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The Essence of Students' Adaptive Reasoning Ability in Mathematics Learning: A Systematic Literature Review

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Abstract: Adaptive reasoning is an essential ability in learning mathematics, which helps students face challenges in problem-solving. This study aims to identify the essence of adaptive reasoning skills through a systematic literature analysis using the content analysis method of a number of articles published in Scopus and Sinta-accredited journals during the period 2013-2024. The main focus of this study was to explore research contributions related to adaptive reasoning, including year of publication, research subject, research design, methods, and learning approaches used, characteristics, and influencing factors. From a total of 66 articles, 19 publications met the inclusion and exclusion criteria after the screening process. After further analysis, 17 articles were selected as the primary sources in this study. Reporting of the study refers to the modified PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines as the standard for conducting systematic literature reviews. The authors highlighted, evaluated, and discussed the importance of the SLR approach in this study. The findings show that most of the studies used experimental designs (29.41%) and qualitative description investigations (23.53%), with the main focus on junior high school students (35.29%). Learning methods such as STEM, CPS, and PBL proved effective in improving adaptive reasoning skills. The results provide important insights into adaptive reasoning in mathematics learning, as well as the importance of innovative learning strategies to support its development.

Keywords: Adaptive reasoning, Mathematics learning, Systematic Analysis

Introduction

Adaptive reasoning is an important component of mathematical expertise, which plays a significant role in the learning process and students' ability to solve problems (Aziz et al., 2021; Yanti et al., 2020). Adaptive reasoning as described by Kilpatrick et al. (2013), is one of the main elements in mathematical proficiency. This concept includes strategic abilities and productive dispositions, focusing on the ability to think logically about relationships, situations, and concepts, and justify the conclusions drawn. Students' ability to think logically, reason, and justify problem-solving strategies is crucial for them to excel in mathematics (Yanti et al., 2020). As a basic ability in mathematics, reasoning is the focus of attention of educators and researchers because it has a major impact on students' overall mathematics performance (Sukirwan et al., 2018).

The importance of adaptive reasoning in mathematics education has been well documented. Reasoning ability enables students to understand the logical structure of mathematics, build confidence in their abilities, and effectively apply their knowledge to solve a variety of problems. Kilpatrick's research highlights the close relationship between adaptive reasoning and problem solving, where adaptive reasoning serves as a determinant

of the validity of problem solving strategies (Syukriani et al., 2017; Süß & Kretzschmar, 2018; Sternberg, 2021; Yanti et al., 2020). In addition, Kilpatrick, et al (2001) said that students' mathematical proficiency includes concept comprehension, procedural proficiency, strategic competence, adaptive reasoning, and a positive learning attitude. Among these components, adaptive reasoning has an important role. Adaptive reasoning is not only limited to deduction that produces conclusions, but also includes induction and intuition, using patterns, analogies, and metaphors as the basis for inference (Susilawatiet al., 2021), which is the glue that holds everything together, the reference star that guides learning (National Research Council, 2001).

Students who do not have adequate reasoning skills will have an impact on the limited mathematical proficiency they have (Stanford, 2022). This adaptive reasoning ability includes four main aspects: (1) explanation of specific problem components; (2) use of logical thinking in dealing with mathematical concepts; (3) construction of appropriate reasons; and (4) reflection on the resulting mathematical concepts (Kilpatrick, Swafford & Findell, 2001; Maoto, Masha & Mokwana, 2018). Students who have good adaptive reasoning skills will have a great impact during problem solving, although students utilize strategic competencies to formulate and represent problems, using heuristic approaches that can provide solution strategies, but adaptive reasoning will take over when students determine the validity of the strategies used (Kilpatrick et al., 2001).

Additionally, the *Programme for International Student Assessment* (PISA) has recognized reasoning as one of the essential mathematical abilities that should be a strategic focus in the future (Permatasari et al., 2020; Sukirwan et al, 2018). However, reports indicate that the level of mathematical reasoning achievement among junior secondary school students is very low, with research revealing that only a small proportion of students are able to demonstrate proficient reasoning skills (Sukirwan et al., 2018; Fisher et al., 2019; Sahara et al., 2021; Wu et al., 2023; Mullis et al., 2016).

