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USING THE METACOGNITIVE STRATEGY WITH CONTEXT SOCIOSCIENTIFIC ISSUES TO ENHANCE STUDENTS' SCIENCE PROCESS SKILLS

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ABSTRACT

This research aimed to explore the effects of application of a metacognitive strategy using socioscientific issues (SSI) in context on students' science process skills. The metacognitive strategy consisted of four stages, namely: preparing, doing, checking, and assessing & following up, abbreviated as MS-PDCA. The method used was a quasi-experiment with a pretest-posttest control group design. This research involved three classes of the eleventh-grade mathematics and sciences program at a government secondary school, in Malang, Indonesia. Two experimental classes were taught using metacognitive strategy with context socioscientific issues (MS-PDCA SSI) & metacognitive strategy (MS-PDCA), while one control class was taught with expository strategy (ES). To evaluate students' progress, the Science Process Skills Test (r=0.823) was used as the research instrument. Data analysis techniques were carried out using the One *Way ANOVA test and* N-*gain & d-effectsize* analysis. The results showed that 1) students taught with the MS-PDCA SSI showed higher improvements in their science process skills compared to those taught with MS-PDCA strategy and ES. 2) MS-PDCA SSI learning strategy was found to be effective in improving students' science process skills, particularly when applied to learning materials that are related to daily life.

Key words:
metacognitive strategy, socioscientific issues, science process skills.

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INTRODUCTION

Background

The demands of the 21st century necessitate the active involvement of science and technology, along with inventive solutions founded on scientific exploration and reasoning. The focus of science education now revolves around enhancing crucial 21st century skills, which include *critical thinking*, *creativity*, *communication*, and *collaboration* (Redhana, 2019). However, the research by Amran et al., (2019) showed that 21st century skills in high school students were categorized as low. Therefore, the objectives of science education international focus on science literacy, which involves understanding scientific phenomena and explaining them scientifically (Holbrook & Rannikmae, 2009). To foster good quality science literacy skills, students need to be equipped with the ability to engage with scientific issues and ideas effectively, enabling them to make informed decisions when confronting everyday problems using scientific information and concepts (Chen & Osman, 2017).

A significant aspect of science learning lies in developing science process skills (Coil et al., 2010). Considering chemistry as an integral part of science, it is essential for chemistry education to be structured around the scientific process. This approach ensures that students not only gain knowledge of chemistry but also acquire and master the fundamental skills of scientific inquiry. Science process skills can be divided into two, namely basic and integrated skills. Basic science process skills include the ability to observe, classify, communicate, measure, predict, and infer. Meanwhile, integrated science process skills include the ability to identify and control variables, analyze relationships between variables, formulate hypotheses, interpret data, define operations, design experiments, conduct experiments, and compile graphs (Aydoglu, 2015; Chabalengula et al., 2012; Seetee et al., 2016; Vitty & Torres, 2006).

Irwanto et al. (2018) showed that students' basic and integrated science process skills were at medium and low levels, respectively. This deficiency may be attributed to inadequate teaching strategies that fail to develop students' science process skills effectively or connect chemical concepts to real-life contexts (Feyzioglu, 2009). The reality shows that the learning facilitated by the teacher in the classroom has not given students the opportunities to construct their understanding, for example, expository learning. In expository learning, students passively receive information from teachers. This kind of learning forces students to learn by rote memorization inhibits the development of critical thinking and meaningful learning, and results in superficial thinking (Paulson, 1999; Schrock & Benko, 2015). This strategy is often selected due to time constraints in covering the curriculum, leading to insufficient conceptual development among students. To address this challenge and enhance the quality of science process skills, employing metacognitive learning strategy proves to be a valuable approach.

Parlan et al. (2018a) developed a metacognitive learning strategy consisting of four stages, namely *preparing* (P), *doing* (D), *checking* (C), and *assessing and following up* (A), which is abbreviated as PDCA called PDCA metacognitive strategy (MS-PDCA). These stages facilitate meaningful learning by 1) establishing a connection between new material and existing knowledge, 2) fostering goal-directed learning, 3) encouraging student-centered learning, 4) promoting students to build their understanding, 5) promoting interaction and cooperation between students, 6) utilizing assessment as an instrument to measure students' complex ability to know the understanding and mastery of the material. Meaningful learning is further enhanced when concepts are related to real-life contexts, making metacognitive learning strategy suitable when supported by the context of *Socioscientific Issues* (SSI). Subsequently, SSI examines issues in social life based on science. SSI is very suitable to be used as a context in science learning because it can provide benefits including making science learning more relevant to daily life, improving learning outcomes, improving the ability to evaluate scientific information, and developing science literacy (Venville & Dawson, 2010; Yapicioglu, 2018; Zeidler et al., 2009).

