International Journal of Religion
2024
Volume: 5| Number 6 | pp. 186 – 194
ISSN: 2633-352X (Print) | ISSN: 2633-3538 (Online)
ijor.co.uk
DOI: https://doi.org/10.61707/agk1xr12

Socio-Scientific Issues-Based Learning: The Effect on High School Students' Metacognitive Skills

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Abstract

Metacognitive skills are fundamental skills that students need to face challenges in the 21st century. However, previous research reported that students' metacognitive abilities tend to be low. This study seeks to explore how socio-scientific issues-based learning (SSIBL) impacts the metacognitive abilities of 11th-grade students. Quantitative data was gathered from a sample of 72 students (28 male, 44 female) studying chemistry at a public school in Jakarta, Indonesia. Employing a quasi-experimental design, two classes were randomly assigned as experimental and control groups using a coin flip method. The students' metacognitive skills were evaluated using the Metacognitive Activities Inventory (MCA-I), and the data was analyzed using independent and paired sample t-tests. The findings indicate that SSIBL positively affects students' metacognitive skills, suggesting its effectiveness in enhancing these skills. This research underscores the potential of SSIBL to be integrated into various subjects in Indonesian secondary education, including chemistry. It offers students hands-on learning experiences, fostering problem-solving, decision-making, and knowledge construction. Hence, educators are encouraged to adopt SSIBL to bolster students' metacognitive skills across different chemistry topics.

Keywords: *Socio-Scientific Issues, Metacognitive Skills, 21st Century Learning, Chemistry.*

INTRODUCTION

In the realm of mastering 21st-century competencies, the objective of secondary education extends beyond mere knowledge provision to the cultivation of students' cognitive abilities. Among these, metacognitive skills emerge as pivotal, essential for navigating the challenges of the contemporary era (Emily & Michaela, 2012). Such skills encompass critical thinking, problem-solving, effective communication, collaboration, creativity, and innovation (Greenhill, 2010). Hence, enhancing metacognitive skills stands out as a crucial aspect of learning in preparation for 21st-century challenges (Emily & Michaela, 2012).

Metacognition is a level in the thinking process. The term "metacognition" was initially introduced by Flavell in 1976. According to Flavell (1976), metacognition entails an understanding of one's learning processes, the capacity to utilize information effectively to accomplish objectives, and the skill to evaluate the cognitive demands associated with particular tasks. Furthermore, Schraw and Dennison (1994) elaborated on metacognition, dividing it into two components: metacognitive knowledge and metacognitive skills. Metacognitive skills encompass an individual's ability to regulate their learning, incorporating elements such as planning, monitoring, and evaluation (Teaching Excellence in Adult Literacy [TEAL], 2012). Students with well-developed metacognitive skills find it easier to solve problems, make decisions, and think logically, as well as being more motivated to learn and able to regulate their emotions to achieve learning goals (Coutinho, 2007). This is because metacognitive awareness enables students to control their cognitive aspects and be able to plan, monitor, and evaluate learning to provide the best results (Schraw et al., 2011).

Metacognition serves as a crucial element in the learning process. Through metacognition, students gain the ability to oversee and manage their cognitive functions, facilitating more efficient and fruitful learning outcomes (Dori & Sasson, 2008). Research conducted by Thomas and Anderson (2014) underscores the effectiveness of metacognition in enhancing chemistry education, enabling students to grasp complex chemical concepts with greater proficiency. Similarly, a study by Hoseinzadeh and Shoghi (2013) demonstrates that students with strong

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metacognitive skills exhibit improved academic performance, highlighting the positive correlation between metacognition and achievement.

Unfortunately, previous studies reported that students' metacognitive skills tend to be low. For example, Kornell and Bjork (2008) in the United States found that students' metacognitive abilities and learning strategies were still low, so that learning became inefficient. The results of Bursali and Öz's (2018) research in Turkey also show that students' metacognitive abilities are low when studying. This is because the learning strategies implemented by teachers are less effective during the learning process. In another study, Ratnawati et al. (2015) found that students' metacognition was still low in solving chemistry questions. This is because students' ability to link previous knowledge in solving learning problems is still low (Ratnawati et al., 2015). The study shows that students' metacognitive skills increase if teachers use learning strategies that make students involved in their cognitive processes.

