transform (continuous), which provides a unifying description of geometric shapes, as a generalization of the Pythagorean theorem (Gielis et al., 2020). The Pythagorean theorem is complex for lines according to the total probability conditions of units, and can provide a way to solve the probability problems of Everettian quantum mechanics (Mandolesi, 2020). The teaching of science relies heavily on visual illustrations and visually organized tasks as methods of teaching and proofing concepts such as the Pythagorean theorem (Due, 2024). Therefore, the Pythagorean theorem is an important topic for students to learn.

Pythagorean theorem has an urgency for students to learn. However, there are many errors faced by students in solving the Pythagorean theorem, including problems that come from students where as many as 99% of students experience conceptual errors, as many as 66% experience procedural errors, and 82% experience computational errors, in solving Pythagorean theorem story problems (W. P. Sari et al., 2020). The research is strengthened by the results of the research (Rina & Bernard, 2021) which states that the most common errors found in students in solving problems of the Pythagorean theorem

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are conceptual errors. According to (Velria Jun et al., 2022) that the type of error that has the highest frequency is indicated at the stage of understanding, followed by the writing of the final answer and transformation. The errors made by the students show that there are difficulties in solving the problem of Pythagorean theorem.

Pythagorean theorem as a science is accepted by students through the process of diffusion. Diffusion of knowledge according to (Chevallard & Bosch, 2020) is a transposition of knowledge from scholarly knowledge to knowledge to be taught, then to taught knowledge and finally to learned knowledge received by students. In addition to the diffusion of knowledge, the thing that needs to be jastified as knowledge is the acquisition of knowledge. Knowledge acquisition according to (Brousseau, 2002a) including action situations, formulation, validation, and institutionalization. In the process of action, a concept image is formed by students. Concept images are made up of all the cognitive structures in an individual's mind that are connected to a particular idea (Jatisunda et al., 2021). If the learning situation is not relevant in helping students construct knowledge and present meaningful experiences, it will affect the student's concept image and cause learning obstacles. Therefore, it is important to examine the learning obstacles and difficulties of students in solving Pythagorean theorem problems. If students' learning obstacles and learning difficulties are not explored, then alternative solutions to overcome students' learning problems are difficult to obtain.

Research that examines the analysis of student errors in Pythagorean theorem topic has been carried out a lot, including a study of student errors in solving Pythagorean theorem through Systematic Literature Review (SLR) conducted by (Hadimiati et al., 2023). The research aimed to describe students' errors in understanding and applying the idea of the Pythagorean theorem. The method used was meta-analysis, the results of the study were in the form of the percentage of student errors found. In addition to the study of student errors, other research also examines the learning obstacles and difficulties experienced by students in solving the Pythagorean theorem. However, the previous study has not been carried out comprehensively through SLR. Therefore, the focus of this research is on what are the learning obstacles experienced by students in solving the Pythagorean theorem based on literature review, and how difficult are students in solving the Pythagorean theorem? What is the relationship between learning obstacles and students' difficulties in solving Pythagorean theorem problems? Using meta-synthesis, this study intends to describe the learning obstacles and difficulties of students in solving the problems of the Pythagorean theorem found empirically through SLR and to analyze the relationship between learning obstacles and difficulties of students in solving the problems of the Pythagorean theorem in selected articles so that they can be used as a reference in the next research.

▪ METHOD

This study aims to describe the learning obstacles and difficulties of students in solving Pythagorean theorem problems found empirically through SLR and to analyze the relationship between learning obstacles and students' difficulties in solving Pythagorean theorem problems in selected articles so that they can be used as a reference in the next research. Therefore, this study uses the SLR method that identifies, tests, researches, and investigates related research (Triandini et al., 2019). According to (Hossain et al., 2022) SLR is used to evaluate and interpret all existing research in a

particular research area with more authentic and verifiable sources that put together a more comprehensive and unbiased search. According to (Gusenbauer & Gauster, 2025), this study uses the SLR method which includes formulate the problems, develop and validate the review protocol, search the literature, screen for inclusion, assess quality, extract data, anylize and synthesize data, report findings.

Formulate The Problems

The first step before collecting data is formulate the problems, namely the research questions. The research questions are as follows: what are the learning obstacles experienced by students in solving the Pythagorean theorem based on literature review, and how difficult are students in solving the Pythagorean theorem? What is the relationship between learning obstacles and students' difficulties in solving Pythagorean theorem problems?

Develop and Validate The Review Protocol

To develop and validate the review protocol, several inclusion and exclusion criteria are used. According to (Memon et al., 2020) that SLR need to follow a comprehensive protocol in data collection. This criterion ensures only relevant articles will be reviewed further and is needed to improve review consistency and reduce researcher bias. In line with Memon et al. (2020), there is a need for a quality assessment criteria protocol to maintain the quality of SLR study results. Criteria are used to assess the quality of the selected studies because they assist researchers in identifying the strength of conclusions and assist researchers in selecting the most relevant research studies. The protocol used in this study includes inclusion and exclusion criteria.