Qamariyah et al. (2021) explored the combination of inquiry learning with SSI, yielding positive outcomes in improving *High Order Thinking Skills* (HOTS). By integrating metacognitive learning strategy with the SSI context, students can practice identifying scientific evidence within SSI contexts presented during learning, and engage in scientific investigations, essential for developing science process skills. Moreover, this strategy helps students to monitor their understanding and attitudes toward learning. Metacognitive learning strategy integrated with the SSI context can assist students in providing scientific explanations of chemical phenomena using macroscopic, submicroscopic, and symbolic representations (multiple representations). According to Sunyono & Sudjarwo (2018) and Widarti et al. (2019), learning through multiple representations can improve students' ability to explain, interpret, and represent chemical phenomena at the molecular level, thereby aiding them in solving chemical problems related to abstract concepts.

Chemistry encompasses numerous abstract and interconnected concepts, requiring a gradual and tiered learning approach. These abstract chemical concepts necessitate the application of three forms of chemical representation (macroscopic, submicroscopic, and symbolic) in helping construct a complete understanding of chemistry (Talanquer, 2011). Moreover, students' comprehension of one concept significantly influences their understanding of others, highlighting the importance of solid prior knowledge to facilitate the understanding of new concepts (Parlan et al., 2018b).

The use of SSI in learning has been widely carried out, among others by Saglam & Eroglu (2022), Pelch & McConnell (2017), Tsai et al. (2019), Türe et al. (2020), Tool et al. (2023), Uysal & Çaycı (2022), Karakaş (2022), and Khajornkhae & Nuangchalerm (2021). Efforts to improve students' science process skills have been carried out, among others, by Ping et al. (2020), Suryanti et al. (2020), Tan et al. (2020) and Senisum et al. (2022). The use of contextual teaching and learning in learning has also been widely done, including Berns & Erickson (2001), Glynn & Winter (2004), Curry et al. (2012), Ekowati et al., (2015), Mukwambo (2016), and Pangemanan (2020). However, the use of SSI as a context in metacognitive learning has not been reported. Therefore, it is necessary to explore the effects of application of a metacognitive strategy using SSI context on students' science process skills.

Literature Review

Science process skills play an important role in understanding the process of knowledge formation because knowledge is acquired through the scientific process. By cultivating these skills, students are better equipped to learn and develop a scientific mindset, ultimately influencing the growth of their knowledge. These skills enable students to access knowledge, select necessary knowledge, and generate new knowledge based on their inquiries (Aydin, 2013). Science process skills are important skills in conducting scientific investigations. Therefore, fostering science process skills is crucial to enhancing students' proficiency in the field of sciences/chemistry and promoting a deeper understanding of scientific principles.

Science process skills play a vital role in nurturing students' responsibility for learning and fostering an understanding of the significance of the scientific method in the learning process (Ongowo & Indoshi, 2013). These skills also offer numerous benefits, such as promoting an active understanding of concepts and enhancing problem-solving in daily life (Ozgelen, 2012; Tan et al., 2020). Moreover, Turiman et al. (2012) explained that science process skills and science literacy support and enhance 21st century skills, as well as facilitate students to explore their curiosity about chemistry/science and improves metacognitive abilities.

Metacognitive abilities play a crucial role in helping students build their understanding of concepts, organize and monitor their learning process, and develop higher order thinking skills about all the knowledge acquired. Subsequently, metacognition plays an important role in training students' higher order thinking skills to facilitate the problem-solving process. Students with high metacognitive abilities have high curiosity, are active learning needs in diagnosing their learning, are disciplined in monitoring and controlling learning activities, place the difficulties experienced as a challenge, and have high initiative in finding and utilizing relevant learning resources and in accordance with needs (Pillena et al., 2019). Metacognitive abilities play a crucial role in influencing students' involvement in the learning process, impacting what they learn, when they learn it, and how they approach the material. When students possess strong metacognitive skills, it positively influences their development of science process skills, leading to significant improvements in their overall learning outcomes. This is also supported by the results of research by Valencia-Vallejo et al. (2019), showing that students who have been equipped with knowledge related to metacognitive will have full awareness and responsibility in their learning activities and can make all decisions well.

