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The Effects of Collaborative Inquiry Learning on the Metacognitive Awareness of Prospective Science Teachers

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This study investigates the effects of collaborative inquiry learning on metacognitive awareness of prospective elementary school teacher with different self-regulated learning (SRL) behaviours. A quantitative approach with a quasi-experimental design was used in this study. A total of 149 students of elementary school teacher education programs are involved as research subjects. In the research process, the experimental class is taught with the collaborative inquiry learning approach and the control class with the conventional teaching approach. Metacognitive awareness post-test data were analysed using analysis of variance. There are three findings in this study, namely: 1) there is a significant difference between the metacognitive awareness of students being taught with the collaborative inquiry learning approach and the conventional teaching approach; 2) there is a significant difference in metacognitive awareness between students with high and low self-regulated learning (SRL); 3) there is a significant interaction between different teaching approaches (collaborative inquiry learning & conventional learning) and SRL behaviour (high and low) on students' metacognitive awareness. This result recommends that teachers consider aspects of self-regulation and social regulation when applying collaborative inquiry learning to increase metacognitive awareness.

Keywords: *Collaborative Inquiry Learning, Metacognitive Awareness, SRL, Pre-Service Elementary Science Teachers*

Introduction

Current science educational reforms encourage student-centred active learning in several ways, including targeting the importance of self-based interest expression, encouraging collaboration, instilling diversity and subjectivity, and developing critical thinking skills (Avanesyan, 2019). However, to achieve this, learning needs to facilitate knowledge, skills, and self-control of the cognitive system. Students need to be trained to set learning strategies, monitor and understand each stage of the task, assess learning progress, control thinking, optimise performance, and reflect on learning outcomes. Primarily, learning outcomes focus on aspects of knowledge, as well as students' awareness and ability to construct meaning. This is because awareness and ability are related to metacognition (Akyol & Garrison, 2011).

Metacognitive awareness does not appear instantly in students but needs support through active and meaningful learning (Aisyafahmi et al., 2019). Teachers with a high level of metacognitive awareness also have substantial reflective thinking (Adadan & Oner, 2018). For this reason, they can create learning environments that improve metacognitive awareness, helping them to be role models for students and take responsibility for their metacognitive awareness (Azizah & Nasrudin, 2018).

Previous research showed that teachers involved in active learning are motivated to plan and instil meaningful learning to their students (Adadan & Oner, 2018). Therefore, prospective teachers need to be taught active and meaningful learning (Bautista & Cipagauta, 2019). Active learning involves collaborative inquiry that fulfils metacognitive awareness (Kuvac & Koc, 2019). It helps students with different background knowledge, experiences, values, attitudes, and behaviours to work together, share ideas, unite vision, and make mutual agreements (Gillies et al., 2013; Hadwin et al., 2018; Järvelä et al., 2013).

Inquiry activities involve students in making observations or investigations, asking questions, formulating problems, making hypotheses, conducting an experiment, building arguments, considering the evidence, and drawing conclusions (Gijlers et al., 2009; Gillies et al., 2013). Using joint inquiry activities, students carry out cognitive, epistemic, and social processes as scientists do (Lee & Songer, 2003).

Previous researches focused on the development of knowledge, and some even used quasi-experimental designs to test the effectiveness of collaborative inquiry learning (e.g. Raes et al., 2012; Roseth et al., 2008; Springer et al., 1999). The recent research also examines the regulation and patterns of social interaction in collaborative learning (e.g., Isohätälä et al., 2017; Järvelä et al., 2016; Kim & Lim, 2018; Näykki et al., 2017).

Although many empirical studies show that collaborative inquiry learning has enormous benefits, the application of inquiry-based learning in groups has not been effective (Jiang & McComas, 2015; Woods-McConney et al., 2014, 2016). Dillenbourg (1999), stated that the core of collaborative learning is not only in the process of cooperating but also in the cognitive phase. These processes require negotiation of meaning and mutual understanding in developing knowledge.

Studies also show that collaborative learning needs to be focused on inquiry skills by considering pedagogical aspects, self, task, and social regulation (Järvelä et al., 2013; Lämsä et al., 2018; Saab et al., 2012). According to these studies, joint learning efforts need to be encouraged by self-will, such as motivation, emotion, cognition. These three behaviours are part of SRL, which also supports metacognitive awareness. SRL is not only seen as a process of planning, controlling, and regulating learning independently, but also helps students to develop interacting skills (Zimmerman, 2015).