Inclusion Criteria

The inclusion criteria used in this study include: articles published from 2014 to 2024. This year's range was chosen because it is to maintain the freshness of research data. The next inclusion criterion is related to the use of language in the articles. Publication languages using Indonesian or English to facilitate understanding. In addition to the year range and language, the next inclusion criteria are in the form of the type of publication in the form of articles, because the article is a secondary source of the most recent research results. The next inclusion criterion that is quite important is the method used in the article. Because this SLR aims to describe learning obstacles and difficulties in solving the Pythagorean theorem, the selected article is an article that uses qualitative, quantitative, or mixed methods. These methods allow researchers to find a description of students' learning obstacles and difficulties so that they are relevant to the research objectives. Related to the purpose of this study, the researcher also pays attention to the subject in the article, namely who experiences obstacles and difficulties in solving the Pythagorean theorem in the scope of education. Therefore, research subjects focusing on high school students. The last inclusion criteria are research topics focusing on students' learning obstacles and difficulties in Pythagorean theorem topic.

Exclusion Criteria

The exclusion criteria applied include: articles published before 2014 or after 2024, publication languages other than Indonesian and English, types of publications in the form of books, magazines, newspapers, or other than articles, methodologies used other than

qualitative, quantitative, and mix methods, research subjects in the form of students, teachers, or other than high school students, research topics that do not address learning obstacles and students' difficulties in solving problems of the Pythagorean theorem.

Search Literature

In the next step is search literature. It used the Google Scholar, Scopus, Springer Link, IEEE Explore, and PubMed databases using keywords "teorema Pythagoras", "Pythagorean theorem", "learning obstacle materi teorema Pythagoras", "learning obstacle of pythagorean theorem", "difficulties in Pythagorean theorem", and "Kesulitan belajar teorema Pythagoras". The choice of these keywords were based on the objective, namely describing the learning obstacles and difficulties in solving the Pythagorean theorem, and the keywords chosen are more specific than using learning obstacles or difficulties keyword. Based on the search results using these keywords, the number of articles is obtained as shown in Table 1 below.

Table 1. Number of articles based on search engine database

Databases	Quantity
Scopus	745
Google scholar	1266
Springer Link	123
IEEE Explore	263
PubMed	66
Total	2.463

Based on Table 1, it is obtained that the number of articles found in the google scholar database is 1266, and in the Scopus database is 745. Then, the number of articles found in the Springer Link database is 123 articles, IEEE Xplore database is 263 articles, and PubMed database is 66 articles. Therefore, the total number of articles found was 2.463.

Screen For Inclusion

At the identification stage, of the 2.463 articles from the Google Scholar, Scopus, IEEE Xplore, Springer Link and PubMed databases that were successfully collected, as many as 47 articles were not selected due to duplication. Then as many as 84 articles were not selected because the languages used included Spanish, German, Chinese, Norwegian, Russian, Polish, Portugues, Japanese, Italian, and Dutch. Furthermore, as many as 689 articles were not selected because they were not articles. In the next reduction stage, there is a screening process where only 1,643 articles are screened. Of these articles, as many as 115 articles did not use qualitative, quantitative, or mix methods. Therefore, there were 1,528 articles left. However, 1.069 articles involved subjects who were not high school students. Therefore, there were 435 articles left, and only 23 articles were in accordance with the research topic, namely learning obstacles and students' difficulties in solving the problems of the Pythagorean theorem. An overview of the selected articles is generally presented in the following Table 2.

Table 2. Selected articles and year of publication

Research Focus	Year of Publication	Number of Articles
Student learning obstacles	2015	1
	2019	1
	2021	1
	2022	2
	2024	2
Student learning difficulties	2017	1
	2018	1
	2019	1
	2020	3
	2021	1
	2022	3
	2023	3
	2024	3
Total		23

Based on Table 2, there are seven articles that focus on the topic of students' learning obstacles in the Pythagorean theorem, and there are 16 articles that focus on students' difficulties in solving the problems of the Pythagorean theorem.

Assess Quality

In the next stage, the researcher assessed the quality of the articles. Assessment includes the validity, reliability, and relevance of the research to the questions asked. Therefore, the researcher used Critical Appraisal Skills Programme (CASP) checklist. The criterias used according to CASP are as follows.

Table 3. The criterias based on CASP

Sections	Questions
Are the results valid?	Was there a clear statement of the aims of the research? Is a qualitative/quantitative methodology appropriate? Was the research design appropriate to address the aims of the research? Was the recruitment strategy appropriate to the aims of the research? Was the data collected in a way that addressed the research issue? Has the relationship between researcher and participants been adequately considered?
What are the results?	Have ethical issues been taken into consideration? Was the data analysis sufficiently rigorous? Is there a clear statement of findings?
Will the results help locally?	How valuable is the research?

Based on the criteria contained in Table 3, out of 23 articles, as many as 19 articles found the criteria according to CASP, with seven articles focusing on learning obstacles and 12 articles focusing on the difficulty of solving problems of the Pythagorean theorem. A total of four articles were not appropiate with the quality criteria, namely they had

research methods or designs that were not relevant to the research objectives, and the research design was not in accordance with scientific principles so that there was a potential for the research results to be biased. Therefore, there are only 19 articles that will be extracted and analyzed.

Researchers used flowcharts of PRISMA "(Preferred Reporting Items for Systematic Review and Meta-Analyses)" to make it easier to read the results of the article selection. Selection results of PRISMA, presented in Figure 1 as follows.