The low level of reasoning skills possessed by students resulted in Indonesia being ranked in TIMSS 2015 for mathematics skills, with students' abilities still in the domains of "knowing" and "applying" or low-level thinking skills (Mullis et al., 2016). One of the factors that causes students to lack adaptive ability is the learning method. Shadiq (Muhammad et al., 2020) said that mathematics teaching in Indonesia is still often "mechanistic," emphasizing memorization and recall rather than reasoning, problem solving, or contextual awareness. Current approaches to learning mathematics tend to pay less attention to developing students' adaptive abilities (Clark et al., 2021). Learning tends to be result-oriented, such as test scores, thus ignoring students' thinking processes in solving problems. As a result, students are less trained to deal with dynamic and complex mathematical situations. This deficiency can reduce the effectiveness of the system in supporting the learning process and student achievement (Richey et al., 2020)

To address this problem, a systematic literature review is needed to identify the essence of adaptive reasoning skills in mathematics learning. By understanding the essence of adaptive reasoning, teachers can design more effective and relevant learning strategies to improve adaptive reasoning skills in mathematics learning. This study aims to explore the characteristics of students' adaptive reasoning ability, he elements that impact the growth of adaptive reasoning ability in mathematics learning, explore effective learning methods and approaches in developing students' adaptive reasoning ability, research methods used to analyze students' adaptive reasoning ability, and identify contributing research, as well as the year of publication that conducted research related to adaptive reasoning.

There are six research questions on which the study was based: (1) Research that contributes very actively in the field of adaptive reasoning?, (2) The year of the most publications related to adaptive reasoning?, (3) The subject of research related to adaptive reasoning?, (4) What research designs are often used in adaptive reasoning research?, (5) characteristics of adaptive reasoning skills in mathematics learning according to the latest literature?, (6) What methods and approaches are effective for improving students' adaptive reasoning skills in the context of mathematics learning?, and (7) What factors influence the development of students' adaptive reasoning skills in mathematics learning. This study is expected to contribute to the development of more innovative and contextualized theories and practices of mathematics learning.

Method

The data used in SLR research consists of a *research question*, *search process*, *define inclusion and exclusion criteria*, quality of research (*define the quality assessment QA) checklist*), data *collection*, *data analysis*, *deviations from protocol* (Triandini, et al. 2019, pp. 65-67, Carrera-Rivera, et al. 2022) with the following provisions:

Research Question

One possible way to assist in providing an overview of coverage in SLR is to use the PICOC method as shown in Table 1.

Table 1. PICOC (Population, ıntervention, comparison, outcome, and context)

Population (P)	Students, College Students, and Teachers
Intervensi (I)	learning strategies, approaches, or methods used to develop students' adaptive reasoning skills.
Comparison (C)	A comparison between students who received a particular intervention or learning approach and students who did not receive the intervention (control) or used a traditional learning approach.
Outcomes (O)	Students' ability in terms of adaptive reasoning, which is the ability of students to adjust their thinking according to different contexts or situations. Other contextual variables, such as individual user characteristics (age, educational background)
Context (C)	Research design used to investigate students' adaptive reasoning skills (methods, measurement instruments, and data analysis used)

The research questions (or research questions) to be answered in this SLR are organized in the form of a table or list, as in Table 2.

Table 2. Research question

ID	Research Question	Motivation/purpose/benefit
RQ1	Research that contributes very actively to the field of adaptive reasoning research?	Identifies the most active and influential researchers who contribute greatly to the field of adaptive reasoning research.
RQ2	Year of the most publications related to adaptive reasoning?	Identify the most published years related to adaptive reasoning.
RQ3	Research subjects related to adaptive reasoning?	Identify and analyze the various subjects or topics researched in the context of using digital tools for teaching and learning geometry.
RQ4	What research designs are often used in adaptive reasoning research?	Identify the most common research designs in adaptive reasoning research.
RQ5	Characteristics of adaptive reasoning skills in mathematics learning according to current literature.	Develop a comprehensive understanding of the concepts and characteristics of adaptive reasoning relevant to mathematics learning.
RQ6	Characteristics of adaptive reasoning skills in mathematics learning according to current literature.	Develop a comprehensive understanding of the concepts and characteristics of adaptive reasoning relevant to mathematics learning.
RQ7	What factors affect students' adaptive reasoning skills in learning Mathematics	Identify internal (such as motivation and self-confidence) and external (such as teaching methods and environmental support) factors that influence adaptive reasoning ability.

Search Process

First, we discuss the title for this SLR. With the development of the world, various new discoveries in the field of Education began to emerge. Therefore, we chose to explore the essence of students' adaptive reasoning ability in learning mathematics. To conduct this review, relevant keywords from the title, abstract and corresponding ones were identified, i.e. the essence of students' adaptive reasoning ability in mathematics learning. The keywords were then combined using the Boolean operators "OR" and "AND" to form a search string that was used in the identification process as part of the literature search strategy. Details of this search strategy can be seen in Table 3.

Table 3. Search keywords

Database/Search Result	Keyword String
Scopus	"Adaptive Reasoning" AND "Mathematics"
Dimensions	"Adaptive Reasoning" AND "Mathematics"

The identification stage began by searching for relevant articles to review. The search process was conducted through Scopus using the keywords listed in Table 3, namely ("adaptive reasoning" AND "mathematics"), the search then continued through Dimensions using the same keywords. At this stage, the keywords were only used to count the number of results from each search engine. The search results identified 12 articles from Scopus and 54 articles from Dimensions. The last search process was conducted on November 9, 2024, which will then be filtered further. The PRISMA protocol workflow is depicted in Figure 1.