An effective and student-centered learning strategy that can improve metacognitive skills is socio-scientific issues-based learning, or SSIBL. SSIBL emerged in the field of education by using global and local issues in learning. According to Zeidler and Nicholas (2009), this learning strategy is social scientific problem-based learning that involves students in observation, analysis, experimentation, and application of concepts by raising social problems relevant to science. SSIBL is hypothesized to improve students' metacognitive skills, because it involves scientific content and social issues, so that students get learning that is interesting and relevant to everyday life (Zeidler & Nicholas, 2009). According to Zeidler et al. (2009), SSI-based learning can improve students' abilities in analyzing, interpreting, self-regulating, and evaluating.

Previous research indicates that the Socio-Scientific Issues (SSI) approach contributes significantly to student learning outcomes across several dimensions. These include fostering interest and motivation in science, as documented by Sadler et al. (2016), enhancing comprehension of the nature of science, as demonstrated by Eastwood (2012), and improving reasoning skills, as found by Lee & Erdogan (2007). Moreover, Gulacar (2020) and other studies have confirmed that SSI implementation can cultivate student interest and boost motivation to learn chemistry specifically. Additionally, SSI has been shown to create a classroom environment devoid of biases, promoting the development of critical thinking skills among students, as evidenced by previous research by Berland & McNeill (2010). In other research, Dauer et al. (2017) argue that SSI learning can reduce students' emotional arguments and increase the level of arguments based on reasons. According to Karahan et al. (2017), SSI can make learning in the classroom constructive. Students can start a conversation when discussing issues/problems that occur in their environment. This allows students to analyze problems critically rather than simply arguing without any information (Karahan et al., 2017). From this research, it can be seen that SSI learning can improve various cognitive aspects of students.

LITERATURE REVIEW

Metacognitive Skills

Flavell (1979) argues that metacognitive skills refer to the cognitive environment and one's learning experience. Learning experiences will link metacognitive strategies so that cognitive activities can be well controlled and achieve cognitive goals. Metacognitive skills initiate a sequence of activities enabling students to regulate their learning process (Schraw et al., 2006). Livingston (2003) also explains metacognitive skills as a sequential process where one's cognitive activities can be controlled so as to achieve the set goals. This helps in the learning process, including planning activities, monitoring cognitive activities, and evaluating or reflecting on the results of these activities.

Metacognitive skills encompass three key indicators: planning, monitoring, and evaluation (Jacob & Paris, 1987). Planning involves selecting suitable strategies and identifying cognitive skills necessary to attain learning goals (Schraw & Dennison, 1994). Monitoring entails executing the plan and overseeing the process toward achieving the learning objectives. Evaluation involves assessing the effectiveness of strategies in reaching those objectives. Thus, metacognitive skills are a learning process that has a series of activities involving planning, monitoring, and evaluation skills so that students can achieve the expected learning goals.

Socio-Scientific Issues-Based Learning (SSIBL)

SSIBL is a strategy that presents problems from several different perspectives. SSIBL helps students develop skills to investigate social science problems that exist in society (Tosun & Yavus, 2012). Through SSIBL, students' metacognitive skills are expected to improve. This is because students actively participate in their own learning (Zeidler et al., 2009). Active participation, inherent in learning by doing, proves more effective than passive reception of information, as it enables learners to confront the challenges of problem-solving firsthand (Chin & Chia, 2006). The SSIBL model necessitates students' active involvement in real-world, problem-oriented scenarios, thus prompting higher-order thinking (Lee & Erdogan, 2007). This learning requires students to learn how to solve problems, so that they can improve their thinking abilities through stages that provide freedom to build their own knowledge. Sadler (2011) suggests that teaching science using relevant socio-scientific issues can stimulate students to contribute to solving problems.

Research Questions

The aim of this study was to examine the impact of SSIBL on the metacognitive skills of high school students. The research question guiding this study is: "Does socio-scientific issue-based learning have an effect on high school students' metacognitive skills?"

METHODOLOGY

Research Design

This study employed a quasi-experimental nonequivalent control group design (Cohen et al., 2018). In the quasi-experimental, the researcher provides different treatments to the two groups, gives a pretest at the beginning of the instruction, and gives a posttest to see the differences between the two groups (Creswell, 2012).

Participants

The participants consisted of 72 grade 11 students (28 males and 44 females) from two intact classes enrolled in the chemistry subject during the academic year 2022/2023. The experimental group comprised 36 grade 11 students (14 males; 22 females) aged between 16 and 17 years, while the control group also consisted of 36 students (14 males; 22 females) within the same age range. One class was randomly assigned to the experimental group, while the other served as the control group. Before receiving treatment, both groups exhibited nearly identical characteristics.