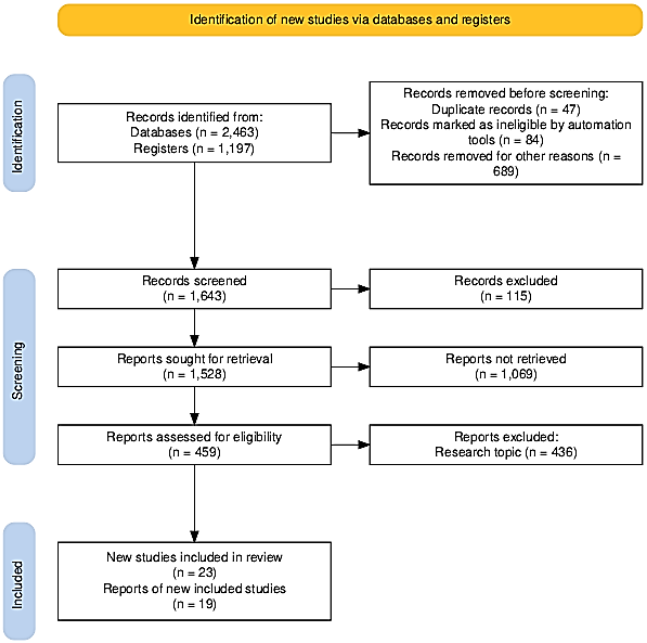

Figure 1. Result of *flowchart* of PRISMA On 2.463 articles

Data Extraction

Data extraction was carried out after the articles are selected. At this stage, the relevant data from each study was extracted. This data included information such as authors, journal, title, research methods and findings.

Data Analysis

The collected articles were presented in a table and then analyzed descriptively to answer research questions. Each research question was answered by analyzing related articles. In analyzing, according to (Memon et al., 2020) that there are several criteria in the analysis to maintain the quality of research results, namely the analysis of how the topic is relevant to the purpose of SLR research, in this case describing the learning obstacles and difficulties of students in completing the topic of the Pythagorean Theorem through SLR from previous studies. The next criterion is how the study represents the context of the research, how the research article describes the research methodology clearly, and how the clarity of the data collection procedure in the research, then how accurate the examples are in the data analysis process. This study used meta-synthesis, namely summarizing various qualitative research to present comprehensive facts (Siswanto, 2010). Meta-synthesis aims to combine findings from various qualitative studies that are interconnected. Unlike meta-analysis in quantitative research, its focus is

on interpretation rather than aggregation. Literature examples suggest that certain aspects of this approach are still evolving and not fully established (Walsh & Downe, 2005). In synthesizing articles, researchers use ATLAS.ti software which assists in reducing and categorizing the findings in the article so that a conclusion can be drawn. In Figure 2, the data analysis process is presented as follows.

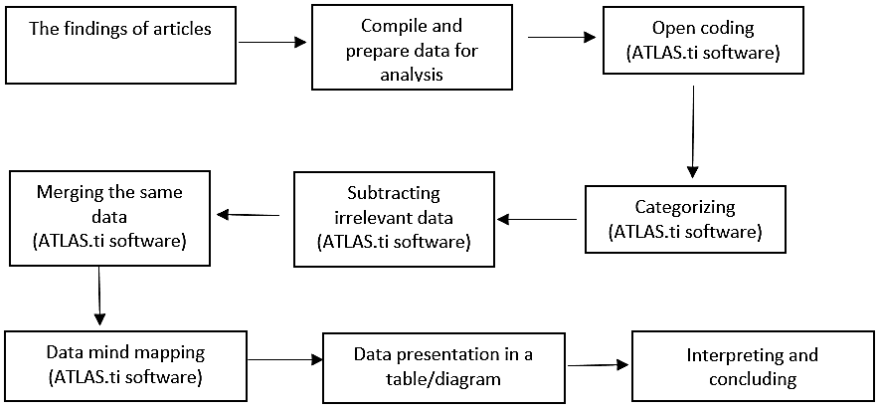

Figure 2. Process of data analysis

▪ RESULT AND DISSCUSSION

Learning Obstacles in Solving Pythagorean Theorem Problems

The following is data extraction of the research on learning obstacles in solving Pythagorean theorem problems as shown in Tables 4. The language in the title corresponds to the original language of the article title in the journal.

Table 4. Research results related to student learning obstacles

No.	Author	Journal	Title	Methods	Research Results
1	Hikmi, Prabawati, & Ratnaningsih, (2024)	Jurnal Penelitian Pembelajaran Matematika Sekolah (JP2MS)	Hypothetical learning trajectory (HLT) on mathematical reasoning ability in the Pythagorean theorem material	Qualitative	• Not understanding mathematical concepts presented in the form of story problems. • Unable to solve square root of problems. • Do not understand the prerequisite material. • Lack of motivation and readiness. • Lack of practice in class.
2	Ifada & Ruli, (2024)	PHI: Jurnal Pendidikan Matematika	Learning obstacles for junior high school students in the Pythagorean theorem material	Qualitative	• Ontogenic obstacle. • Didactical obstacle. • Epistemological obstacle.

