

SYSTEMATIC LITERATURE REVIEW: METACOGNITIVE STRATEGY IN SCIENCE LEARNING

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Abstract. The purpose of this review article was to understand the application of metacognitive strategies in science education as well as identify the syntax of these strategies and their impact on the studied variable. The method used was called a systematic literature review (SLR), and it consisted of three steps: planning, carrying out, and reporting. The process of searching and filtering articles was carried out using the PRISMA method in electronic journals. Sixteen articles were relevant to the research goal and were published in twelve journals (Scopus). The results of the study indicated that students were most often used as research subjects in metacognitive strategy research. Most articles on metacognitive strategy in science learning were published in 2019, and quasi-experimental research designs were most frequently used. Chemistry is the scientific discipline that uses this strategy the most. The main metacognitive strategy syntax had three stages: planning, implementing learning, monitoring, and evaluating. The most researched metacognitive strategy has an influence on improving student learning outcomes. Therefore, metacognitive strategies could be a choice for teachers in schools to improve student learning outcomes in science. Metacognitive strategies still have great opportunities to be developed and applied in science learning in the future.

Keywords: metacognitive strategy, science learning

INTRODUCTION

Science learning is learning that requires scientific methods to prove theories. Science learning essentially means training students to process and think actively about the phenomena being studied (Tina et al., 2020). Students are expected to be able to use their knowledge to solve problems that occur. Teachers, as facilitators, are expected to be able to use strategies or learning models that can motivate students to learn science actively.

Various science learning strategies have been widely implemented. One of these strategies is a metacognitive learning strategy, which emphasizes high-level thinking processes that direct students to be active in learning (Iskandar, 2014). Nosratinia & Adibifar (2014) stated that metacognitive strategies invite students to manage, direct, regulate, monitor, and evaluate their own learning so that this strategy can contribute to improving the quality of student learning. Metacognitive strategies refer to increasing awareness of thinking processes so that if awareness grows, students can be invited to plan, monitor, and assess what is being studied (Romli, 2010). Thus, metacognitive strategies are learning strategies that involve students consciously and actively in designing strategies to gain knowledge, monitoring the extent to which the strategies are implemented, and evaluating the strategies carried out.

By using metacognitive strategies, it is hoped that students will be able to understand their own ability to think and be able to find solutions to overcome the obstacles they face. A good culture of thinking can improve learning achievement.

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Apart from that, metacognitive strategies can also make the learning process more meaningful because students plan, monitor, and evaluate their learning. Several studies state that metacognitive learning strategies can improve academic achievement (Mitsea & Drigas, 2019). Parlan et al., (2018) stated that metacognitive learning strategies can improve metacognitive abilities, scientific explanation abilities, high-level thinking abilities, and learning achievement. Khoiriah (2019) also stated that metacognitive strategies improve student learning outcomes on the concept of the digestive system in humans. Therefore, this strategy is suitable for application in school learning, especially science learning.

The positive impact of using metacognitive strategies has caused researchers to be interested in exploring the development of this strategy in the form of a literature review. Several literature review studies on metacognitive strategies have been conducted. Ellis et al., (2014) study on metacognitive learning strategies found that this strategy is suitable for application in various disciplines and educational levels from elementary to high school and is effective for increasing academic knowledge and skills. Arslantas et al., (2018) identified metacognitive research directions focusing on teaching metacognitive concepts and the importance of metacognition for chemistry students' learning and learning outcomes. The latest review of metacognitive learning was carried out by Rivero Galeano et al., (2020) which mapped the methods, indicators, strategies, techniques and instruments of metacognitive learning in secondary education.

This review of research aims to collect information about the results of research on the use of metacognitive strategies specifically for science learning, examine the syntax of the metacognitive strategies used, and examine how metacognitive strategies influence the dependent variables studied from 2012 to 2022.

METHODOLOGY

This review article uses the systematic literature review (SLR) method, which consists of three stages, namely planning, conducting, and reporting. The subjects of this research are articles published in international journals during the last 10 years (2012 - 2022) in Google Scholar, ERIC, and Taylor & Francis Online. The planning stage is an activity to determine the topic and article search criteria. The topic of the research article is metacognitive strategies in science learning. The article search criteria included: 1) articles about metacognitive learning strategies in science and mathematics learning; 2) publication between 2012-2022; 3) full text, journal articles and open access; and 4) reputable journals (Q1-Q4).

