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RESEARCH ARTICLE

ENHANCING SCIENCE LEARNING THROUGH METACOGNITIVE AWARENESS

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ABSTRACT

Metacognitive awareness refers to thinking about one's thinking and learning processes. It involves setting learning goals, monitoring progress, and evaluating the effectiveness of different study strategies. By becoming more aware of their cognitive processes, students can develop a deeper understanding of the subject matter and support long-term knowledge retention. This paper attempts to review the existing literature on instructional strategies that have been found effective and promising in promoting metacognitive awareness, which leads to the enhancement of learning and performance of secondary school students studying Science. It also discusses the potential benefits of incorporating metacognitive instruction in secondary science education. The literature suggests that metacognitive strategies significantly enhance secondary students' science learning. Various studies have proved that metacognitive instructions and specific metacognitive strategies are effective in improving science achievement. Furthermore, metacognitive strategies such as setting learning goals, planning and monitoring progress, and evaluating and revising understanding are particularly effective in enhancing science learning. However, more research is needed to fully understand how metacognition leads to improved science learning and to develop practical instructional approaches that can be widely implemented in secondary science classrooms.

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INTRODUCTION

Science education is crucial in preparing students for success in the modern world. As a result, improving Science learning among secondary students has been a significant focus of educational research and practice. The secondary stage is an important phase of education when students move from elementary to high school and develop more advanced skills and knowledge. Students are exposed to more complex and challenging scientific concepts at the secondary stage, which require them to develop higher-level thinking and problem-solving skills. Metacognition plays a crucial role in supporting students' learning at the secondary stage by helping them develop a deeper understanding of these complex concepts and processes. It also helps students develop important skills, such as critical thinking, self-regulation, and collaboration, which are essential for success in their academic and personal lives.

METACOGNITION AND SCIENCE LEARNING

There is a common assumption that the primary objective of the metacognition construct is to help students become more effective in their learning processes and get better learning outcomes (Thomas *et al*., 2008). The significance of metacognition is that it can be used to gain insights, investigates, and consequently improves the student's learning and thinking processes (Thomas and Mac Robbie, 2001). Metacognition is defined as individuals' knowledge, control and awareness of cognitive processes, including their strengths and limitations as a learner (Flavell, 1979; Baired, 1990; Thomas & McRobbie, 2001) and the ability to think about one's thinking (Gilbert, 2005). Further, Veenman *et al*. (2006) also suggested the terms often associated with metacognition, such as; Metacognitive awareness, self-regulation, Metacognitive Skills, and metacognitive strategies. The researchers have suggested two broad components of metacognition: Knowledge of cognition and 2. Regulation of cognition (Schraw & Moshman, 1995; Schraw, 1998). These components are also called metacognitive knowledge and metacognitive skills. Knowledge of cognition refers to what individuals know about their cognition. This component comprises three different types of knowledge: i. Declarative Knowledge (Knowledge about the task), ii. Procedural knowledge (knowing how to accomplish the task), iii. Conditional knowledge (knowing when and why to do the task). Regulation of cognition refers to the ability of an individual to control their cognition. This component comprises three types of regulatory processes: i. Planning ii. Monitoring iii. Evaluating, through these processes, learners guide their learning. Research has shown that metacognitive strategies can effectively enhance learning and academic performance across various subjects, including Science (Dunlosky *et al*., 2013).One key mechanism by which metacognition improves science learning is by assisting students in developing a deep understanding of subject matter that is meaningful learning. Metacognition helps students to become more aware of their different kinds of knowledge- personal, task, and strategy knowledge. It also enables the learner to monitor, evaluate and regulate their learning processes (Schraw and Dennison, 1994). Various researchers proposed that learning is a conscious process and remaining conscious while learning signifies metacognition. Thus it can be said that learning is a function of metacognitive knowledge and metacognitive skills (Flavell, 1979; Resnick, 1987).

Metacognition is a significant factor in meaningful learning and academic performance, as reported by researchers (Cross & Paris, 1988; Brown & Palincsar, 1989; Schraw *et al*., 2006). Furthermore, one of the critical benefits of metacognitive awareness is that it enables students to become more active and engaging while learning by explicitly teaching students how to monitor and regulate their learning and to develop a deeper understanding of the material. By evaluating their understanding of the material, learners can identify gaps in their knowledge and take steps to address them. Evaluation can help them to be more efficient and effective in their learning. Overall, metacognition helps learners to regulate their learning by being more strategic and reflective in their approach (Cook *et al*., 2013; Delvecchio, 2011; Mutambuki *et al*., 2020). Thus, by understanding the cognitive processes involved in learning (Metacognition), teachers and learners can develop strategies and approaches that support and enhance learning. Here is an example to better understand the benefits of metacognition in enhancing learning; suppose a student is studying for an exam. In this scenario, the student might engage in metacognitive processes in several ways. For instance, they might think about how they approach the task, what they understand and do not, and what strategies they can use to improve their understanding and retention of the material. They might also plan their study time, monitor their progress, and evaluate their learning strategies to see what works well and what could be improved. Thus in this way, students may employ metacognitive knowledge and metacognitive regulation to manage and regulate their learning processes.