3	Meika, Berliana, & Sartika, (2022)	Teorema: Teori dan Riset Matematika	Didactic design for junior high school (SMP) students' conceptual understandin g of the Pythagorean theorem material.	Qualitatitve	• Obstacles to understanding the concept of right triangles. • Obstacles in applying Pythagorean's theorem. • Obstacles in determining the type of triangle. • Obstacles in understanding the triple pythagoras.
4	Rahmi, Yulianti, & Prabawanto ,(2022)	AIP Conference Proceedings	Students' learning obstacles on the topic of pythagorean theorem	Qualitative	• Ontogenic obstacle. • Didactical obstacle. • Epistemological obstacle.
5	Sari & Fuadiah, (2021)	Jurnal Didaktis Indonesia	Learning obstacle, hypothetical desain hipotetik pembelajaran teorema pythagoras: hypothetical learning trajectory pembelajaran teorema Pythagoras	Qualitative	• Inability to complete addition and subtraction operations. • Not understanding the concept of flat building quadrilaterals and triangles. • Lack of thoroughness in determining the symbol of the calculation operation. • Not understanding the concept of the formula of the Pythagorean theorem. • Incorrect settlement procedure. • Disability to define formula.
6	Metikasari, (2019)	In Journal of Physics: Conference Series	Mathematics learning disabilities of the slow learner students on pythagorean theorem	Qualitative	• Could not do the procedure properly. • Difficulty in operating the algebraic form. • Disability in learning arithmetic facts. • Disability in using the principle. • Confused when the triangle was rotated.

7	Hutapea, Suryadi, & Nurlaelah, (2015)	Jurnal Pengajaran MIPA	Analysis of students' epistemological obstacles on the subject of pythagorean theorem	Qualitative	• Employ a short cut to solve problems without fully grasping the concept. • Recall a term without really understanding it • Struggle to solve problems involving implicit information. • Struggle to solve problems that call for visual aids. • Students don't like word problems and lengthy question problems.

Based on Table 4, there are seven articles that are relevant to the topic of student learning obstacles. The articles were published in 2015 and 2024. All of the articles use a qualitative approach, with data collection procedures in the form of tests and interviews. The pose that is carried out guarantees the accuracy of the data obtained because it uses data triangulation (Creswell, 2013).

From the findings of the research in Table 4, the results of reduction and categorization with ATLAS.ti software on these findings can be classified according to (Brousseau, 2002b) as follows table 5.

Table 5. Classification of learning obstacles in pythagorean theorem

No.	Types	Description	Reference
1	Epistemological obstacles	The epistemological obstacle is caused by previous students' knowledge that is not compatible with the learning carried out.	(Hikmi et al., 2024; Hutapea et al., 2015; Ifada & Ruli, 2024; Meika et al., 2022; Metikasari et al., 2019; Rahmi et al., 2022; H. P. Sari & Fuadiah, 2021)
2	Ontogenic obstacles	Ontogenic obstacles that are directly related to the student's condition, including lack of interest in mathematics, poor study habits, and low motivation to learn.	(Hikmi et al., 2024; Ifada & Ruli, 2024; Rahmi et al., 2022)
3	Didactic obstacles	Learning that does not pay attention to the stages of sequential thinking and knowledge heirarchy.	(Hikmi et al., 2024; Ifada & Ruli, 2024; Rahmi et al., 2022)

Referring to Table 5, there are three classifications of learning obstacles found. As many as 100% of the research found epistemological obstacles in classroom, Then 43% of the studies gave results of ontogenic obstacles and didactic obstacles respectively in classroom. Therefore, epistemological obstacles are the most common type of obstacle

encountered in the classroom. Epistemological obstacles can be found on students who not understanding mathematical concepts presented in the form of story problem, namely word problems (Hikmi et al., 2024; Hutapea et al., 2015). Students also unable to solve square root of problems. Bacause of the square root is the prerequisite material, so it shows that students do not understand the prerequisite material in Pythagorean theorem (Hikmi et al., 2024), and students do not understand the concept of right triangles (Hutapea et al., 2015; Ifada & Ruli, 2024; Meika et al., 2022; Metikasari et al., 2019; Rahmi et al., 2022; H. P. Sari & Fuadiah, 2021). It is in line according to (Agustin et al., 2024) that epistemological obstacles regarding students' inability to understand geometric concepts. In addition to concepts, students also have obstacles in applying the Pythagorean torema formula (Hutapea et al., 2015; Meika et al., 2022; Metikasari et al., 2019). Research by (Zapatera Llinares et al., 2024) that didactical obstacles, one of them is a frequently decontextualized teaching that gives priority to special topics and relegates the other topic, and also lack of practice in class, incoherent presentation of textbook material (Hikmi et al., 2024; Ifada & Ruli, 2024; Rahmi et al., 2022). Ontogenic obastacles can be found on students who lack of motivation and readiness (Hikmi et al., 2024; Ifada & Ruli, 2024; Rahmi et al., 2022). According to (Hendriyanto et al., 2024), that ontogenic obstacles is stemming from factors such as a lack of interest in mathematics. These are in accordance with the opinion (Brousseau, 2002a) that academic learning obstacles are related to three things, namely didactical obstacles, ontogenic obstacles, and epistemological obstacles. Therefore, based on the explanation mentioned above, it was obtained that students experienced learning obstacles in the form of didactical obstacles, ontogenic obstacles, and epistemological obstacles in solving Pythagorean theorem problems. The learning obstacles experienced by students cause students to have difficulties in solving problems of the Pythagorean theorem.

Students' Difficulties in Solving Problems of Pythagorean Theorem

The following is data extraction of the research on difficuties in solving Pythagorean theorem problems as shown in Tables 6. The language in the title corresponds to the original language of the article title in the journal.