The conducting stage is the stage of carrying out article searches, article selection, and data synthesis. The keywords used to search for articles are "metacognitive learning strategy" and "metacognitive strategy in science." Search results in 4 databases with these keywords produced 3,843 articles. The articles were reduced to 851 after checking for duplicates and were selected in the 2012-2022 period. The first filter was carried out by reading the title, and 618 articles were excluded because they did not focus on metacognitive strategies. The results from filter 1 were 233 articles. The second filter, by reading the abstracts, obtained 28 articles, of which 205 articles were excluded because they were review articles (8), articles from non-quartile journals (62), not focused on science learning (127) and proceedings (8). The third filter was to read the full text of 28 articles, and 13 articles were excluded because the articles were not quantitative research and were not suitable. The article search and selection process uses the PRISMA method (Moher et al., 2009) as follows:

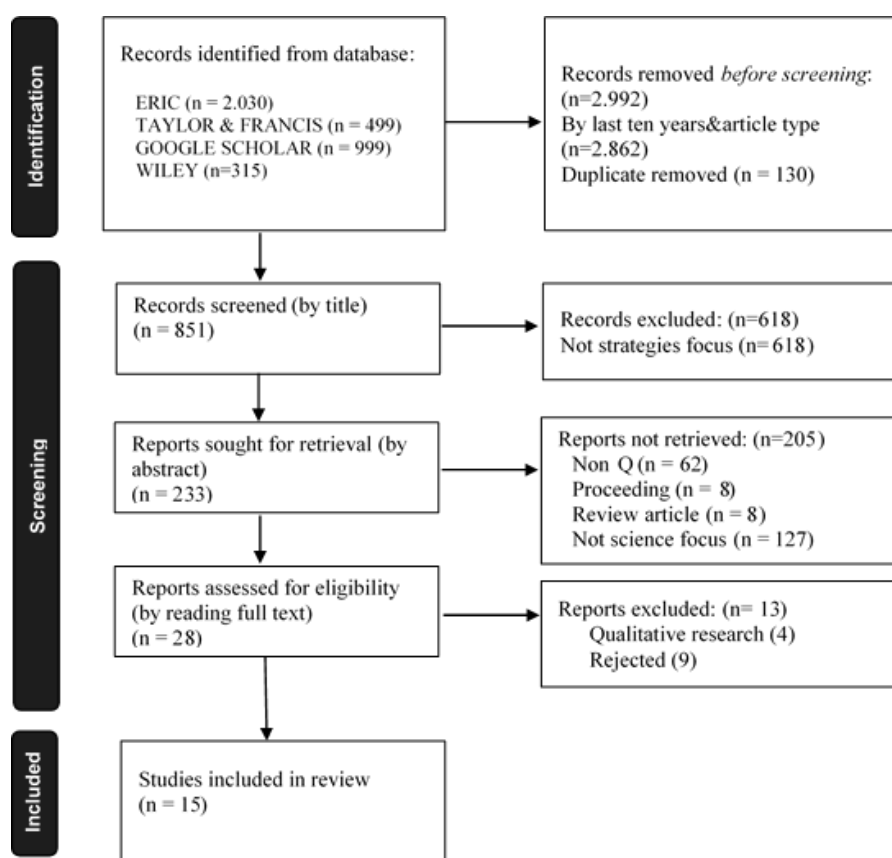


Figure 1. Flow diagram of article search stages using the PRISMA method

Based on the search results and article filters above, the final articles selected for review were 15 articles, as follows:

Table 1. Results of article selection on metacognitive strategies in science learning

No.	Author	Selected Journal	Database
1	Cook et al., 2013	Journal of Chemical Education (Q2)	Google Scholar
2	Spellman et al., 2021	Ecosphere (Q1)	Google Scholar
3	Parlan et al., 2018	International Journal of Instruction (Q1)	ERIC
4	Baliram & Ellis, 2019	School Science and Mathematics (Q2)	Wiley
5	Mutambuki et al., 2020	Journal of Chemical Education (Q2)	Google Scholar
6	Yusnaeni, 2017	International Journal of Instruction (Q2)	ERIC
7	Valencia-Vallejo et al., 2019	Knowledge Management & ELearning (Q2)	ERIC
8	Casselman & Atwood, 2017	Journal of Chemical Education (Q2)	Google Scholar
9	Muhali et al., 2019	Malaysian Journal of Learning and Instruction (Q1)	Google Scholar
10	Moser et al., 2019	Science Education (Q1)	WILEY
11	Besoondyal, 2017	International Journal of Special Education (Q3)	ERIC
12	Pilten et al., 2020	International Electronic Journal of Elementary Education (Q3)	ERIC