According to Dori et al. (2018) high-intensity context-based science learning integrated with metacognitive clues can improve scientific understanding of texts. Metacognitive learning strategy aids students in recognizing both the limitations and benefits of their existing knowledge concerning the subject matter. This strategy empowers students to determine how to enhance their learning process, leading to construction of more meaningful knowledge. The quality of metacognitive abilities obtained from learning can improve the quality of experimental abilities, which are an important part of science process skills (Bruckermann et al., 2017).

Metacognitive learning strategy empowers students to effectively monitor and regulate their cognition, enabling a more streamlined problem-solving process driven by critical thinking (Lavi et al., 2019). This strategy supports an in-depth understanding of the material, leading to improved memory (Mutambuki et al., 2020). By employing metacognitive learning strategy, students learn to evaluate new knowledge by leveraging their existing knowledge, facilitating the comprehension process (Rickey & Stacy, 2000). One noteworthy approach to meaningful learning involves the use of the metacognitive learning strategy with SSI, which integrates real-life issues into the learning process and connects new knowledge with prior knowledge (Agra et al., 2019; Parlan et al., 2018a). This learning strategy aligns with important indicators of meaningful learning, which must meet several important components, namely: 1) students have the prior knowledge needed to understand new knowledge, 2) new knowledge must be meaningful and relevant to the knowledge that students have built, and 3) students can relate new knowledge to real life (Bretz, 2001; Novak, 2011). Subsequently, meaningful learning can begin by identifying learning objectives and outlining steps to be taken to achieve learning objectives. Core learning activities are carried out by involving self-control, which includes monitoring learning activities and learning effectiveness. Self-reflection is in the form of evaluating the achievement of learning outcomes and checking understanding of the results that have been achieved (Opstal & Daubenmire, 2017).

Metacognitive learning strategy facilitates students to increase their metacognitive awareness. Metacognitive awareness of students can be trained through metacognitive learning strategy oriented towards monitoring learning progress (Parlan et al., 2018b). Students with high metacognitive awareness will be disciplined in monitoring all information and findings obtained before, during, and after practicum activities. This is in line with research conducted by Saribas et al. (2013), which explained that metacognitive awareness played an important role in improving students' science process skills and understanding of concepts. Metacognitive awareness also contributes to developing students' ability to design experiments. It is also an indicator of science process skills including identifying variables, designing experiments, proposing hypotheses, and interpreting data (Handayani et al., 2021). Within the context of practicum activities, metacognitive awareness fosters constructive discussions among students, where they collectively refine experimental steps, ask relevant questions, and offer feedback on the practicum implementation (Saribas & Bayram, 2009). Moreover, metacognitive awareness aids students in self-reflection during the learning process. By using monitoring and evaluation indicators for self-reflection, students identify areas of improvement, allowing them to master important science process skills optimally (Veal et al., 2009).

Research Purpose

This research aimed to explore the effects of application of a metacognitive strategy with socioscientific issues (SSI) in context on students' science process skills. Specifically, we were intrigued to find out whether there are differences in students' science process skills learned with PDCA metacognitive strategy with context SSI (MS-PDCA SSI), PDCA metacognitive strategy (MS-PDCA), and expository strategy (ES).

METHOD

Research Design

The research design used was a quasi-experiment with a pretest-posttest control group *design* (Creswell, 2013). The population consisted of all students in the eleventh grade of the mathematics and sciences program at government secondary schools in Malang, Indonesia. This research involved three classes that received different treatments, namely experimental class 1 was taught with MS-PDCA SSI, experimental class 2 was taught with MS-PDCA, and the control class was taught using ES. The learning activities in the three classes are shown in Table 1. The research design is presented in Table 2.