Table 6. Research results related to student difficulties

No.	Author	Journal	Title	Methods	Research Results
1	Retnawati, (2020)	Journal of Physics: Conference Series"	Diagnosis of learning difficulties in mathematics for students resolving problems related to topic in the Pythagorean theorem for 8th-grade students in SMP 1	Qualitative	• Difficulties in a number of areas. • Difficulties in writing formulas, puzzles, and hints. • Difficulties in coming up with answers, going over them, and making conclusions. • Difficulties in applying the Pythagorean theorem to compute the square root of the results.

			Todanan and SMP Muhammadiyah 9 Todanan, academic year 2018/2019		• Difficulties in misplacing the formulae and techniques needed to complete the tasks. • Tended to speed through the challenges and were careless.
2	Sari, Anwar, Choirudin, Maghfiroh, & Hernawan, (2023)	Delta-Phi: Jurnal Pendidikan Matematika	*Analisis kesulitan belajar siswa pada materi teorema Phytagoras di sekolah berbasis pondok pesantren*	Qualilative	• Low interest in learning. • Tend to be uncaring. • Lacking enthusiasm, and unfocused • do not understand and unable to work in solving Pythagorean theorem.
3	Rudi, Suryadi, & Rosjanuardi, (2020)	MaPan: Jurnal Matematika dan Pembelajaran	Identifying students' difficulties in understanding and applying Pythagorean theorem with an onto-semiotic approach	Qualitative	• Difficulties in understanding definitions • Difficulties in explaining mathematical symbols or notations. • Difficulties in giving meaning to mathematical objects.
4	Khoerunnisa & Sari, (2021)	JPMI: Jurnal Pembelajaran Matematika Inovatif	*Analisis kesulitan siswa dalam menyelesaikan soal teorema Phytagoras"*	Qualitative	• Difficulties in understanding the concept of the Pythagorean theorem. • Difficulties in understanding problems. • Difficulties in answering questions related to the Pythagorean theorem.
5	Wulandari & Riajanto, (2020)	JRPIPM: Jurnal Riset Pendidikan dan Inovasi Pembelajaran Matematika	*Analisis kesulitan siswa SMP dalam menyelesaikan soal Materi teorema pythagoras*	Qualitative	• Difficulties in solving Pythagorean theorem. • Difficulties in understanding the problem 100%; difficulties in planning the completion of 40%; difficulties in implementing the plan 54.4%; and difficulty in re-checking 76.7%.

6	Irfan, Safaria, & Sangila, (2022)	Jurnal Ilmiah Pendidikan Matematika Al-Qalasadi	*Analisis kesulitan belajar matematika siswa konsep teorema pythagoras ditinjau dari gaya belajar*	Qualitative	• Difficulties in arithmetic, • Difficulties in transferring information, • Difficulties in visual perception.
7	Ritonga & Hasibuan, (2022)	Jurnal Cendekia: Jurnal Pendidikan Matematika	*Analisis kesulitan siswa dalam pembelajaran matematika materi teorema pythagoras ditinjau dari minat belajar siswa di SMP negeri 1 rantau utara*	Qualitative	• Difficulties in understanding concepts. • Difficulties in performing number operations. • Difficulties in solving verbal problems. • Difficulties in distinguishing symbols. • Difficulties in performing number operations. • Difficulties in giving unit name symbols to problems.
8	Handayani, Mashuri, & Rahmawati, (2022)	LAPLACE : Jurnal Pendidikan Matematika	*Analisis kesulitan siswa dalam menyelesaikan soal pythagoras*	Qualitative	• Difficulties in understanding the problem, • Difficulties in understanding the concept.
9	Ahmad, (2023)	ELIPS: Jurnal Pendidikan Matematika	*Analisis kesulitan dalam menyelesaikan soal-soal teorema phytagoras pada siswa*	Qualitative	• Difficulties in pouring out the completion procedure. • Difficulties in performing calculation operations. • Difficulties in understanding concepts. and unsupportive learning places.
10	Mulyanti, Yani, & Amelia, (2018)	JPMI: Jurnal Pembelajaran Matematika Inovatif	*Analisis kesulitan siswa dalam pemecahan masalah matematik siswa smp pada materi*	Qualitative	• Lack mastery of the concepts or prerequisite materials of phytagoras theorems and revivals. • Lack of meticulousness in calculations. • Lack of skills in relating problems between situations.

			teorema phytagoras		
11	Rachmawati, (2017)	JRAMathedu	An analysis of students difficulties in solving story based problems and its alternative solutions	Qualitative	• Difficulties in determining the direction of wind direction, • Difficulties in understanding the intent of the language that is understood about the story, • Difficulties in making a mathematical model • difficulties in calculating. • Difficulties in determining the drawing of wind direction.
12	Indrawati, Nuramilan, Amin, (2024)	Kognitif: Jurnal Riset HOTS Pendidikan Matematika	*Analisis kesulitan siswa dalam memecahkan masalah teorema pythagoras*	Qualitative	• Subjects with low level of category ability experience difficulties in implementing the plan.

Based on the information in Table 6, there are 12 articles discussing students' difficulties in solving the problem of the Pythagorean Theorem. The articles are relevant to the purpose of the research. The articles used a qualitative approach in their research. These studies identify and describe the difficulties of students in the process of solving problems of the Pythagorean theorem. The research also displays the problems of the Pythagorean theorem presented to students and displays examples of student answers. Based on the results of reduction and categorization using ATLAS.ti software, student difficulties can be classified into student difficulties based on mathematical objects, and student difficulties based on their errors.