REVIEW OF RELATED LITERATURE

In literature, metacognition has been established as a significant predictor of academic achievement in many subjects, including Science. In recent years, there has been increasing interest in practising or using metacognitive strategies or techniques in enhancing the teaching and learning of sciences among secondary students. One of the key findings in the literature is the consistent findings that show the effectiveness of metacognitive instruction in improving science learning and achievement. Metacognitive instruction is a teaching method that focuses on helping students become more aware of their thought processes and learning strategies. It involves teaching students to reflect on their learning, evaluate their understanding of the material, and adjust their study strategies accordingly. The goal of metacognitive instruction is to help students develop a deep understanding of the material they are learning and to become more independent, self-directed learners. For instance, a teacher might ask students to reflect on their learning at the end of each lesson and identify areas where they struggled or felt confused. This approach helps students to become more aware of their strengths and weaknesses as learners and to take an active role in identifying areas where they need to focus more attention. A study by de Boer *et al*. (2018) revealed that secondary students who got explicit instruction on metacognitive strategies in their science classes outperformed the control group students who did not receive such instruction on metacognition. Another study by Hacker and Dunlosky (2012) found that students who received metacognitive instruction as a self-regulation strategy showed significant gains in science achievement compared to traditional instruction. Another study by Pintrich and De Groot (1990) found that students who received metacognitive instruction scored significantly higher on a scientific reasoning test than those who did not. In addition, a more recent study by Dunlosky *et al*. (2013) found that metacognitive instruction improved science achievement among secondary school students.

INSTRUCTIONAL STRATEGIES FOR ENHANCING SCIENCE LEARNING

Cognitive control and improvement of learning are the goals of metacognitive strategies. Metacognitive strategies are more challenging to teach than cognitive strategies because their usage requires students to monitor and regulate their learning, which includes the use of cognitive strategies (Veenman, Van Hout-Wolters, & Afflerbach, 2006).In science education, metacognition can play a significant role in facilitating meaningful learning at the secondary stage. Metacognitive strategies can help students become more self-aware and reflective learners who can better engage with the material and connect new information and their existing knowledge. It can help students to become more independent learners and problem-solvers (Hartman, 2001). Based on the significant findings from the review of related literature (Gilbert,2005; Schraw *et al*., 2006; Veennman *et al*., 2006; Pulmones, 2007; Cooper&Sandi-Urena,2009; Cook *et al*., 2013; Thomas & Anderson, 2014; Lindquist, 1975; Schraw, 1998; Schraw *et al*., 2006; Tanner,2012; de Boer *et al*., 2018; Mutambuki, 2020), this paper found the several instructional strategies that have been found effective in enhancing the metacognitive awareness and learning of Science among students are briefly discussed below:

- Providing explicit instruction on metacognitive strategies, such as planning and monitoring one's learning, evaluating the effectiveness of different learning strategies, and adapting one's approach in response to feedback and new information.
- Encourage students to think about their learning processes by asking them to reflect on their understanding of a particular concept or principle and identify areas where they need additional clarification or support.
- Creating learning environments that support metacognitive development, such as providing opportunities for students to work collaboratively on problem-solving tasks or using formative assessment techniques like ongoing feedback and self-assessment.
- Using metacognitive prompts, such as asking students to think aloud while working on a task or providing prompts that encourage students to reflect on their learning processes.
- Providing opportunities for students to practice and apply their metacognitive skills, such as by asking them to plan and carry out an investigation or experiment or by providing open-ended problems that require them to use their critical thinking and problem-solving skills.
- Encouraging students to self-assess their learning and progress by providing them with rubrics or other tools that help them evaluate their work and identify areas for improvement.
- Helping students to develop their metacognitive skills through metacognitive scaffolding, such as providing them with step-by-step instructions or guiding questions that help them break down a complex task into smaller, more manageable steps.
- Using metacognitive feedback, such as providing students with specific, targeted feedback, helps them understand how their thinking and problem-solving strategies affect their learning and performance.
- Providing students with opportunities to learn from their mistakes, such as by encouraging them to reflect on their errors and misunderstandings and providing them with support and guidance as they revise and improve their work.
- Helping students to transfer their metacognitive skills to new contexts and tasks, such as by providing them with opportunities to apply their skills in different subject areas or by encouraging them to think about how their metacognitive skills can be helpful in real-world situations.