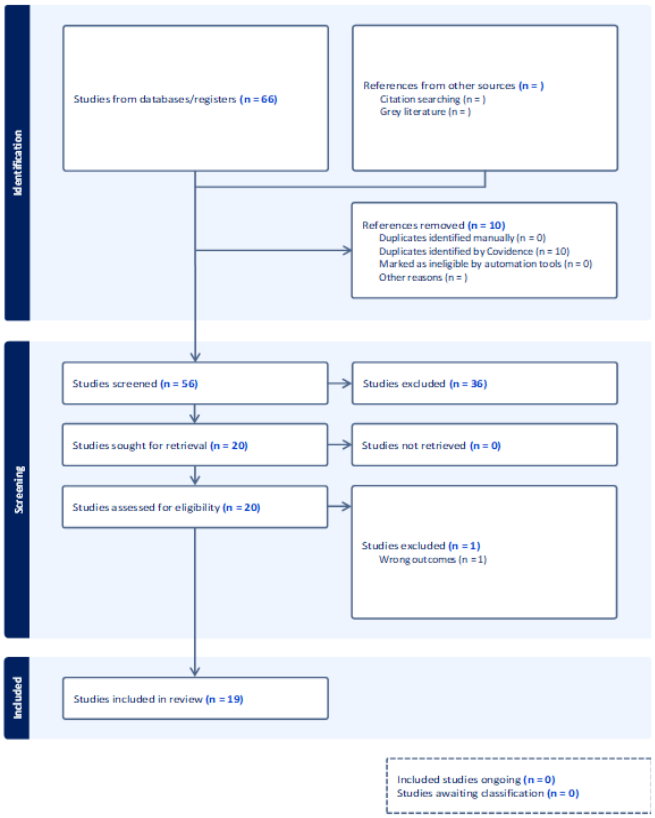

Figure 1. Export PRISMA data

Inclusion and Exclusion Criteria

Table 4. Selection criteria (inclusion and exclusion)

Inclusion criteria	1. The article used is only the essence of students' adaptive reasoning ability in learning mathematics. 2. Journal studies only to be included 3. Articles published in 2013-2024 4. Articles written in English
Inclusion (exclusion) criteria	1. Articles that do not use the essence of students' adaptive reasoning skills in mathematics learning 2. In addition to journal studies 3. Articles published outside of 2013-2024 4. Articles not written in English

The filtering stage begins with removing duplicates from the identification results. From the results obtained, 10 articles were found to be duplicates and removed using the PRISMA protocol flowchart. Next, the data was selected based on several criteria, namely article title, publication year, document type, language and article accessibility. The title of the article must be in accordance with the research topic, namely the essence of

students' adaptive reasoning skills in learning mathematics. The year of publication was limited to between 2013 and 2024 to ensure the relevance and novelty of the research, given the rapid advancement of technology. The document type selected was an original study published in a scientific journal. The language used was limited to English to maintain research consistency, while accessibility was limited to full-text articles which are freely available. The screening process was conducted through each search engine, with details of the inclusion and exclusion criteria listed in Table 4.

The primary study selection process was conducted through two stages of screening. In the first stage, only the titles and abstracts of the studies were reviewed. Subsequently, in the second stage, the passing studies were studied in depth through full-text reading. In both stages, an inclusion approach was applied to prevent premature exclusion of studies. In other words, if there is any doubt about a study, it will still be included in the selection.

Research *Quality* (*Quality Assessment*)

The data obtained from the SLR research will be analyzed using quality assessment criteria, which include the following aspects:

Table 5. Research *quality* (*quality assessment*)

ID	Question Quality Assessment Criteria
QA1	Were journal articles published in 2013-2024
QA2	Does the journal article include information used for the essence of students' adaptive reasoning skills in mathematics learning?

For each question, quality assessment criteria will be used to evaluate each selected journal paper.

a. Y (Yes): for journal articles that meet the quality assessment criteria.
b. T (No): for journal articles that do not meet the quality assessment criteria.

Data Analysis

At this stage, the data that has been collected will be analyzed to show:

1. Students' adaptive reasoning ability in mathematics learning (RQ1 & RQ2).
2. Adaptive reasoning characteristic of literature sources (RQ5).
3. Classify research based on education level and analyze the pattern of development of adaptive reasoning skills at each level, as well as the research methods used (RQ3 & RQ4).
4. Learning methods and approaches used to improve adaptive reasoning skills (RQ6)
5. Internal and external factors that influence adaptive reasoning (RQ7)

Report Deviation (*Deviation From Protocol*)

After the Evaluation, the author documented modifications that related to deviations from the protocol.