Table 1. Learning activities in classes MS-PDCA SSI, MS-PDCA, and ES

Learning Activities	Learning Strategy		
	MS-PDCA SSI	MS-PDCA	ES
Introduction	The teacher opens the lesson	The teacher opens the lesson	The teacher opens the lesson
Core Activities	Phase 1: *Preparing* Students learn the learning material and determines learning objectives Students identify important concepts to be learned and previously relevant concepts that have been understood, make summaries, and lists questions to be proposed in the classroom The teacher provides SSI articles to students. The teacher directs students to understand, analyze, and find solutions to SSI	Phase 1: *Preparing* Students learn the learning material and determines learning objectives Students identify important concepts to be learned and previously relevant concepts that have been understood, make summaries, and lists questions to be proposed in the classroom	Phase 1: *Preparation* The teacher prepares class (students and learning materials) systematically.
	Phase 2: *Doing* Students actively learn in class (presentations, discussions, questions and answers, practicums, and making notes or learning summaries)	Phase 2: *Doing* Students actively learn in class (presentations, discussions, questions and answers, practicums, and making notes or learning summaries)	Phase 2: *Apperception* The teacher asks about previous material to check students' preparation in accepting new material
	Phase 3: *Checking* Students check or monitor their learning progress Students identify difficulties encountered during learning and find alternative solutions assisted by the teacher	Phase 3: *Checking* Students check or monitor their learning progress Students identify difficulties encountered during learning and find alternative solutions assisted by the teacher	Phase 3: *Presentation* The teacher presents the material with the lecture method or asks students to read the prepared study material
	Phase 4: *Assessing & Following Up* The teacher assesses students' learning progress and evaluate whether learning objectives have been achieved (verbal or written) The teacher orients students to plan the next learning activity	Phase 4: *Assessing & Following Up* The teacher assesses students' learning progress and evaluate whether learning objectives have been achieved (verbal or written) The teacher orients students to plan the next learning activity	Phase 4: *Evaluation* The teacher asks questions and students answer according to the material learned or students formulate or answer in their own words according to the subject known as applying (*application*). The teacher asked students to present the results of the discussion in front of the class and conclude (*generalization*)
Closing	The teacher ends the lesson and gives a closing greeting	The teacher ends the lesson and gives a closing greeting	The teacher ends the lesson and gives a closing greeting

Table 2. Research design

Subject	Pretest	Treatment	Posttest
E1	O_1	X_1	O_2
E2	O_1	X_2	O_2
C	O_1	X_3	O_2

Information:
E1: Experimental class 1
E2: Experimental class 2
C: Control class
X_1: Learning with MS-PDCA SSI
X_2: Learning with MS-PDCA
X_3: Learning with ES
O_1: *Pre-test* using the science process skills test
O_2: *Post-test* using science process skills test
All students in both experimental classes (E1 and E2) and control class (C) were given a pre-test (O_1) and post-test (O_2) with the same instrument, namely the Science Process Skills Test. The pre-test is given before learning and the post-test is given after attending learning.

Participants

This research involved 96 students of eleventh grade mathematics and sciences program at government secondary schools in Malang, Indonesia, who had the same abilities of science process skills (p=0.955; *sig.*>0.05) (see Table 9), and were divided into three classes with cluster random sampling technique, namely experimental class 1 (learned with MS-PDCA SSI), experimental class 2 (learned with MS-PDCA), and control class (learned with ES). Details of students in experimental class 1, experimental class 2, and control class are presented in Table 3.

Table 3. Details of students in experimental class 1, experimental class 2, and control class

Classes	Students	
	Male	Female
Experimental Class 1	12	20
Experimental Class 2	12	20
Control Class	11	21

Research Instruments

In this research, the instrument used is the Science Process Skills Test (SPST) ($r_{\text{Cronbach Alpha}}$=0.823) to measure students' science process skills on the *pre-test* and *post-test.* It comprises of multiple choice test consisting of 25 items, each focusing on indicators of basic science process skills (observe, predict, measure, classify, communicate, and infer) and integrated science process skills (identifying and controlling variables, formulating hypotheses, and conducting experiments) adapted from Chabalengula et al. (2012) and Rezba et al. (2007).

Data Analysis

Students' answers were given a score of 1 for correct answers and 0 for incorrect answers. The total scores for all students' answers were then computed, and the percentage of achievement was calculated using the following formula:

$$\text{\% Students' Achievement} = \frac{\text{Total Scores Obtained}}{\text{Maximum Scores}} \text{ X } 100$$

The results of calculating the percentage of students' achievement are then classified into several categories as shown in Table 4.