No.	Author	Selected Journal	Database
13	Rieser et al., 2016	British Journal of Educational Psychology (Q1)	WILEY
14	Susantini et al., 2018	Asia Pacific Education Review (Q2)	Google Scholar
15	Wagaba et al., 2016	Research in Science & Technological Education (Q1)	Taylor & Francis

The final stage of SLR is the reporting stage. The activity in this stage was to write the results of the study of articles that had been found. Writing study articles was adjusted to a predetermined format and adapted to the objectives.

RESULT AND DISCUSSION

Metacognition is the ability to know, organize, and control cognitive processes consciously (Khan & Khan, 2013). Research on metacognition was pioneered by Flavell in the 70s. In 1979, Flavell proposed a cognitive process model for monitoring and regulation that emphasizes what happens in the learning process, and controlling cognitive processes. The elements involved in the model are metacognitive knowledge, metacognitive experience, and metacognitive goals and strategies.

Year of Article Publication

Research on metacognitive strategies has often been carried out. Based on the results of this article review, researchers found 15 articles that examined metacognitive strategies in science learning during the period 2012 - 2022. In accordance with the article selection stage, this review only used quantitative and mixed method research. The year the article on metacognitive strategies in science learning was published is seen in Figure 2.

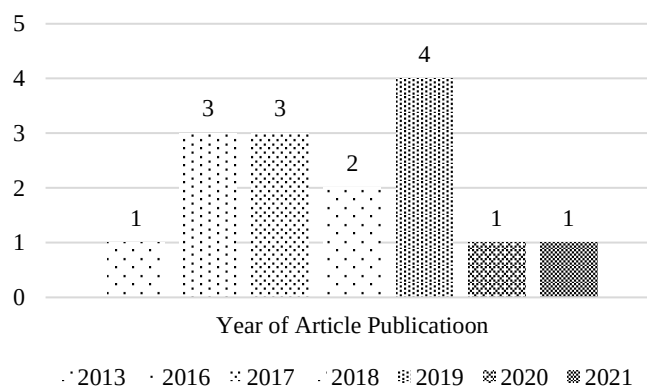


Figure 2. Year of article publication

Based on Figure 2, the most research on metacognitive strategies in science learning was done in 2019. This may happen because metacognitive strategies are an active learning strategy where students are invited to be active in planning, monitoring, and evaluating their own learning. This strategy article will decrease in 2022. This may be because Indonesia has started to be hit by the Covid-19 outbreak.

Research Subject

The use of metacognitive strategies can be taught to students from an early age at school. Students are invited to prepare their learning by starting at home. This study preparation can help students better understand the subject matter presented by

teachers at school. Based on the results of the analysis, the research subjects used in metacognitive strategy research are as follows:

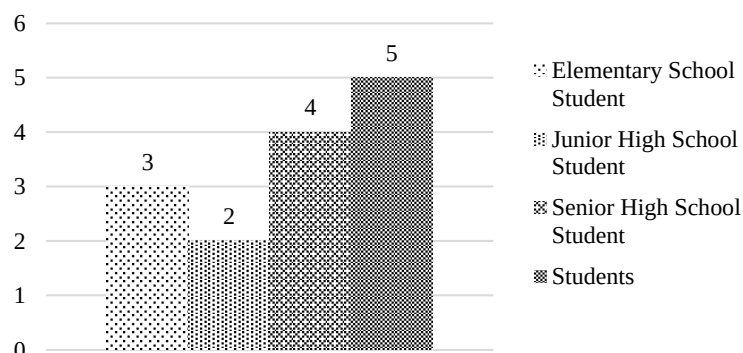


Figure 3. Research subject of metacognitif strategy

Figure 3 shows that metacognitive strategy research subjects have been used from elementary school students to college students. Most research on this strategy is carried out at the student level. This can happen because metacognitive strategies require independent learning, starting from planning learning, implementing learning to evaluation. Students are considered to have better learning independence than students at the high school level and below. However, it does not rule out the possibility that the use of metacognitive strategies, such as underlining techniques, can also be taught to elementary school students.