1. This study identifies the essence of students' adaptive reasoning ability in mathematics learning and responds to the research questions.
2. Collect scientific publications to answer questions, guarantee excellence, and provide necessary data.
3. This research aims to provide a more comprehensive picture of the essence of students' adaptive reasoning skills in learning mathematics.

Results and Discussion

In the results and discussion section, there are 7 main questions analyzed as the focus of research using the Systematic Literature Review approach. The following presents an overview of the results based on these research questions.

Contributing Research

Based on the results of Export PRISMA data using *Covidence*, there are 17 articles that match the keywords of this study. As shown in Table 6 below.

Table 6. Most active researchers related to adaptive reasoning

No	Article title	Autor First	Second author onwards	Excerpt
1	Mathematics Instructional Package Based on Creative Problem Solving to Improve Adaptive Reasoning Ability and Creative Thinking Ability	Wasiran	Andinasari	3
2	The effect of problem posing and problem solving with a realistic mathematics education approach to the conceptual understanding and adaptive reasoning	Mahendra	Slamet & Budiyono	1
3	Effective teaching practices from the perspective of Kilpatrick, Swafford and Findell's (2001) model: A video-based case study analysis of the teaching of geometry in Namibia	Stephanus	-	
4	Colleges of Education Students' Mathematics Proficiency: Assessing Strategic Competency and Adaptive Reasoning during Supported Teaching in Schools	Baah-Duodu	John, Amoaddai, Gyamfi & Ndamenenu	39
5	Exploratory Analysis on Adaptive Reasoning of Undergraduate Student in Statistical Inference	Lestari	Utami & Yudhanegara	5
6	The Effectiveness of Learning Mathematics according to the STEM Approach in Developing the Mathematical Proficiency of Second Graders of the Intermediate School	Elsayed	-	2
7	Application of Problem-Based Learning Approaches With Probing-Prompting Techniques to Improve Students' Adaptive Reasoning Capabilities	Gardenia	Herman, Rahadyan & Dahlan	
8	Enhancing Adaptive Reasoning Ability In Senior High School Students Using The Guided Inquiry Method: A Quasi-Experimental Study	Jatisunda	Nahdi, Cahyaningsih & Rasyid,	
9	Adaptive reasoning and strategic competence through the problem-based learning model in middle school	Darwani	Zubainur & Saminan	5
10	Adaptive Reasoning Characteristics of Vocational School Students in Solving Mathematical Problems	Afifah	Syauqy & Nafián	
11	Adaptive Reasoning Based on Microsoft Mathematics	Susilawati	Rachmawati & Nuraida	
12	Students' Adaptive Reasoning in Solving Pythagoras Theorem Problems Viewed by Gender	Fitri	Prabawanto & Mulyaning,	
13	Investigating Adaptive Reasoning and Strategic Competence: Difference Male and Female	Syukriani	Juniati & Siswono	1
14	Adaptive Reasoning, Mathematical Problem Solving and Cognitive Styles	Yanti	Budayasa & Sulaiman	
15	The use of creative problem solving model to develop students' adaptive reasoning ability: Inductive, deductive, and intuitive	Ansari	Taufiq & Saminan	12
16	Exploring students' adaptive reasoning skills and van Hiele levels of geometric thinking: A case study in geometry	Rizki	Frentika & Wijaya	8
17	Analysis of Students' Adaptive Reasoning Ability in Solving HOTS Problems Arithmetic Sequences and Series in Terms of Learning Style	Darmayanti	Sugianto, Muhammad& Santiago	

Table 6 shows that article number 4 has the highest number of citations, with 39 citations. Furthermore, the article with the second highest number of citations, namely 12 citations, is in number 15, while the article with the third highest number of citations is in number 16. These articles can be used as the main reference for further research related to the essence of adaptive reasoning.

Adaptive reasoning ability is an important aspect in learning mathematics, both for students and college students. The three articles illustrate that this ability is influenced by various factors, one of which is the learning approach used. Baah-Duodu et al. (2022) revealed that prospective teachers showed higher mastery in strategic competencies than adaptive reasoning skills related to the mathematics content they would teach. This suggests a challenge in preparing prospective teachers to have optimal adaptive reasoning skills.

Learning methods are key in developing students' adaptive reasoning skills. Ansari et al. (2020) found that the CPS (Creative Problem Solving) learning model effectively improved students' adaptive reasoning skills, especially in the indicators of making predictions and drawing conclusions. This is supported by the expression of Muin et al (Stanford, 2022) saying that he creative problem-solving learning model can enhance students' mathematical adaptive reasoning skills, making it a viable alternative for teachers to apply in mathematics instruction. In addition, Rizki et al. (2018) showed that the Knisley Learning Model (KLM) provides more significant results than the traditional expository method in developing students' adaptive reasoning skills. The effectiveness of the CPS and KLM methods shows that innovative learning strategies that encourage students to think creatively, analytically, and reflectively can improve their overall cognitive abilities, including adaptive reasoning. It is important to create learning that focuses not only on concept mastery but also on the development of higher-order thinking skills.