The success of collaborative inquiry learning needs to be supported by proper management (Yoon et al., 2018). This can be made on aspects of learning behaviour and structures, such as socio-cognitive settings. To support collaborative inquiry learning, managements help improve performance and skills (Lin & Reigeluth, 2016). Several previous studies have focused on cognitive support in collaborative learning (Rummel et al., 2012). This study uses socio-cognitive regulatory support to enhance metacognitive awareness in collaborative inquiry learning. There are no studies on the effects of socio-cognitive regulatory support and SRL on metacognitive awareness in collaborative inquiry learning.

Metacognitive awareness is needed to prepare prospective teachers to discharge their responsibility in the future effectively. According to Kuvac and Koc (2019), teachers using metacognitive skills effectively motivate students to regulate metacognition. There are two components of metacognition used as a basis for measuring awareness, including cognition knowledge and regulation (Flavel,1979). Cognition knowledge includes declarative, procedural, and conditional skills. Regulation of cognition is based on the ability of students to regulate and control their cognitive activities, which can be identified from the planning, monitoring, and evaluation stages. To support both components, socio-cognitive regulation is needed in collaborative inquiry learning (Hogan, 1999). It involves granting access to personal resources, interactive processes, roles, and group norms.

Metacognitive awareness is needed to deliver elementary school teacher candidates to understand, plan, and monitor their cognitive processes. This is not only for their learning needs but also for the future of their generation. This can be achieved if they are trained to be involved together in planning, designing, and experiment. Therefore, this study aims to investigate the effects of collaborative inquiry learning and SRL on the metacognitive awareness of prospective elementary school science teacher. Specifically, the research problem is formulated as follows:

RQ1: Are there differences in metacognitive awareness between students being taught collaborative inquiry learning approach and conventional teaching approach?
RQ2: Are there differences in metacognitive awareness between students with high SRL and low SRL?
RQ3: Are there interactions between collaborative inquiry learning and SRL with metacognitive awareness?

Method

Design

The study uses a quantitative approach with a quasi-experimental design. The 2x2 factorial nonequivalent control group design was used to analyse data. The research design is shown in Table 1.

Table 1: Research Design with 2x2 Factorial ANOVA

SRL Skills (Y)	**Learning Approach (X)**	
	Collaborative Inquiry (X1)	**Conventional Learning (X2)**
High (Y1)	Group A (X1Y1)	Group C (X2Y1)
Low (Y2)	Group B (X1Y2)	Group D (X2Y2)

The research process consisted of pre-test, treatment, and post-test. The experimental class (X1) used a collaborative inquiry learning approach, while the control class (X2) used conventional learning approach. Before using in both classes, SRL was measured through a questionnaire and classified into two categories, including high (Y1) and low (Y2). At the end of the experiment, students were given a metacognitive awareness questionnaire. To keep quasi-experimental results valid, other variables affecting the dependent variable were tightly controlled during the research process.

Participants

A total of 149 students of the Elementary School Teacher Education program at the Khairun University in Ternate Indonesia participated in this research. These were first-year students learning basic science courses. They were divided into four classes A, B, C, and D, each with 36-38 students with the same ability. In this study, they were further divided into two classes. The experimental classes (A = 36 and B = 38), were treated used collaborative inquiry learning while control classes (C= 38 and D= 37) utilised the traditional teaching approach. This distribution was carried out randomly based on metacognitive awareness pre-test scores, and the information from personal identity form (FIP). Both classes were declared equivalent based on independent sample test results, with pre-test "t" scores in experimental and control groups which is t (149) = 1,031 p> 0.05. FIP data shows that the average age between the experimental and control group is 22 years. However, Parents economical background was at the lower middle level, while those with the educational level was in the low category

Data Collection

Data were collected through three instruments, including:

Personal Identification Form (PIF)

PIF is distributed to students a week before the lecture, with the aim to obtain data about the personal information which includes name, gender, origin, address, educational status, and parent's occupation. This data was analysed to show the similarity between experimental and control groups.