Classification of Student Difficulties According to Mathematical Objects

Based on Table 4, it can be seen that some of the students' difficulties are that students are unable to solve problems related to mathematical objects, namely a lack of understanding of factual knowledge, procedures, concepts, and metacognition. According to (Anderson & Krathwohl, 2001) that knowledge of facts is related to terms, symbols, notations or things specifically related to a particular subject. Furthermore, procedural knowledge is related to procedures or stages in solving a problem. Then the difficulty of understanding the concept is related to the difficulty in understanding definitions, theories, categories, and classifications. The knowledge of metacognition is related to students' awareness in determining the best technique to solve a problem. This is related to the re-examination to ensure that the technique used is correct or not, and or

the application of the formula is appropriate or not. Regarding the students' difficulties in understanding the mathematical objects, the classification of students' difficulties is based on the mathematical objects as shown in Table 7.

Table 7. Summary of students' difficulties in pythagorean theorem

No.	Types of Difficulty	Description	Reference
1	Difficulty understanding factual knowledge	Students' difficulty in understanding terms, symbols, notations or things specifically related to a particular subject.	(Rudi et al. (2020); Sari et al. (2022); Ritonga & Hasibuan (2022))
2	Difficulty understanding procedural knowledge	Students' difficulty in understanding the procedures or stages in solving a problem.	(Retnawati (2020); Wulandari & Riajanto (2020); Khoerunnisa & Sari (2021); Handayani et al. (2022); Irfan et al. (2022); Ritonga & Hasibuan (2022); Ahmad (2023); dan Sari et al. (2023); Indrawati et al. (2024))
3	Difficulty understanding conceptual knowledge	Students' difficulty in understanding the definitions, theories, categories, and classifications of related materials.	(Rahmawati (2017); Mulyanti et al. (2018); Retnawati (2020); Rudi et al. (2020); Wulandari & Riajanto (2020); Khoerunnisa & Sari (2021); Handayani et al. (2022); Ritonga & Hasibuan (2022); Ahmad (2023); Nurmayunita et al. (2024))
4	Difficulty understanding metacognition knowledge	Students' difficulty in determining the best technique to solve a problem. This is related to the re-examination to ensure that the technique used is correct or not, and or the application of the right formula.	(Retnawati (2020); Hadimiati et al. (2023); dan Nurmayunita et al. (2024))

According to Table 7, as many as 18.75% of the articles contained students' difficulties in knowledge of facts, a total of 68.75% of the articles contained students' difficulties in procedural knowledge, as many as 75% of the articles contained students' difficulties in understanding concept knowledge, and as many as 25% of the articles contained students' difficulties in metacognition knowledge. This shows that students' difficulties in conceptual knowledge are the most common findings in the research. This happens because students do not know the definitions, theories, categories, and classifications of related materials. Indicators of students not understanding conceptual knowledge in the material of the Pythagorean theorem, one of which was revealed by (Hutapea et al., 2015) when students are given problems as shown in Figure 3 below.

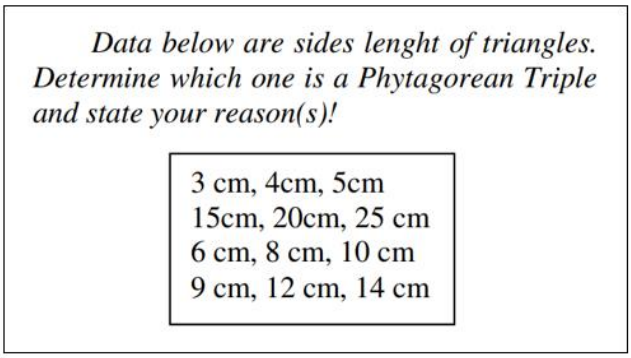

Figure 3. Question 1 in research from hutapea et al. (2015)

Based on Figure 3, students are asked to determine the long pairs of triangle sides which are the Pythagorean triples of several pairs of triangle side lengths. When students are given the question, the student is able to answer the question. However, when students were clarified through interviews, it turned out that students only memorized formulas $c^2 = a^2 + b^2$ without knowing the reason for writing the formula when solving the Pythagorean Theorem. Students find the answer through trial and error by trying to put each pair of numbers into the formula. This shows that students do not understand the definition of Pythagorean theorem. Students' difficulties in understanding definitions are also shown by the results of the research (Mulyanti et al., 2018) as shown in Figure 4 below. Then the indicators of students' difficulties in understanding concepts are also shown by (Rudi et al., 2020) as shown in Figure 5 as follows.

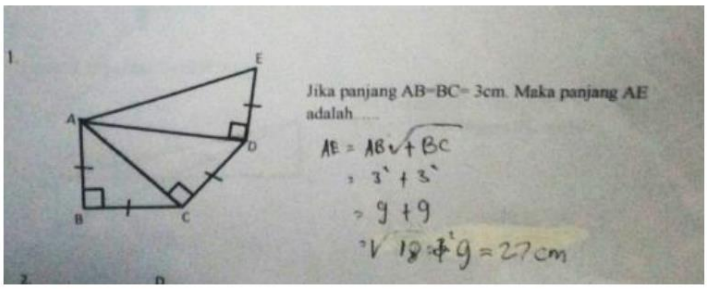

Figure 4. Questions and answers of students in research from mulyanti et al. (2018)