Year of Article Publication

The number of article publications reflects the frequency of research conducted over a period of time as shown in Figure 2 below.

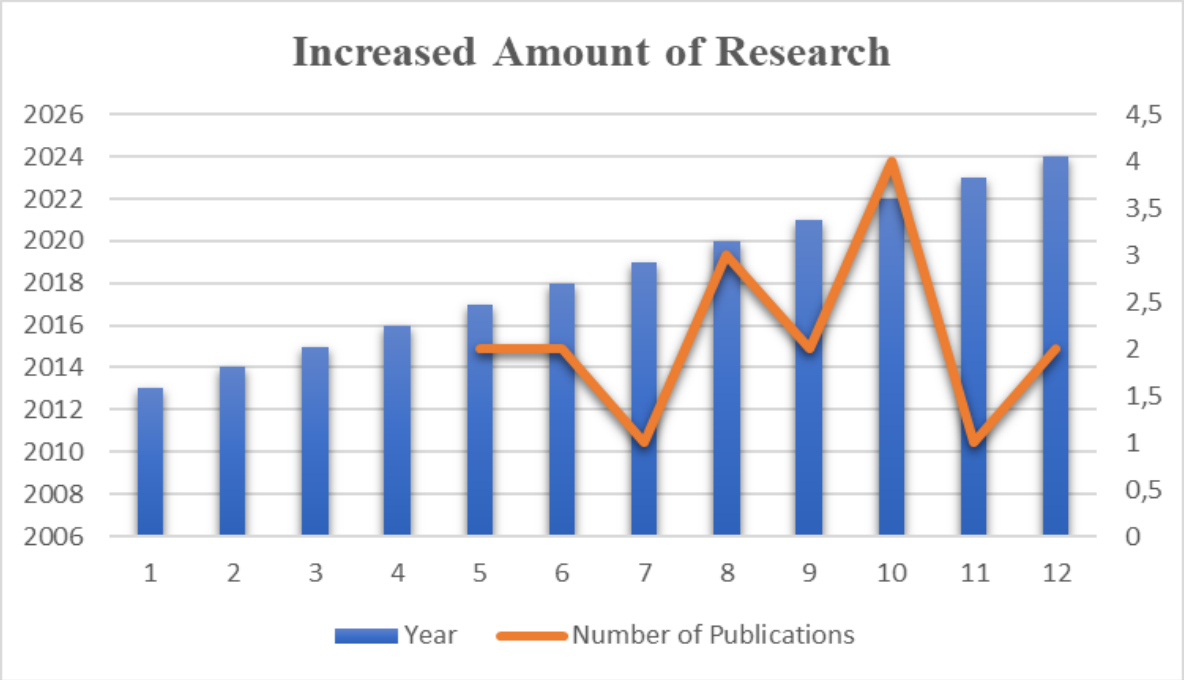

Figure 2. Trend of increase in number of research on adaptive reasoning ability in mathematics learning

Based on Figure 2, there is an increasing trend in the number of studies on adaptive reasoning skills in mathematics learning from year to year. The graph shows that since 2013, the number of publications has tended to increase compared to previous years. This indicates that attention to the topic of adaptive reasoning skills is growing, along with the increasing need to understand and develop higher-order thinking skills in students in mathematics learning.

This increase in the number of studies also reflects the importance of adaptive reasoning skills as one of the crucial cognitive aspects in mathematics education. The research conducted is not only to understand the ability of students and college students in applying adaptive reasoning but also to explore effective learning methods, such as CPS (Creative Problem Solving) and KLM (Knisley Learning Model), which are proven to support the development of adaptive reasoning skills. Overall, this graph shows that there is an increasing awareness among researchers and educational practitioners about the importance of integrating adaptive reasoning into the mathematics learning process so that it has a positive impact on students' mastery of concepts and skills.

Research Subject

Research subjects refer to elements or individuals who are the center of attention or the main target in a study. Their role is very crucial because the data obtained in the research comes from these subjects. Figure 2 shows the distribution of research subjects, especially related to the study of adaptive reasoning skills in mathematics learning.