Self Regulated Learning

The questionnaire was used in measuring student's SRL, and its instrument substantively includes setting-in cognitive, motivation, and learning skills or strategies (Zimmerman, 2015; Zimmerman, et al., 2002; Erdogen & Senemoglu; 2015). The SRL consists of 60 items using a 5-point Likert scale ranging from 1 (never) to 5 (always). Furthermore, total scores range from 60 to 300, where larger scores represent greater skills. The instruments were arranged in Indonesian and adjusted to the various students' characteristics, social conditions, cultures, and education. Also, to ensure the instrument is ready for use, a validity and reliability test was conducted. The results show the instrument is feasible to use with a correlation coefficient greater than 0.3 and a Cronbach alpha value greater than 0.7 (Cohen, 1988). Subsequently, the instruments were distributed to students to be filled out before lecturing activities begin. The SRL filling results were analysed to classify students into high and low categories.

Metacognitive Awareness

Student metacognitive awareness was assessed before and after the intervention, and instruments were arranged in the form of questionnaires adapted from existing instruments such as the Inventory MAI (Schraw & Dennison, 1994). Substantially, the metacognitive awareness questionnaire consists of three components, such as declarative, procedural, and cognitive knowledge. The awareness instrument was limited to only 45 items using a five-point Likert scale (5 = always; 4 = often 3 = sometimes; 2 = rarely 1 = never). Moreover, the highest and lowest scores obtained from the intervention were 225 and 45, respectively. Thus, as the score increases, the awareness level also increase. To ensure the instrument is ready for use, a validity and reliability test was conducted, and the internal consistency coefficient of alpha Cronbach for the original MAI version was 0.96 (Schraw & Dennison, 1994). Therefore, Cronbach's alpha coefficient for metacognitive awareness was calculated at 0.89, which showed the instrument was feasible

Data Analysis

Data obtained in the study were analysed descriptively and inferentially. Descriptive data is collected, arranged, and processed systematically to calculate the average pre-test, post-test, and test the normality and homogeneity of variance. Factorial ANOVA was used to examine the statistical differences between the two conditions in metacognitive awareness with the help of SPSS for Windows Version 21. The distribution normality test uses the Lilliefors Significance Correction from Kolmogorov-Smirnov, while the variant homogeneity determination uses the Levene's test. The decision to state if the group's data distribution is normal and if the variance between the groups is homogeneous is based on a significance level of 5% or $\alpha = 0{,}05$. If the significance level is more than 5% ($\alpha = 0{,}05$), the distribution is declared normal, and the variance homogeneous.

Results

This study consisted of two categories of students, the ones taught using collaborative inquiry learning models with socio-cognitive support (experimental) and those taught without it. Metacognitive awareness is the impact of both treatments, while SRL is a moderator variable which is categorised into two, high and low. This category is based on the acquisition of values measured using a questionnaire. Before ANOVA inferential statistical tests are performed, normality and homogeneity tests are first determined. The test results were explained in tables 4, 5, and 6.

Table 4 showed pre-test, and post-test score data in metacognitive awareness were usually distributed. This is based on the Kolmogorof Smirnof test results from pre-test and post-test scores with significance values of 0.475 and 0.067.

Table 4: Kolmogorov-Smirnov test results on the pre-test and post-test scores of the metacognitive awareness in the experimental and control groups.

Independent Variable	N	Mean	Std.D	Kolmogorov-Smirnov Z	p
Metacognitive Awareness (Pre-test)	149	102.208	9.950	0.844	0.475
Metacognitive Awareness (Post-test)	149	128.074	13.258	1.302	0.067

Table 5 presents Levene test results on the pre-test and post-test scores obtained by the experimental and control groups on the metacognitive awareness scale. Homogeneity results showed the significance value of the metacognitive awareness in pre-test and post-test was 0.094 and 0.156, respectively. This value indicates the data have homogeneous variation between the treated groups.

Table 5: Levene test results on the pre-test and post-test scores of metacognitive awareness in the experimental and control groups.

Independent Variable	**F**	**df1**	**df2**	**Sig.**
Metacognitive Awareness (Pre-test)	2.170	3	145	0.094
Metacognitive Awareness (Post-test)	1.765	3	145	0.156

Table 6 presents the results of independent sample t-tests for the pre-test scores in experimental and control groups. The metacognitive awareness equality obtained a significance value of 0.304 pre-test. Therefore it showed that experimental and control group data have an average equivalence.