Research Design

The type of research in this review article was chosen for quantitative and mixed method research only. In the mixed method research, only one article was obtained with an exploratory sequential design, while the other articles were quantitative research. The quantitative research design in metacognitive strategy research that has been carried out is as follows:

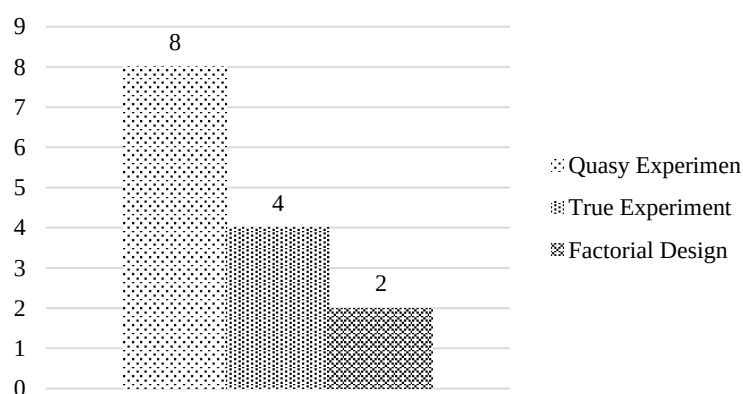


Figure 4. Research design

Figure 4 shows that quasi-experimental research designs are most widely used in metacognitive strategy research. This can happen because the research design is in accordance with the research subjects, namely humans (students), who are quite difficult to control when given treatment. Apart from that, the quasi-experimental research design makes it easier for researchers to take samples because the samples used can be taken from each class.

Science Discipline

Science learning includes chemistry, biology, physics, and mathematics. The branches of science taught with metacognitive strategies are as follows:

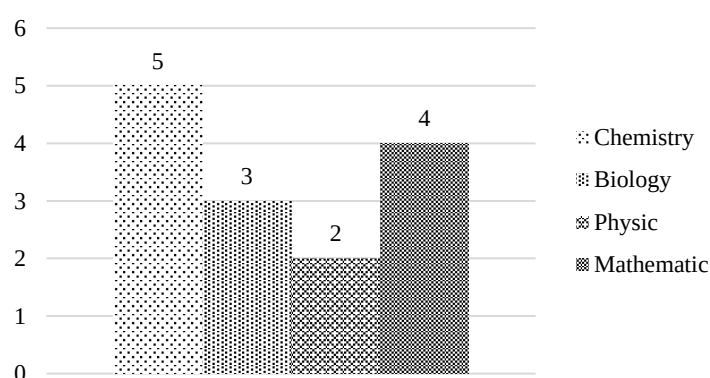


Figure 5. Science disciplines taught with metacognitive strategies

Based on Figure 5, chemistry is mostly taught with metacognitive strategies. This can happen because chemistry lessons are included in lessons that require a deeper understanding of concepts, so better preparation and evaluation of learning are needed. The other reason is teachers should design activities that showcase how chemistry helps us understand the "mysteries" of the world around us, the second reason is students need to know how they arrange scientific information, their learning styles and preferences, and their social interactions during laboratory activities while learning about chemistry (Tsai, 2001). The better the preparation for learning chemistry, the faster students will understand the concepts being taught (Casselman & Attwood, 2017).

Syntax of Metacognitive Strategy

Syntax is a general reference regarding managing learning in the classroom so that there is conformity between the rules, objectives, and results to be achieved. The metacognitive strategy syntax proposed by Cook et al., (2013) is: 1) Preview before class. Students are invited to study the material before entering class. Activities that can be carried out at the preview stage include skimming the material, writing the title and words in bold, reading the summary, determining objectives and asking questions. 2) Attend class. Students are asked to attend class. Students can ask questions in class and take important notes. 3) Review after class, read notes and ask questions. 4) Study, learn and answer questions like why, how and what if. Students can carry out intense learning activities, for example, 3-5 study sessions per day. Apart from that, students can do a weekly review by reading the previous week's notes and material. 5) Assess your learning, evaluate yourself periodically, for example, by

answering questions about whether the learning methods you have used are effective and whether you understand the material that has been taught.