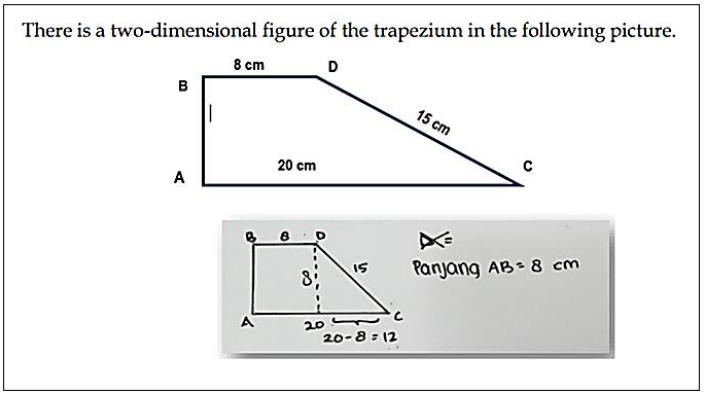

Figure 5. Questions and answers of students in research from Rudi et al. (2020)

Based on the problem in Figure 4, students are asked to determine the length of the AB line segment which is the high side of the trapezoid. In Figure 3 of the students' answers, it appears that the students are unable to solve the problem because they do not understand the application of the Pythagorean theorem formula to other topics, namely trapezoidal topic.

Classification of Student Difficulties According to Errors Made

In addition to being classified according to mathematical objects, the difficulties in learning mathematics faced by students are also classified according to their errors. Errors in solving mathematical problems in this study refer to the method of analyzing student errors according to Castolan theory and Newman's theory. In Table 8, a summary of the classification of students' difficulties is presented from their errors according to some of these methods.

Table 8. Types of student errors

No.	Types of Errors	Detail	References
1	Conceptual errors	Students are wrong in choosing or applying formulas so that the answers are not appropriate, students do not answer the questions correctly, and students do not do the questions. This type of error refers to the Castolan theory.	(Hutapea et al. (2015); Mulyanti et al. (2018); Retnawati (2020); Rudi et al. (2020); Wulandari & Riajanto (2020); Khoerunnisa & Sari (2021); Handayani et al. (2022); Ritonga & Hasibuan (2022); Ahmad (2023); Sari et al. (2023); Nurmayunita et al. (2024))
2	Procedural errors	Students do not complete the questions according to the requested steps, students do not complete the questions to the final stage or the simplest form, students do not write down the information that is known and asked, and students do not process the answers in order. This type of error refers to the Castolan theory.	(Retnawati (2020); Wulandari & Riajanto (2020); Khoerunnisa & Sari (2021); Handayani et al. (2022); Irfan et al. (2022); Ritonga & Hasibuan (2022); Ahmad (2023); dan Sari et al. (2023); Indrawati et al. (2024))
3	Technical errors	Students are wrong in counting, students are wrong in writing down signs in math, and students are wrong in writing constants, coefficients and variables. This type of error refers to the Castolan theory.	(Hutapea et al. (2015); Rudi et al. (2020); Sari et al. (2022); Ritonga & Hasibuan (2022); Mulyanti et al. (2018); Ahmad (2023); Irfan et al. (2022); Retnawati (2020))
4	Reading errors	Students cannot read the questions correctly, as well as when students cannot read mathematical symbols or	(Ritonga & Hasibuan (2022); Irfan et al. (2022); Khoerunnisa & Sari (2021); Sari et al. (2023))

		notations correctly. This falls into the category of error according to Newman's theory	
5	Misunderstood the problem	Students cannot mention what is known and what is asked by the question. This falls into the category of error according to Newman's theory	(Nurmayunita et al. (2024); Mulyanti et al. (2018); Ritonga & Hasibuan (2022); Wulandari & Riajanto (2020); Khoerunnisa & Sari (2021); Rudi et al. (2020); Hutapea et al. (2015); Sari et al. (2023); Retnawati (2020))
6	Transformation errors	Students cannot write or mention formulas or calculations that are in accordance with the question request. This falls into the category of error according to Newman's theory	(Nurmayunita et al. (2024); Ahmad (2023); Handayani et al. (2022); Ritonga & Hasibuan (2022); Irfan et al. (2022); Wulandari & Riajanto (2020); Khoerunnisa & Sari (2021); Rudi et al. (2020); Hutapea et al. (2015); Sari et al. (2023); Retnawati (2020))
7	Mistakes in process skills	Students cannot perform calculation operations or calculation steps precisely. This falls into the category of error according to Newman's theory	(Nurmayunita et al. (2024); Mulyanti et al. (2018); Ahmad (2023); Handayani et al. (2022); Ritonga & Hasibuan (2022); Irfan et al. (2022); Wulandari & Riajanto (2020); Khoerunnisa & Sari (2021); Hutapea et al. (2015); Sari et al. (2023); Retnawati (2020))
8	Errors in the final answer	Students are wrong or do not write the conclusion as the final answer to the question. This falls into the category of error according to Newman's theory	(Nurmayunita et al. (2024); Handayani et al. (2022); Ritonga & Hasibuan (2022); Wulandari & Riajanto (2020); Khoerunnisa & Sari (2021); Hutapea et al. (2015); Sari et al. (2023))

In accordance with Table 8, that student errors in the material of the Pythagorean Theorem reviewed from the Castolan theory are dominated by conceptual errors, characterized by the number of studies that produce findings in the form of conceptual errors. As for Newman's theory, then student errors are dominated by errors in transformation and errors in process skills.