Table 6: T-test results for the metacognitive awareness pre-test scores in the experimental and control groups.

	Treatment	**N**	**M**	**SD**	**t**	**df**	**p**
Metacognitive Awareness (Pre)	Experiment	74	103.054	9.466	1.031	147	0.304
	Control	75	101.373	10.401			

In general, the results of normality, homogeneity, and equality tests show that parametric statistics can be used to analyse the metacognitive awareness post-test data after treatment. The results are presented in Table 7.

Table 7: The Results of Metacognitive Awareness Post-test

Class	**SRL**	**Mean**	**Std. Deviation**	**N**
Experiment	High	142.250	10.771	36
	Low	120.421	8.382	38
	Total	131.041	14.557	74
Control	High	131.658	10.225	38
	Low	118.460	7.669	37
	Total	125.147	11.181	75
Total	High	136.811	11.706	74
	Low	119.453	8.044	75
	Total	128.074	13.256	149

Table 7 showed the average student's score with high SRL skills in the experimental group was 142,250, with a standard deviation of 10,771 from 36 students. The low skills in the experimental group obtained an average score of 120,421, with a standard deviation of 8,382 from 38 students. Meanwhile, the students' test results with high SRL in the control class obtained an average score of 131,658 with a standard deviation of 10,225 from 38 students. Furthermore, those with low SRL obtained an average score of 118,460, with a standard deviation of 7,669 from 37 students.

The data in Table 7 also shows there are significant differences between the experimental and control groups on the post-test scores of students' metacognitive awareness. This difference is shown by the acquisition of an average score of 131,041 for the experimental group and 125,147 for the control group. Therefore, the average score in the experimental group was higher than the control. In addition to the intervention factors of the inquiry collaborative learning approach, the difference also depends on SRL skills. Hence, those with high SRL skills get higher scores compared to students with low SRL skills. The data in Table 7 shows the average score of metacognitive awareness in those with high SRL was 136,811 with a standard deviation of 11,706 from 74 students. Whereas, those with low obtained an average score of 119,453 with a standard deviation of 8,044 from 75 students. These results indicate that students with high SRL skills have higher metacognitive awareness than those with low skills. The results of inferential statistical analysis with two-way variance analysis (ANOVA) using the SPSS program with a significance level of 0.05 are presented in Table 8 below.

Table 8: Result of ANOVA Two Ways Tests of Between-Subjects Effects

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	13368.433[a]	3	4456.144	51.095	.000
Intercept	2447513.040	1	2447513.040	28063.915	.000
Treatment	1466.871	1	1466.871	16.820	.000
SRL	11419.944	1	11419.944	130.944	.000
Treatment * SRL	693.301	1	693.301	7.950	.005
Error	12645.755	145	87.212		
Total	2470047.000	149			
Corrected Total	26014.188	148			

a. R Squared = .514 (Adjusted R Squared = .504)

Table 8 shows the results of the first hypothesis testing with ANOVA, and based on the treatment factor towards the metacognitive awareness post-test, and F_{count} value of 16,820 and significance of 0,000 was obtained ($p < 0.05$). These results indicated that the null hypothesis (H_0) was rejected. Therefore, there was a significant difference ($p < 0.05$) between the experimental and control groups.

The results of the second hypothesis testing with ANOVA based on the SRL factor towards the metacognitive awareness post-test obtained a F_{count} of 130,944 and significance of 0,000. These indicate that there are significant differences ($p < 0.05$) between the high and the low SRL group towards the metacognitive awareness post-test.

However, the third hypothesis results are based on the interaction of treatments, and SRL factors toward the metacognitive awareness post-test obtained a F_{count} test value of 7,950 and significance of 0.005. These indicated that there is a significant difference ($p < 0.005$) based on the factor interaction.

Discussion

This research broadens our knowledge of how individuals with different SRLs are taught using collaborative inquiry learning, influencing metacognitive awareness. Descriptive findings indicate that metacognitive awareness, on average, increases in both treatments. However, the group taught with a collaborative inquiry learning approach was significantly superior compared to the conventional teaching approach, a finding that is in line with Kuvac & Koc (2019).