Other researchers made modifications to the syntax of metacognitive strategies, namely metacognitive strategies (MS PDCA) (Parlan et al., 2018). The MS PDCA syntax is as follows:

1. *Preparing*
This stage aims to prepare students for learning. Teachers facilitate students to study teaching materials, determine learning objectives, identify concepts to be studied, develop initial knowledge that is appropriate to the material and concepts already understood, and create summaries and lists of questions to ask in class.
2. *Doing*
Students are facilitated to build understanding through active learning, for example, through presentations, discussions, questions and answers, and taking notes.
3. *Cheking*
Teachers give students the opportunity to check or monitor their learning activities, help students reflect on their learning, and help students find out their difficulties while studying.
4. *Assessing and Following Up*
This stage functions to determine the achievement of learning objectives, provide feedback, and follow up on learning results. The teacher guides students to plan what needs to be done at the next meeting.

Muhali et al., (2019) also introduced another metacognitive strategy called the Reflective-Metacognitive Learning Model (RML). RML is a learning model to facilitate the development of students' metacognitive abilities. The syntax of RML is:

1. *Orientation Reflection*
At this stage, the teacher can convey general learning objectives and ask students to read information from appropriate learning sources.
2. *Organization Reflection*
The teacher asks students to identify the goals that are requirements for achieving the final goal and establish steps to solve the general problems that have been identified. The teacher divides students into groups and guides students in formulating hypotheses, defining variables in learning and determining problem-solving steps.
3. *Excecutio Reflection*
The teacher asks students to carry out the problem solving plans that have been made, assesses the performance of implementing problem solving based on the fluency and accuracy of the students' problem-solving, asks students to formulate decisions by assessing hypotheses, and reflecting through internal processes in accordance with the problem solving steps.
4. *Verification Reflection*
The teacher asks students to provide an explanation regarding the results of implementing their problem solving plan, explain the relevance of the results of problem solving to the previously formulated goals, and provide new phenomena that are still related to problem solving.

Susantini et al., (2018) also developed a metacognitive strategy that consists of six stages. First stage: clarifying learning objectives and exploring initial knowledge. The teacher explains specific learning objectives, provides motivation to

students through brainstorming, distributes worksheets known as SUES and guides students in responding to SUES. Second stage: Organizing the student learning process. The teacher divides students into groups and asks each group to work together to describe their initial knowledge. Third stage: Monitoring students' conceptual changes. The teacher asks each group to differentiate between the initial knowledge they have and the knowledge they have acquired. Fourth stage: presenting important concepts. Teachers explain important concepts depicted in students' books and guide students using various learning strategies. Fifth stage: checking student understanding and providing feedback. Teachers discuss the results of students' work in SUES to check whether there are still misconceptions. The sixth stage, encourages self-monitoring and evaluation. Teachers ask students to rate their own work based on agreed-upon score ranges. Then students, with the teacher's guidance, conclude the correct concept.

Based on the explanation above, it can be concluded that metacognitive strategies generally have three main stages. First, planning activities where students are invited to prepare their learning either independently or with teacher guidance. Students are invited to consciously know the initial knowledge they have before learning. Students are given the opportunity to read and write prerequisite material related to the learning that will be given. Apart from that, students are also invited to read the material first before learning begins. This is to provide students with the material that will be discussed with the hope that students will be able to connect with the new material and their understanding will increase as learning progresses. Students are also motivated to ask questions related to material they do not yet understand. Second, implementation of learning. The learning process carried out in class can be done by listening to lectures from the teacher, taking important notes, discussing in groups and asking questions that have been made about material that is still not understood. Students' ability to create and ask questions is one technique for improving critical thinking skills (Ariadila et al, 2023). Third, monitoring and evaluation. Teachers encourage students to monitor their own learning to see whether it is in accordance with the initial plan, has been used effectively in carrying out assignments and has understood the material that has been studied. The teacher invites students to evaluate themselves regarding the learning they have done. The teacher asks students to assess whether students can draw conclusions about the material they have studied, assess whether there is still material they do not understand, and what obstacles they experience when studying. Teachers encourage students to understand each individual's thinking process so that students consciously carry out higher stages of thinking.