Table 4. Science process skills criteria (Arikunto, 2015)

Percentage	Category
0–20%	Very low
20–40%	Low
40–60%	Enough
60–80%	High
80–100%	Very high

The improvement of students' science process skills was tested with One Way ANOVA and LSD *Post-hoc Test* to determine whether there were differences between research classes. To assess the impact of the implemented learning strategies on students' science process skills, N-gain and d-effect size analyses were conducted. The N-gain, denoted by <g>, is calculated using the formula proposed by (Hake, 1998):

$$\langle g \rangle = \frac{post - test - pre - post}{100 - pre - test}$$

Information:
<g>= *N-gain*
Posttest= Post-test score
Pretest= Pre-*test score*

The N-gain is categorized according to the criteria presented in Table 5.

Table 5. N-gain criteria (Hake, 1998)

N-gain	Category
<g>>0.8	High
0.3<<g><0.8	Medium
<g><0.3	Low

The *d-effect* size criterion is taken based on the impact size category of the learning strategy presented in Table 6 (Leech et al., 2015).

Table 6. Criterion of d-effect size (Leech et al., 2015)

d-effect size	Category
d≥0.90	Much larger than usual
0.70≤d<0.90	Bigger than usual
0.40≤d<0.70	Regular or medium
d<0.40	Smaller than usual

RESULTS

In this research, the hypotheses tested are as follows 1) there were significant differences in the science process skills among students taught with MS-PDCA SSI, MS-PDCA, and ES; 2) the science process skills of students taught with MS-PDCA SSI are higher than those taught with MS-PDCA and ES.

To evaluate the normality of the initial ability (*pre-test*) and final ability (*post-test*) data regarding students' science process skills, the *Kolmogorov Smirnov's One-Sample* test was used. The results of the normality test of *pre-test* and *post-test* data of students' science process skills of MS-PDCA SSI, MS-PDCA, and ES classes are shown in Table 7.

Table 7. Pre-test and post-test data normality test for students' science process skills

Classes		N	Average	SD	Sig.	Information
MS-PDCA SSI	Pre-test	32	37.38	10.87	0.067	Normal
	Post-test		87.63	7.513	0.137	Normal
MS-PDCA	Pre-test	32	37.75	8.55	0.146	Normal
	Post-test		81.00	10.60	0.065	Normal
ES	Pre-test	32	38.12	10.15	0.200	Normal
	Post-tests		70.38	8.18	0.113	Normal

Based on Table 7, it is known that the pre-test and post-test data of students' science process skills in all classes are normally distributed. The results of the homogeneity test of the pre-test and post-test science process skills of MS-PDCA SSI, MS-PDCA, and ES are shown in Table 8.

Table 8. Data homogeneity of pre-test and post-test students' science process skills

	α	Sig. (2-tailed)	Criteria	Information
Pre-test	0.05	0.352	α<*Sig.*	Homogeneous
Post-tests	0.05	0.063	α<*Sig.*	Homogeneous

Based on the data in Table 8, it is known that the pre-test and post-test of students' science process skills in all classes were homogeneous.

Average Similarity Test

The pre-test difference test of science process skills was carried out using parametric statistics *One-Way ANOVA test*. The results of the pre-test science process skills difference test are shown in Table 9.

Table 9. One-way ANOVA pre-test science process skills

	Sum of Squares	df	Mean Square	F	Sig.
Between-group	9.000	2	4.500	0.046	0.955
Within group	9137.000	93	98.247		
Total	9146.000	95			

Table 9 shows that there was no difference in the pre-test scores of science process skills of experimental and control classes (p=0.955, *sig.*>0.05).

Science Process Skills Post-test Data

The description of the percentage of science process skills achievement is shown in Table 10.

Table 10. Description of Science Process Skills Achievement

SPS' Aspect	% Achievement			Category		
	MS-PDCA SSI	MS-PDCA	ES	MS-PDCA SSI	MS-PDCA	ES
Classifying	96.87	100	100%	Excellent	Excellent	Excellent
Observe	79.68	75	56.74%	Good	Good	Enough
Measure	90.62	73.43	53.12	Excellent	Good	Enough
Predict	90.62	85.93	93.75	Excellent	Excellent	Excellent
Identify and control variables	90.62	95.31	54.68	Excellent	Excellent	Enough
Analyze relationships between variables	70.31	53.12	59.37	Good	Enough	Enough
Formulating hypotheses	95.83	86.45	88.54	Excellent	Excellent	Excellent
Design an experiment	90.62	88.54	81.24	Excellent	Excellent	Excellent
Conduct experiments	75	81.25	84.37	Good	Excellent	Excellent
Interpret data	80.48	71.87	74.99	Excellent	Good	Good
Create a chart	100	68.75	78.12	Excellent	Good	Good
Conclude	96.87	98.43	93.87	Excellent	Excellent	Excellent
Average	80.57	75.38	72.13			