The Link Between Learning Obstacles and Student Difficulties

The difficulties in completing the Pythagorean theorem topic experienced by students are caused by various factors. These factors include: students' carelessness in doing the questions (Puspitarani & Retnawati, 2020), lack of interest in learning and lack of focus, lack of understanding of symbols, lack of understanding of the application of formulas, lack of attention, unsupportive learning methods, impaired concentration, and less conducive learning places (Ahmad, 2023). The factors mentioned are part of the learning obstacles conveyed by (Brousseau, 2002b), namely epistemological obstacle,

ontogenic obstacle, and didactic obstacle. According to (Murniasih et al., 2024) that epistemological obstacles associated with obstacles in symbols representation, language representation, generalization, and intuitive. In line with (Zapatera Llinares et al., 2024) that the difficulties to differentiate the different meanings of the minus sign is the persistence of the epistemological obstacle. Therefore, students with these learning obstacles unable to understand the problems in Pythagorean theorem. It causes unable to solve the problems. Therefore, unovercome learning obstacles will cause students to have difficulties in solving problems with the Pythagorean theorem. The link between learning obstacles and students' difficulties in learning can be seen in the following Figure 6.

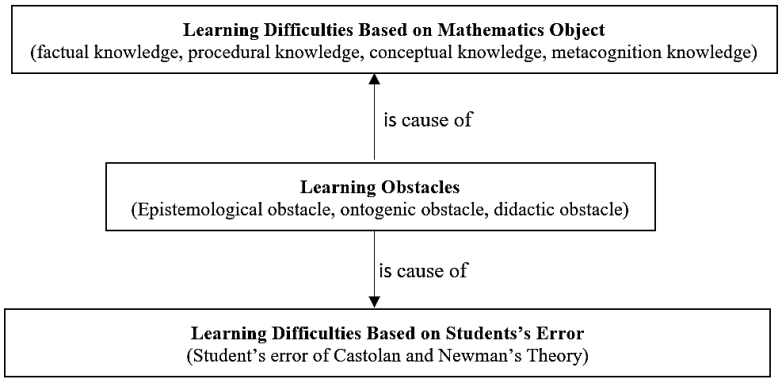

Figure 6. The link between learning obstacles and students' difficulties

Based on Figure 6, it can be seen that learning obstacles cause the difficulties based on mathematics object and the difficulties based on students's errors. According to Brousseau (2002) that the epistemological obstacle is caused by previous students' knowledge that is not compatible with the learning carried out. Therefore, there are obstacles in obtaining new knowledge and deviating from the expected mathematical reasoning on factual knowledge, procedural knowledge, conceptual knowledge, and metacognition knowledge, regarding students's errors based on Castolan and Newman's theory, namely students learning difficulties. Not only epistemological obstacles, but also ontogenic obstacles and didactic obstacle cause learning difficulties in classroom. Brousseau (2002) stated that ontogenic obstacles that are directly related to the student's condition, including lack of interest in mathematics, poor study habits, and low motivation to learn, all of which affect learning outcomes. Therefore, teachers must understand the students characteristic. By understanding it, teachers tend to obtain interested learning for students, for example teachers obtain visual or audio aids to support students skill in solving problem. Then, teachers use diverse instructional model for increasing students interest.

Didactic obstacle means learning that does not pay attention to the stages of sequential thinking and knowledge heirarchy (Brousseau, 2002). An ineffective learning process can interfere with the educational process because the structural and/or functional relationships between the situations developed are not always based on the results of the analysis of student characteristics. Teachers need to apply diverse instructional model in their classroom that appropiate with student characteristics. Differentiated instruction can be one of the alternative instructional model. This instructional model obtains what student need in learning process because it provides guidance for teachers in addressing

student differences in readiness, interest, and learning profile with the goal of maximizing the capacity of each learner (Tomlinson, 2017).

Understanding epistemological obstacles can assist a teacher in identifying and addressing students' misconceptions and numbers of didactical practices justified by the simply additive classical model must be reviewed (Maknun et al., 2022). Analyzing learning obstacles and students' difficulties in solving problems of the Pythagorean theorem through literature review can be a reference for teachers, one of which is in identifying the types of student difficulties in learning. Identifying learning obstacles and student difficulties can provide alternative solutions for students to overcome their learning problems.

▪ CONCLUSION

The learning obstacles experienced by students in solving Pythagorean theorem problems include epistemological obstacles, ontogenic obstacles, and didactical obstacles. This learning obstacles cause difficulties for students in solving problems, both difficulty in reviewing from the mathematical object, and difficulty in reviewing the error. The SLR results of all the studies described above state that the most dominant difficulty according to mathematical objects is difficulty in understanding concepts. As for if the review is based on students' errors in solving mathematics according to the Castolan theory, it is dominated by conceptual errors, and is dominated by errors in transformations and errors in the skills of the process of obedience according to Newman's theory. This happens because students have not mastered the concept of the Pythagorean theorem, and the concept of prerequisite material and are not precise in determining the formula used in solving problems related to the Pythagorean theorem. This research is expected to add research insights in the field of mathematics education, especially in examining students' difficulties in solving the problems of the Pythagorean theorem. Then, the results of this study are recommended for further research in the form of efforts to overcome student difficulties, namely research to develop theory-based diagnostic instruments to identify students' difficulties.

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