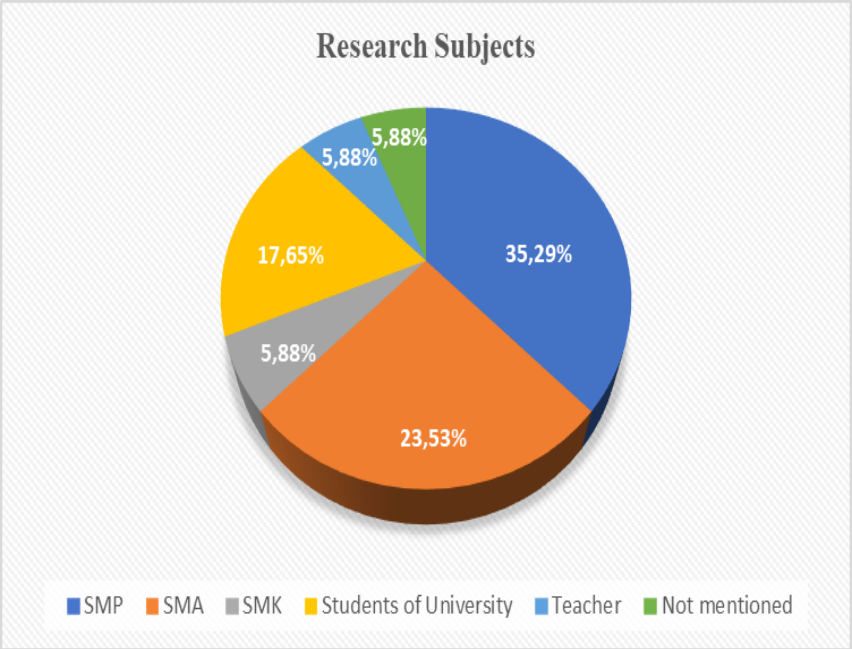

Figure 3. Distribution of research subjects on adaptive reasoning ability in mathematics learning

Based on Figure 3, the distribution of research subjects related to adaptive reasoning skills in mathematics learning shows that most of the research was conducted on junior high school students, which amounted to 35.29%. This shows greater attention to the development of adaptive reasoning skills at the junior high school level, which is an important phase in the formation of basic critical and adaptive thinking skills. Research on high school subjects ranks second with a percentage of 23.53%, followed by university students at 17.65%.

Meanwhile, SMK subjects and teachers each have the same percentage, which is 5.88%. In addition, there were 5.88% of research subjects that were not specifically mentioned. This distribution reflects that most of the research on adaptive reasoning focuses on students (junior high school, high school, and university students), with a much smaller portion allocated to teachers. The role of teachers is very important in developing students' adaptive reasoning skills through effective learning methods.

Research Design

Research design is very important in a study because it serves as a map or plan that determines how the research will be carried out. A good research design will affect the quality, validity, and relevance of the research results. Figure 3 shows the distribution of research designs used in the study of adaptive reasoning skills in mathematics learning.

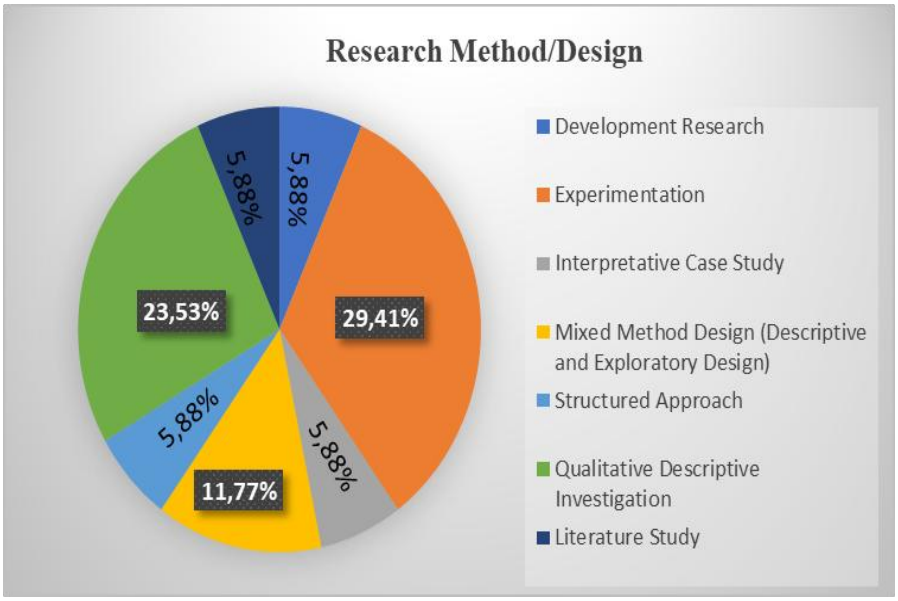

Figure 4. Distribution of research design for adaptive reasoning ability in mathematics learning

Based on Figure 4, the distribution of research designs related to adaptive reasoning skills in mathematics learning shows that experimental designs are the most frequently used (29.41%), indicating a high focus on testing the effectiveness of certain learning methods. Qualitative descriptive investigations were also quite widely used (23.53%), reflecting the need to understand the phenomenon of adaptive reasoning in depth. However, developmental research designs, literature studies, structured approaches, and interpretative case studies are still relatively few, with only 5.88% each. *Mixed-method* designs are increasingly being applied due to their ability to combine quantitative and qualitative data to produce more comprehensive findings. Ahmed, A. et al. (2024) state that by combining qualitative and quantitative data, researchers can explore a broad scope of phenomena (quantitative) while exploring the human experience (qualitative). Halcomb (2018) adds that mixed methods research aims to integrate data to reveal richer insights, which are difficult to achieve if only one approach is used separately.