The achievement of science process skills in the MS-PDCA SSI class (80.57%) was higher than the MS-PDCA class (75.38%) and ES class (72.13%). These results showed that MS-PDCA SSI has a better impact than MS-PDCA and ES. The results of the One-Way ANOVA Post-test Science Process Skills are shown in Table 11.

Table 11. One-way ANOVA post-test science process skills

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	4846.333	2	2423.167	31.549	0.000
Within group	7143.000	93	76.806		
Total	11989.333	95			

Based on the data in Table 11, it is known that there are differences in post-test students' science process skills in classes MS-PDCA SSI, MS-PDCA, and class ES. LSD test results and post-test data on students' science process skills, are shown in Table 12.

Table 12. LSD test of science process skills

Class	Class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
MS-PDCA SSI	MS-PDCA	6.625	2.191	0.003	2.27	10.98
	ES	17.250	2.191	0.000	12.90	21.60
MS-PDCA	MS-PDCA SSI	-6.625	2.191	0.003	-10.98	-2.27
	ES	10.625	2.191	0.000	6.27	14.98
ES	MS-PDCA SSI	-17.250	2.191	0.000	-21.60	-12.90
	MS-PDCA	-10.625	2.191	0.000	-14.98	-6.27

Table 12 shows that: 1) there are differences in students' science process skills taught with the MS-PDCA SSI strategy with MS-PDCA classes; 2) there are differences in students' science process skills taught with the MS-PDCA SSI strategy with ES; 3) there are differences in the science process skills of students taught with MS-PDCA with ES.

Table 12 also shows which class has better science process skills, judging by the mean difference between the two pairs of classes. Students taught with MS-PDCA SSI had an average difference in science process skills scores of 6.625 higher than students in classes taught with MS-PDCA and 17.250 higher than ES classes. Students in the MS-PDCA class had an average score difference of 10.625 higher than ES class.

Impact of Learning Strategy on Science Process Skills

The impact of learning strategy on students' science process skills is known from the *N-gain* and *d-effect size* in each class. *N-gain* is used to identify how effective learning strategy is in the three classes (SM-PDCA SSI, SM-PDCA, and ES). The determination of the *N-gain* category is adjusted based on Table 13. Table 13 shows the *N-gain* values for students' science process skills in these three classes, allowing for a better understanding of their learning outcomes.

Table 13. N-gain science process skills

Score	Class MS-PDCA SSI			Class MS-PDCA			Class ES		
	Pre-test	Post-test	N-gain	Pre-test	Post-test	N-gain	Pre-test	Post-test	N-gain
Average	37.38	87.63	0.80	37.75	81.00	0.69	38.13	68.36	0.52
Maximum Score	56	100		48	100		56	88	
Minimum Score	16	72		24	60		16	56	
Number of students (N)	32	32		32	32		32	32	

Table 13 shows that *N-gain* in students' science process skills in SM-PDCA SSI class (0.80) is categorized as high, SM-PDCA class (0.69) is categorized as medium, and ES (0.52) is categorized as medium. The results of the *calculation of the d-effect size* of science process skills of experimental and control class students are shown in Table 14.

Table 14. D-effect size science process skills

Score	Class MS-PDCA SSI			Class MS-PDCA			Class ES		
	Pre-test	Post-test	d-effect size	Pre-test	Post-test	d-effect size	Pre-test	Post-test	d-effect size
Average	37.38	87.63	5.46	37.75	81.00	4.48	38.13	70.38	3.49
Deviation Standard	10,87	7,13		8,55	10,60		10,15	8,18	
DS_{pooled}	9.19	9.19		9.63	9.63		9.22	9.22	
Number of students	32	32		32	32		32	32	

Table 14 shows the *d-effect size* scores of students' science process skills taught with MS-PDCA SSI, MS-PDCA, AND ES classes. The results indicated that the effect sizes observed in these categories were significantly larger than what is typically expected. Based on d-effect size data, it is known that the three strategies have a very strong impact on improving students' science process skills, but the MS-PDCA SSI strategy has the strongest impact compared to MS-PDCA and ES.