The metacognitive strategies described previously have a learning syntax. Several other researchers use metacognitive strategies such as making concept maps, reflective reading, making metacognitive journals, making portfolios, making self-reflective illustrations and constructivist metaphors (Spellman et al., 2016). Yusnaeni et al., (2017) used the underlining technique as a metacognitive strategy combined with a problem-based learning model. The study of metacognitive strategies in this research focuses on metacognitive strategies that have learning syntax.

The Influence of Metacognitive Strategies on the Dependent Variable Under Study

Metacognitive strategy research is followed by varying dependent variables. The use of metacognitive strategies can have an influence on this dependent variable.

The dependent variables that have been studied in metacognitive strategy research are as follows:

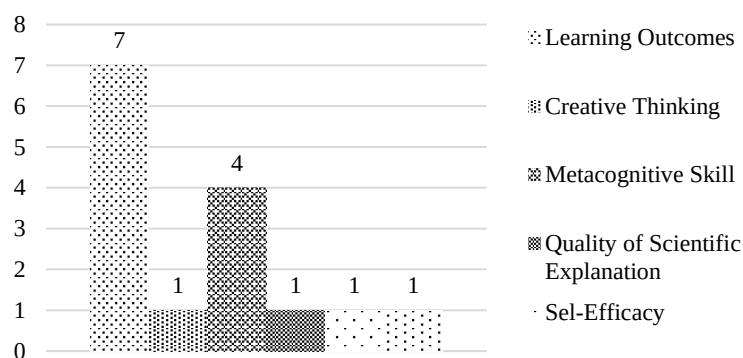


Figure 6. Dependent variables in metacognitive strategy research

Based on Figure 6, the data shows that learning outcomes are the dependent variable that is most influenced by metacognitive strategies. Metacognitive strategies provide opportunities for students to be actively involved in learning through group discussions. Each student is free to express opinions, debate and test their understanding in the discussion. Student understanding is formed through social interaction with other students, teachers and learning resources. Teachers also play a role in providing a learning environment that allows students to build their understanding (Avargil et al, 2018). Therefore, the use of metacognitive strategies can increase students' understanding so that their learning outcomes also increase.

Students' final exam results improved after learning metacognitive strategies. This recommends that understudies with the aim to profoundly comprehend data tend to be effective in their academic performance (Countinho, 2007). Cook et al (2013) explained several reasons for the increase in student performance, including: 1) In general, chemistry students are quite motivated to excel because they aspire to a career in the health sector, so they are willing to try using metacognitive strategies, 2) Students understand higher order thinking skills because students are taught not only to learn by memorizing the use of metacognitive strategies, 3) students easily apply concrete strategies such as working on high-level thinking questions, 4) students who have applied metacognitive strategies are able to have good understanding and success, so they are motivated to continue using metacognitive strategies and have good performance in the form of higher final exam results than students in the control class (Bessoondyal, 2017).

Metacognitive strategies have an effect on increasing students' metacognitive abilities. Increasing students' metacognitive abilities occurs because, in learning metacognitive strategies, students are facilitated by conducting discussions and experiments. It is hoped that this activity can develop science processing skills to increase understanding of the material being studied. Muhali et al., (2019) stated that the RML model emphasizes the reflection process in each phase, which has an important role in improving students' metacognitive skills by accommodating scientific activities. The reflection process in the RML model prevents students from repeating mistakes that may occur in the learning process.

CONCLUSION

This article contains a review of research results regarding metacognitive strategies in science learning. Based on the studies that have been carried out, information has been obtained that the use of metacognitive strategies in science learning is mostly carried out in student research subjects, and chemistry is the scientific discipline that uses this strategy the most. The publication year of most articles was found in 2019, and research designs for metacognitive strategies mostly used quasi-experiments. Metacognitive strategies have a big influence on student learning outcomes. Student learning outcomes are higher after using this strategy. The metacognitive strategy syntax contains three main stages: planning, implementing learning and monitoring, and evaluation.

There is a difficulty in order to understand the metacognition components. The area for improvement in the future research can discuss the specific aspect about cognitive knowledge such as person and task knowledge, self-appraisal, epistemological understanding, declarative knowledge, procedural knowledge, strategy knowledge and conditional knowledge.

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