Data Collection Tool

The Metacognitive Activities Inventory (MCA-I) adapted from Cooper and Sandi-Urena (2009) was used to measure students' metacognitive skills. The MCA-I consisted of 27 items with a 5-point Likert scale: strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree (1), eight of which were coded negatively. Examples of items in the MCA-I are: "*I make sure that my solution actually answers the question, I sort the information in the statement and determine what is relevant, I do not check that the answer makes sense,* and *I spend little time on problems I am not sure I can solve*. The reliability coefficient of the MCA-I was 0.91. The maximum and minimum scores that students can obtain are 135 and 27 respectively. All students took 15 mins to complete the instrument.

Procedure

At this stage, the researchers administered a pretest to both the control group (CG) and experimental group (EG). Subsequently, distinct treatments were provided. Students in the experimental class engaged in learning activities using the SSIBL method, while students in the control class pursued learning utilizing a conventional scientific approach. In the experimental class, the teacher explored students' knowledge, presented issues in the form of discourse regarding the use of salt in everyday life, and asked students to answer questions before carrying out experiments. Then, the teacher directed students to carry out experiments to determine the acidic and basic properties of various solutions, and guided students in carrying out experiments. The teacher then gave directions to students to process experimental data, directed students to make conclusions based on experimental results, guided students to make written reports, and directed students to make presentations on experimental results. Finally, the teacher evaluated the results of the experiment, concluded the learning and asked students to reflect. In the control class, the teacher instructed students to search for information from the internet, asked students to carry out experiments, instructed students to process data, and analyzed experimental data. Then, the teacher asked students to do exercises, lead discussions, and draw conclusions.

Data Analysis

Descriptive statistics were utilized to examine the data characteristics, including mean, standard deviation, minimum, and maximum scores. Kolmogorov-Smirnov and Levene's tests were conducted to assess the assumptions of normality and homogeneity, respectively. Following the examination of these assumption tests, it was found that both pretest and posttest scores exhibited normal and homogeneous distributions ($p > 0.05$). Consequently, the pretest and posttest data were deemed suitable for analysis using t-tests. An independent samples t-test was employed to ascertain whether statistically significant differences existed in the mean scores between the two sample groups. Additionally, a paired samples t-test was conducted to investigate the effect of SSIBL on students' metacognitive skills within each group. Furthermore, the increase in students' scores before and after treatment was computed using the effect size formula (*d*) (Cohen et al., 2018), with Cohen's d values indicating the magnitude of the difference between pretest and posttest scores. Inferential analysis was performed at a significance level of 0.05 using the statistical software SPSS 25.0.

RESULTS

In order to determine whether there was a significant difference in the mean scores between the CG and EG, the independent sample *t*-test was conducted. The results of the comparison of the pretest mean scores of the CG and EG are presented in Table 1.

Table 1. Independent Sample T-test Results for Pretest

Group	N	M	SD	*t*	*p*
Experimental	36	2.812	0.932	1.504	0.137
Control	36	2.760	1.360		

At the end of treatment, posttests were given to both groups. The results of the comparison of the mean posttest scores of the CG and EG are presented in Table 2.

Table 2. Independent Sample T-test Results for Posttest

Group	N	M	SD	*t*	*p*
Experimental	36	3.677	1.139	12.083	0.000
Control	36	3.302	1.123		

Tables 1 and 2 indicate that the significance value in the independent sample t-test for the pretest is 0.137 ($p > 0.05$). This suggests that there is no statistically significant gap between the initial metacognitive skills of CG and EG students before treatment. In testing the independent sample *t*-test for the posttest, a significance value of 0.000 is obtained. It can be suggested that there is a significant gap between the metacognitive skills of students in both groups after treatment.

The results of the paired sample t-tests for both the CG and EG are presented in Table 3. This analysis aimed to determine if there was a significant increase between the mean pretest and posttest scores of students' metacognitive skills in each group. Additionally, Cohen's d was calculated to assess the effect size of the observed changes.