DISCUSSION

Science process skills play a vital role in supporting students' comprehension of scientific concepts. After conducting post-tests, notable differences were observed in the science process skills of students taught with three different approaches: MS-PDCA SSI, MS-PDCA, and ES. Based on data on the acquisition of *N-gain* and *d-effect size* MS-PDCA SSI is considered effective in improving science process skills when compared to MS-PDCA and ES.

The "preparing" stage of these learning strategies (MS-PDCA SSI and MS-PDCA) directs students to keep a learning journal before learning activities are carried out. This journal involves identifying learning objectives, essential concepts, unclear concepts, and prior knowledge required for building new understandings. The teacher verifies and monitors students' prior knowledge during this stage to facilitate the process of constructing new understanding. At this stage, students' prior knowledge is monitored and verified by the teacher before stepping into learning to help facilitate the process of constructing new understanding. Furthermore, at this stage students can also monitor their learning activities, such as evaluating the extent of understanding that has been built, which can be identified through asking questions. Therefore, to support the learning process carried out by students, the teacher must always be active and disciplined in providing learning motivation to foster and increase metacognitive awareness to students to be able to achieve the learning goals set.

The teaching of science/chemistry is not only results-oriented, but it also emphasizes the importance of the learning process itself. To achieve this, engaging in learning activities are essential to stimulate students' active participation. In the "doing" stage, students are directed to be actively involved in learning activities such as discussions, questions and answers, presentations, and practicums. The existence of the SSI context presented in learning can make chemistry learning more relevant to phenomena encountered in daily life and attract students' learning interest. Metacognitive strategy combined with SSI context can further enhance students' curiosity, fostering a positive attitude towards science and chemistry. One form of learning activity in metacognitive learning strategy in SSI context is practicum. This kind of learning activity can stimulate students' curiosity as a form of the scientific attitude of a scientist. Subsequently, practicum activities carried out can facilitate students to be able to design a scientific investigation guided by the scientific method by emphasizing inquiry or discovery processes. These scientific investigation activities can train students' science process skills. Some important indicators of science process skills that can be developed are classifying, observing, measuring, predicting, identifying and controlling variables, analyzing relationships between variables, formulating hypotheses, designing experiments, conducting experiments, interpreting data, graphing, making inferences, and communicating (Chabalengula et al., 2012; Rezba et al., 2007; Vitty & Torres, 2006). Moreover, scientific investigation activities lead to meaningful learning experiences, validating the concepts they have learned. This is also reinforced by previous research explaining that laboratory inquiry activities carried out in learning can improve students' science process skills (Hırca, 2012; Reynders et al., 2019; Yadav & Mishra, 2013). In the metacognitive learning strategy with context SSI class and the metacognitive learning strategy without context SSI class instruct students to independently design experiments in groups on the topic of factors affecting reaction rate. This can spur students to think critically, creatively, and collaborate in groups. In contrast, the expository strategy provides students with pre-defined experimental procedures, limiting their opportunities for critical thinking, creativity, and collaborative efforts. Based on this information, it can be thought that metacognitive learning strategy with context SSI and metacognitive learning strategy are very suitable for new paradigm learning whose learning activities lead students to be actively involved and practice 21st century skills that are very important to use for the problem-solving process in life.

Metacognitive abilities are crucial for successful practicum activities and laboratory inquiries. This can be shown at several stages of laboratory inquiry, namely: 1) In the problem formulation stage, metacognitive abilities come into play as students propose problem formulations, drawing upon their declarative knowledge, personal thoughts, or group discussions. 2) When designing experiments, students can apply their procedural knowledge by thinking logically and systematically in compiling experimental steps in accordance with the concepts that have been learned. 3) When conducting experiments and changing experimental designs, students can apply their cognition regulation planning to find appropriate problem-solving. 4) At the final stage of laboratory inquiry activities, namely writing reports and drawing conclusions, students can apply their conditional knowledge. 5) During laboratory inquiry activities, students can apply monitoring and evaluation to their cognitive processes (Kipnis & Hofstein, 2008). The effectiveness of metacognitive abilities in laboratory inquiry is reflected in students' achievement of science process skills and concept understanding. Higher metacognitive abilities correlate with greater success in laboratory inquiry activities (Saribas & Bayram, 2016). It can be inferred that students' metacognitive abilities are needed in carrying out practicum activities or laboratory inquiry. As a result, by the end of the learning process, classes taught with MS-PDCA SSI and MS-PDCA show significant improvement in science process skills achievement.