Characteristics of Adaptive Reasoning

From the 17 articles analyzed, various characteristics were found that reflect the essence of adaptive reasoning in mathematics learning. These characteristics can be grouped into several main aspects, as shown in Table 7, based on the frequency and focus of each study.

Table 7. Grouping of adaptive reasoning characteristics

Group of Characteristics	Main Characteristics
Logical thinking	Logical explanation, drawing conclusions, the validity of arguments, testing, and pattern recognition
Problem-solving ability	Systematic problem solving, Solution flexibility, non-routine based task completion
Reflection and justification	Reflective practice, method justification, and Solution evaluation
Integration with other competencies	Critical thinking, strategic competence, and scientific literacy
Development and application	Development through experience, knowledge application, and improvement through instruction
Creativity and intuition	Inductive and deductive reasoning, pattern recognition, intuition in task completion

Adaptive reasoning is a cognitive and complex ability that covers a wide range of aspects, from logical thinking to creative application. These characteristics develop through experience, practice, and appropriate learning methods (Kilpatrick et al., 2013). A thorough grasp of these concepts' characteristics can assist teachers and researchers in designing strategies to improve students' adaptive reasoning abilities (Goldstone et al., 2017).

Learning Methods and Approaches

Learning methods and approaches are needed in improving students' cognitive abilities because the right method can affect the way students understand, manage, and remember information. In the context of adaptive reasoning, cognitive ability relates to the cognitive processes involved in learning, including attention, memory, problem-solving, decision-making, and critical thinking. Figure 4 is the distribution of methods or approaches used to improve students' adaptive reasoning skills based on the analysis of 17 articles.

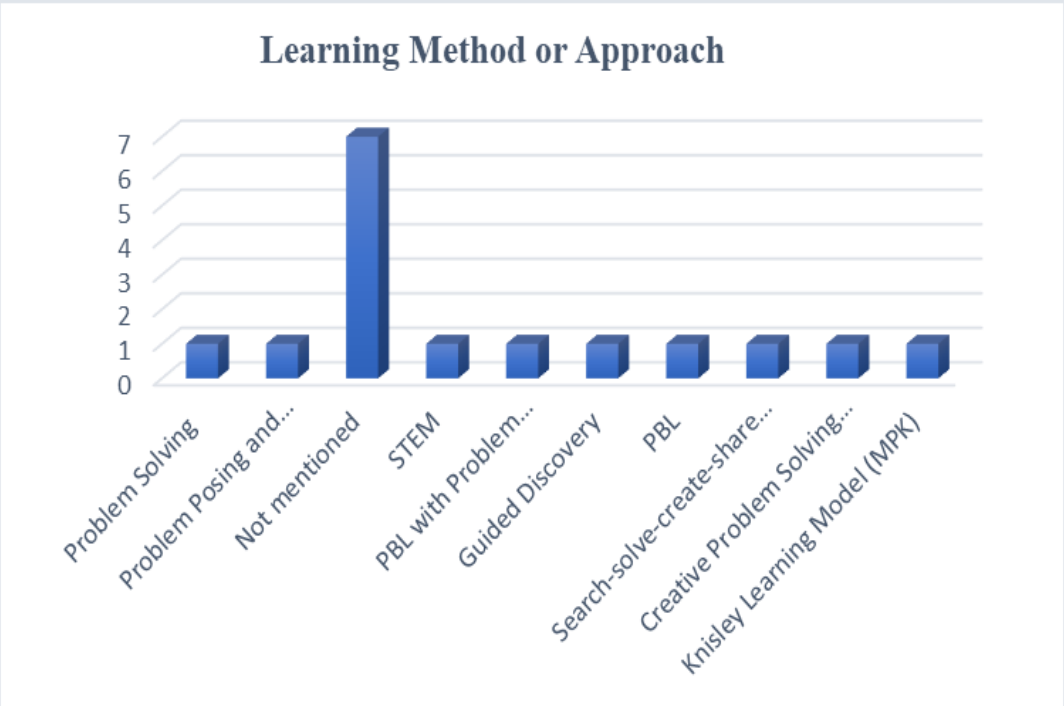

Figure 4. Distribution of adaptive reasoning ability research in mathematics learning based on learning model or approach

The distribution of research shows that various learning methods and approaches have been explored to improve students' adaptive reasoning ability. However, the majority of studies (7 out of 17) did not mention the methods used, indicating the need for more detailed exploration and reporting in future research. Approaches such as CPS, MPK, and STEM look promising in developing students' adaptive reasoning skills, while other methods, such as problem solving and PBL with its variations, continue to contribute to mathematics teaching.