Table 3. Paired Sample T-test Results of Control and Experiment Groups

Group		N	M	SD	*t*	*p*	Cohen's *d*
Experimental	Pretest	36	2.812	0.932	-27.357	0.000	0.831
	Posttest	36	3.677	1.139			
Control	Pretest	36	2.760	1.360	-15.620	0.000	0.434
	Posttest	36	3.302	1.123			

According to the results presented in Table 3, the significance value for both the CG and EG is 0.000 ($p < 0.05$). This indicates a statistically significant increase in the mean score of metacognitive skills in both the CG and EG after the treatment. Based on the calculation results, Cohen's *d* value in the EG was 0.831 indicating a moderate effect size. It can be concluded that socio-scientific issues-based learning has a moderate effect on improving students' metacognitive skills. Conversely, the Cohen's d value in the control group is 0.434, indicating a low effect size. This implies that the scientific approach has a relatively lower impact on improving students' metacognitive skills. Therefore, based on these findings, it can be concluded that SSIBL is more effective in enhancing students' metacognitive skills compared to the scientific approach.

DISCUSSION

This study effectively investigated the impact of socio-scientific issues-based learning (SSIBL) on the metacognitive skills of grade 11 students. The results of the independent t-test revealed a statistically significant difference in the metacognitive skills of students between the experimental group (EG) exposed to SSIBL and the control group (CG) exposed to the scientific approach. Notably, both CG and EG students demonstrated an increase in metacognitive skills, with the EG exhibiting the most substantial improvement. This underscores the positive influence of SSIBL on students' metacognitive skills. These findings are consistent with prior research (e.g., Dauer et al., 2017; Wu et al., 2022), further supporting the efficacy of SSIBL in enhancing students' metacognitive abilities.

The observation that students in both groups exhibited similar and relatively low levels of metacognitive skills prior to the intervention aligns with findings from the research conducted by Bursali and Öz (2018). Their study likely sheds light on factors contributing to the low metacognitive skills observed among students in the learning process. Identifying and understanding these factors can inform strategies to address and enhance students' metacognitive abilities, which is crucial for effective learning outcomes. This concludes that the learning model used so far has not been able to improve students' metacognitive skills. In addition, the learning model applied by teachers during the learning process is less efficient and effective (Trilling & Fadel, 2009). In general, teachers still use conventional learning and there are still few teachers who use the SSIBL. This conventional learning is teacher-centered which allows students to only listen to the teacher's explanation so that the classroom atmosphere becomes passive (Taber, 2013).

During the intervention, students in the EG received instruction using the SSIBL model, while those in the CG followed a scientific approach. Based on the results, there was an increase in the average score of metacognitive skills in the CG and EG before and after the intervention. This suggests that both SSIBL learning and the scientific approach positively influenced the enhancement of students' metacognitive skills regarding the topic of salt hydrolysis. However, based on the results of Cohen's *d* calculation, EG students experienced higher metacognitive skills improvement than the control class. The EG showed a medium effect size, while the CG showed a low effect size. Thus, it can be concluded that in enhancing students' metacognitive skills related to the topic of salt hydrolysis, the SSIBL model has a more pronounced effect than learning with a scientific approach.

In this study, there was a gap in the mean score of metacognitive skills of the CG and EG students, possibly because EG students received the SSIBL model. The SSIBL supports students to use metacognitive skills in learning activities to deal with relatively new problems (Zeidler et al., 2009), so that students' metacognitive skills increase during the intervention. This is in line with Downing (2010), who argues that students' use of metacognitive skills will increase if they receive social and scientific problem-based learning. On the other hand, students who receive the SSIBL encourage the development of their metacognitive skills. Through the SSIBL stages implemented in learning, especially the fifth stage, namely analyzing and evaluating the problem-solving process, students are encouraged to familiarize themselves with checking whether the final answer is in accordance with the learning objectives. This agrees with Papleontiou-Louca (2003) who states that students' metacognitive skills can improve when reflecting and evaluating their understanding of learning outcomes through learning activities. This shows that the metacognitive skills of students through the SSIBL model increase. Students with the teacher act as facilitators in the SSIBL to analyze group discussion answers during the intervention. At this stage, other students' responses and teacher guidance, can help students verify that their answers meet expectations.

In this study, EG students experienced a higher increase in metacognitive skills than the CG. This proves that students in the EG have applied planning skills well to solve problems. Through activities in SSIBL learning, students start learning about science issues. This activity is to find out what knowledge students already have related to the problems. Thus, students are encouraged to make plans during the problem-solving process. Wessinger (2004) revealed that when students are faced with a new problem, students will use their metacognition to develop a problem-solving plan. After students received SSIBL, the mean score increased. This increase was due to the practicum activities carried out by students in the EG using simple materials commonly found in everyday life. During this process, students asked questions and experimented with problems that arose during their studies. In a previous study, Celiker (2015) noted that in the process of identifying problems and designing experiments, students are involved in using and managing their cognition. Consequently, SSIBL has a positive impact on enhancing students' metacognitive abilities.