The integration of SSI context on metacognitive learning strategy interests and motivates students' learning. SSI context presents issues in social life that are controversial and related to science. SSI context in the metacognitive learning strategy with SSI context is presented at the "doing" stage. At this stage, students are directed to analyze and evaluate SSI articles to find appropriate problem-solving, and the integration of SSI in learning is a form of implementation of contextual learning, which can improve students' higher-order thinking, decision-making, and problem-solving skills (Qamariyah et al., 2021). Contextual approaches applied in learning can improve creativity and integrated science process skills (identifying and controlling variables, analyzing relationships between variables, formulating hypotheses, designing experiments, conducting experiments, and interpreting data) (Holbrook, 2014; Istijabatun et al., 2016; Ngozi, 2018). SSI context presented in learning can train students' 21st century skills. This is supported by the results of research by Susilawati et al. (2021), which showed that SSI integrated into learning can improve several students' soft skills such as the ability to collaborate, problem-solving, communication, creative thinking, and social interaction, as well as work together in teams. A strong correlation exists between high soft skills and competent science process skills, as emphasized by the MS-PDCA SSI strategy. This approach enables students to apply their soft skills adeptly when tackling problems in the laboratory, unlike traditional expository classes that lack connections to real-life contexts. This does not occur in expository classes that do not connect learning material with contexts in daily life. This observation aligns closely with multiple prior investigations, which emphasize that the incorporation of SSI as a crucial aspect of context-based learning fosters the development of a scientific mindset among students (Calik & Karatas, 2019; Wiyarsi et al., 2021). The involvement of SSI has a positive impact on basic and integrated science process skills to support increasing effectiveness and efficiency in learning. Subsequently, SSI's controversial texts locally, nationally, and globally attract students' motivation and interest in learning. Based on the analysis conducted on SSI context, it can foster a mindset to students that chemistry is closely related to life and provides positive benefits in supporting the problem-solving process. Therefore, the integration of SSI in metacognitive learning strategy can make learning meaningful. Learning orientation does not only focus on understanding concepts but also on how students can apply concepts that have been built in solving problems presented, specifically in laboratory inquiry activities, thereby facilitating the learning implemented, which can be stored in long-term memory.

Classes that are treated with expository strategy have several characteristics, such as being teacher-centered, lack of interaction between students, passive learning among students, and monitoring of students' learning activities is rarely carried out (Nasution, 2020). Expository strategy exhibits several shortcomings, primarily being confined to students with strong auditory skills, lacking the means to track individual comprehension progress, and offering limited support for students' development of 21st century skills (Udo, 2011; Udoh & Udo, 2020). Consequently, this type of learning falls short in facilitating critical, creative, and collaborative thinking. Students in the expository strategy class are also given Independent Learning Activity Unit (ILAU) facilities to support the learning process. ILAU used by students in learning has a scientific approach that introduces students to the scientific method (Utami & Murti, 2018). However, despite the use of ILAU, expository learning strategy fails to actively engage students in the learning process, which limits their effectiveness in improving science process skills. Effective science (chemistry) learning should emphasize the process of concept construction and actively involve students in the learning experience.

CONCLUSION

In conclusion, based on the results of the comprehensive analysis and discussion as well as a review of relevant literature, the following conclusions were formulated. 1) Students taught with MS-PDCA SSI showed significant improvement in students' science process skills than students taught with MS-PDCA and ES. 2) The implementation of MS-PDCA SSI learning strategy proved to be highly effective in enhancing students' science process skills.

The limitation of this study lies in the research method. This study only involved a small group of students from one school, so it is necessary to conduct studies that involve more students so that the impact can be observed more deeply.

MS-PDCA SSI strategy utilizes socioscientific issues as a learning context. So, this strategy was particularly well-suited for teaching materials related to daily life and real-world applications. If the teacher wants to implement this strategy, materials related to students' daily lives should be selected.

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