As stated by Stanford (2022), teaching approaches like the creative problem-solving model and the problem-based learning model can be utilized to foster the growth of adaptive reasoning in mathematics classrooms. This is confirmed by the results of research conducted by Samuelsson (2010), which states that teachers who teach with a problem-solving approach significantly improve students' adaptive reasoning skills. In addition to the problem-solving approach, the STEM approach can also significantly improve students' adaptive reasoning skills (Elsayed, 2022).

Factors Affecting Adaptive Reasoning Ability

Adaptive reasoning ability is one of the important skills in mathematics learning that supports students to think logically, flexibly, and creatively in dealing with various types of problems. This ability not only helps students solve problems effectively, but also prepares them to adapt to challenges in the dynamic and complex real world. However, the development of adaptive reasoning is influenced by various factors, both in terms of learning methods, learning environment, and individual student characteristics. Therefore, understanding these factors becomes very important for educators to design strategies that can support the improvement of students' adaptive reasoning skills optimally. Below are a number of factors that influence adaptive reasoning, which have been identified from 17 articles and grouped by category.

Table 8. Groups of factors ınfluencing adaptive reasoning

Category	Factors
Learning Method and Model	Creative Problem Solving (CPS), STEM approach, problem-based learning (PBL), Knisley Learning Model (KLM), problem prompting, and structured instructional scaffolding.
Learning Environment	Problem-solving challenges, habituation of logical reasoning, peer interaction, a comfortable classroom atmosphere, and a supportive learning climate.
Basic Skills and Conceptual Understanding	Prior knowledge, conceptual understanding, contextual relevance, task comprehension, measurement skills, and understanding of adaptive reasoning indicators.
Motivation and Engagement	Meaningful and contextualized tasks, active student engagement, and students' learning motivation.
Cognitive and Personality Factors	Cognitive styles, creativity, intelligence, prior learning experiences, and gender differences.
Technology and Other Instructional Approaches	Integration of educational technology (e.g., Microsoft Mathematics), habituation with non-routine problems, and the use of external representations.

From the findings related to factors that influence adaptive reasoning, as in Table 8 above. It shows that 6 categories affect students' adaptive reasoning skills, namely learning methods and models, learning environment, basic skills and understanding, motivation and involvement, cognitive and personality factors, and technology and other approaches. One of the factors that affects adaptive reasoning ability is the CPS model. Stanford (2022) said the creative problem-solving learning model can enhance students' mathematical adaptive reasoning abilities, making it an effective alternative for teachers to implement in mathematics instruction. Not only the CPS model but also the PBL model can foster adaptive reasoning skills in mathematics instruction (Darwani et al. 2020). Another factor that can also affect students' adaptive reasoning ability is basic ability, in this case, conceptual understanding, which can reflect students' ability to build mathematical knowledge and connect it to previous experiences, thus affecting students' adaptive reasoning ability (Altarawneh, 2021).

Conclusions

Based on the results and discussion, the number of publications related to adaptive reasoning ability research tends to increase compared to previous years. Adaptive reasoning in mathematics learning involves various key characteristics, such as logical thinking, flexibility, reflection, justification, evaluation skills, and integration with strategic and creative competencies. These characteristics are developed through experience, practice, and the application of innovative learning methods, such as Creative Problem Solving (CPS), Problem-Based Learning (PBL), and the Knisley Learning model (KLM), which have proven effective in improving students' abilities. Research also shows that meaningful learning experiences and routine practice with non-routine problems play an important role in the development of adaptive reasoning.

Most of the studies used experimental approaches and qualitative investigations, with subjects that included students from various levels of education to prospective teachers, highlighting the importance of an in-depth understanding of adaptive reasoning in various contexts. Therefore, collaborative efforts from teachers, researchers, students, and policymakers are needed to support the development of adaptive reasoning skills through innovative learning strategies, training, and supportive education policies.

Recommendations

However, the study is limited to Scopus-indexed articles, which may reduce the diversity of perspectives analyzed. Future research should expand to include articles from broader databases such as SAGE and Emerald to provide a more comprehensive understanding. Additionally, investigating contextual factors, such as the influence of learning technologies or STEM-based approaches, could offer deeper insights into the development of mathematical creativity across diverse educational settings.

Scientific Ethics Declaration

* The authors declare that the scientific, ethical, and legal responsibility of this article published in EPESS journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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