In addition to these instructional methods and strategies, learners can also employ various metacognitive strategies and techniques to advance their learning in Science. The following are suggested metacognitive strategies and techniques:

- Planning and monitoring one's learning, such as setting specific goals, creating a study plan, and regularly checking in on one's progress.
- Evaluating the effectiveness of different learning strategies, such as by trying different techniques and reflecting on which ones are most helpful for understanding and retaining new information.
- Adapting one's approach in response to feedback and new information, such as by revising one's study plan or changing one's learning strategies in response to feedback from a teacher or peer.

- Using metacognitive prompts and cues, such as asking oneself questions or providing oneself with reminders,helps focus one's attention and improve one's learning.
- Engaging in self-assessment and self-regulation, such as by regularly checking in on one's understanding and progress and making adjustments to one's learning strategies as needed.
- Seeking help and support when needed, such as by asking for clarification or assistance from a teacher or peer when facing a difficult concept or problem.
- Reflect on one's learning processes, such as thinking about what works well and what could be improved and using this information to inform future learning.
- Using metacognitive scaffolding, such as breaking down a complex task into smaller, more manageable steps or using graphic organisers or other tools to organise and structure one's thinking.
- Seeking feedback and guidance from others, such as by asking for feedback from a teacher or peer or seeking additional resources or support when needed.
- Transferring one's metacognitive skills to new contexts and tasks, such as applying one's skills to different subject areas or real-world situations and thinking about how one's metacognitive skills can be helpful in various settings.

METACOGNITIVE TECHNIQUES

- Summarising: Summarising the information can help to synthesise and organise it in a way that is easy to remember.
- Visualisation: Using visual aids, such as diagrams and pictures, can help to understand complex scientific concepts better.
- Reflective writing: Learning about learning experiences can help one think more deeply about the material.
- Concept mapping: Concept mapping can help organise and connect information visually.
- Journaling: Keeping a learning journal can help to reflect on progress and identify areas for improvement.
- Peer teaching: Teaching the material to oneself or other learners can help one better understand and retain the information.
- Metacognitive dialogue: Engaging in metacognitive dialogue with oneself or other learners can help one think more deeply about the material.
- Learning contracts: Developing learning contracts with oneself or other learners can help to take ownership of learning and set goals for progress.

Here are a few examples of how these techniques could be employed to learn topics in physics, chemistry, and biology on one's own

- In learning about motion in physics, a student could use self-questioning to clarify their understanding of the concept of velocity.
- In learning about the periodic table in chemistry, students could use the summarising technique to synthesise the information they have learned.
- In learning about genetics in biology, a student could use visualisation to help understand the concept of gene expression.

DISCUSSION

The above-suggested metacognitive strategies and techniques help students become more reflective learners and acquaint them with the necessary skills and strategies to understand the learning material meaningfully. For example, setting learning goals and planning helps students focus their attention and effort to reach the goal. In contrast, planning and monitoring progress can help them to organise and track their progress. Evaluating and revising understanding can help students to identify gaps in their knowledge and to adjust their learning strategies accordingly. For instance, a study by Schraw and Dennison (1994) found that high school students who used metacognitive strategies such as; setting learning goals, planning and monitoring their understanding obtained significantly higher science achievement scores than those who did not use these strategies. In addition to metacognitive instruction, the literature also highlights the importance of practising specific metacognitive strategies in science learning. Setting learning goals, planning and monitoring progress, and evaluating and revising understanding are particularly effective in enhancing science learning. One key reason why metacognitive instructions are effective in enhancing science learning might be that they explicitly teach students how to monitor and regulate their learning with examples and illustrations following the nature and requirements of the concepts in Science. Despite these promising findings and potential benefits of metacognitive instructions and metacognitive strategies, much is still not known about how metacognition leads to improved science learning. More research is needed to fully understand the specific cognitive mechanisms involved and develop more effective instructional approaches that can be widely implemented in secondary classrooms. For example, future research could investigate the metacognitive strategies most effective for different science topics or student populations. Additionally, more research is needed to determine the optimal timing and duration of metacognitive instruction and to identify effective methods for assessing and monitoring students' metacognitive skills.

CONCLUSION

The developed metacognitive skills of secondary students have the potential to advance their learning level, prepare them for higher education, and enable them to select the right profession. By providing explicit metacognitive instruction and strategies and creating learning environments that foster metacognitive development, teachers may help students develop the skills and strategies they need to become more effective and independent learners. Additionally, learners can actively advance their learning level and achieve academic goals by employing research-based metacognitive strategies and techniques. The literature suggests that metacognition is critical in enhancing science learning among secondary students. Metacognitive instruction and the use of specific metacognitive strategies are effective in improving science achievement. However, further research is needed to fully understand how metacognition leads to improved science learning and to develop practical instructional approaches that can be widely implemented in the classroom.

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