The increase in metacognitive skills may be due to the teacher as a facilitator, thus encouraging discussion between students by asking questions and making learning collaborative. This aligns with the perspective of Schraw et al. (2006) who argue that cooperation between teachers, students, and groups established through scientific discussion activities provides a stimulus for students to improve metacognitive skills. Also through procedural problems on worksheets in SSIBL, students' metacognitive abilities during the problem-solving process will increase. This notion resonates with Celiker's (2015) argument that engaging in problem-solving activities related to socio-scientific issues promotes the enhancement of students' metacognitive skills through advanced planning and problem-solving strategies.

In SSIBL learning, students are involved in complex situations with practicum activities and then present the results of the practicum activities to obtain information in problem-solving. This activity makes it easier for students to find mistakes and correct wrong or inaccurate answers. Through practicum, students' monitoring skills can be well developed. Schraw and Moshman (1995) argue that students' monitoring skills will improve well during the practicum process. In addition, the SSIBL learning context demands learner interaction with friends in small groups, as well as learner-teacher interaction in the context of problem-solving. This is in accordance with the opinion of Emily and Michaela (2012), that discussions between students can develop and improve metacognitive skills. Students are asked to monitor their understanding and learning process in order to realize mistakes in learning (Maduabuchi & Angela, 2016). This is also in accordance with the view of Schraw (2001), that students' metacognitive skills develop rapidly through direct interaction during the learning process. This is the reason why students in the EG have better metacognitive skills than the CG. The metacognitive skills can increase perhaps because students have the opportunity to reflect on what they have learned during the SSIBL process. This notion is consistent with Java's (2014) findings, which suggest that problem-based learning positively impacts students' metacognitive skills. Overall, the multifaceted nature of SSIBL, including practical activities, collaborative learning, and reflection opportunities, contributes to the enhancement of students' metacognitive abilities.

Based on the results of the analysis and discussion above, the effect size of the EG students' metacognitive skills indicators is in the medium category, while in the CG in the low category. Thus, the use of SSIBL has a positive impact on students' metacognitive skills on the topic of salt hydrolysis Jam et al., (2017). It is possible because the activity of the EG to regulate the cognition of students during learning is facilitated by SSIBL-based worksheets which can encourage students to involve their cognitive control. This finding is related to the research of Tosun and Erdal (2013), finding that learning related to social science problems has a positive impact on students' metacognitive skills. In addition, it is also in accordance with the findings of Kuvac and Koc (2018) which states that students who take part in learning activities involving the problem-solving process can improve metacognitive skills.

CONCLUSION

In summary, socio-scientific issues-based learning (SSIBL) shows a positive influence on the metacognitive skills of EG students. Based on the independent *t*-test analysis, there is a gap in metacognitive skills scores between the EG and the comparison group in favor of the intervention group ($p = 0.000$; <0.05). Based on paired *t*-test analysis, students in the EG also showed an increase in the mean score of metacognitive skills higher than the CG. SSIBL improved the metacognitive skills of EG students with a moderate effect size of 0.831. It can be concluded that the metacognitive skills of students in both groups increased significantly. However, the greatest improvement was found in the EG. In other words, SSIBL is more effective in elevating students' metacognitive skills than the scientific approach.

SSIBL has a positive influence on improving students' metacognitive skills. This is because the EG's activities to regulate their cognition during learning are facilitated with socio-scientific issues-based worksheets which can encourage students to involve their cognitive control. Apart from that, students are directly involved with social science problems which can provide students with interesting and relevant learning experiences to everyday life. SSIBL is proven to have a positive influence on improving students' metacognitive skills. Increasing students' metacognitive skills can have a positive influence on other students' cognitive aspects, especially in the problem-solving process.

According to the results, we put forward several recommendations. The socio-scientific issues-based learning (SSIBL) model can help teachers in presenting learning models that make it easier for students to solve chemical problems. Also, chemistry teachers can apply the SSIBL learning model to other concepts in chemistry, especially concepts that require students to actively participate in the process of solving chemical problems. Our study only investigated the effect of SSIBL on the topic of salt hydrolysis. Future research can apply SSIBL to other chemistry topics to get more comprehensive results. This research was only conducted for five meetings. Future research can analyze the effect of SSIBL on metacognitive skills with a longer research duration to obtain holistic findings. Lastly, this study only used a sample of 72 students. Future research can reach a wider sample in order to get results that can be more generalized.

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