There are several reasons why this happened, including, first, students in the control class were processed using traditional inquiry teaching. They were given detailed guidance. Learning activities carried out separately between theory and inquiry activities, where the teacher delivers the material directly to students and then invites them to carry out inquiry activities. Students do not face challenges in accessing the material, plan, design, and conduct inquiry activities. The teachers focused more on facilitating their investigative activities. They prepare material, clear guidelines for investigation, determine groups freely, and give clear instructions.

Second, students are less involved in organising assignments and setting shared goals, and therefore, they face difficulties in each learning session. This difficulty is shown by the passivity of group discussion because there is no balance of roles and tasks. According to Hadwin et al., (2018), students working in groups have difficulties setting their goals and strategies, in case they do not start with the perceptions of each group member.

In contrast, students in the experimental class were actively involved in collaborative inquiry learning. Initially, they experienced difficulties and implications for uncertainty in the group and classroom. However, when socio-cognitive support is given several times, they ward off the uncertainty by completing the weaknesses and strengths of each group member. These results are in line with (Van den Bossche et al., 2006), which states that team performance improves in case students are shown interpersonal relationships and social interactions.

Socio-cognitive support help students work with a clear and mutually agreed framework of tasks. Collaborative work begins with sharing duties, setting goals, and designing joint strategies. Each member of the group is allowed to discuss their tasks and roles, identify problems that impede the task, and agree on their duty and how to take responsibility. These show students setting assignments and set goals can increase mutual awareness to fulfil their task goals and expectations (Faradiba et al. 2019).

Students in the experimental class are also encouraged to access information and study material individually before being discussed in groups. After arranging group assignments, they organise their investigation plan. This starts with identifying the problem, agreeing on the topic of an investigation, designing and conducting an experiment, analysing data to draw conclusions. The teacher's role as a facilitator and motivator is to provide socio-cognitive support. Teacher support has a significant positive impact on students' cognitive development (Hutagalung et al. 2020; Jin & Kim, 2018; Kim & Lim, 2018).

These results prove that socio-cognitive support for collaborative inquiry learning is highly effective in actively involving students through teamwork. It makes it easy for students to plan, carry out, and report inquiry activities and easily access tasks from different perspectives. More specifically, groups of students with socio-cognitive support performed significantly better than almost all investigation processes, and this improved metacognition.

The findings of this study also indicate that there are significant differences in metacognitive awareness between students with e high and low SRL. Students with high SRL always consciously try to focus attention on learning tasks such as setting goals, making plans, motivating themselves, controlling themselves, using flexible strategies, monitoring, seeking help, and conducting self-evaluations (Midun et al., 2020; Ormrod, 2009). Students involved in collaborative inquiry learning activities ranging from the pre-investigation stage to the reporting stage have high SRL. This is in line with Olakanmi & Gumbo (2017), which showed that students involved in high SRL activities had higher metacognitive and chemistry learning achievement. SRL effectiveness studies by (Eissa 2015) show that SRL interference contributes positively to cognitive and metacognitive.

Studies also prove that collaborative learning and SRL simultaneously have a positive effect on metacognitive awareness. Interaction is caused by collaborative inquiry learning involving students in joint investigation activities. However, students also need to be responsible for personal learning that results in metacognitive regulation. (Järvelä, Kirschner, et al., 2016). This includes the adoption of SRL skills aimed at optimising individual understanding during collaborative investigation and problem solving (Järvelä et al., 2013). Collaborative inquiry learning methods and SRL involve social, emotional, cognitive, and metacognitive aspects. They are mutually integrated and interact as long as students are involved in joint investigations, which ultimately train metacognitive awareness. The results of this study also support Nunaki et al., (2019), proving that inquiry learning, which actively engages students in teamwork improves metacognitive skills. Additionally, Zhang et al., (2015) and Khosa & Volet (2014), also showed that metacognitive encouragement and regulation in collaborative learning improve students' inquiry abilities and conceptual understanding. This shows that there is a mutual relationship between the support of metacognitive regulation and inquiry and conceptual understanding.

In this research, collaborative inquiry learning is designed and implemented by actively involving students to understand the context, plan, design, and implement and report the results of investigations in groups. They are trained to share assignments, express arguments, combine the different perspectives, and make decisions together. For instance, in case the instructor gives the assignment to investigate the transfer and transformation of heat energy, each group discusses the problem of their investigation. Afterwards, they present the results of the discussion in front of the class and finally agree that they would work together to carry out an investigative project. This investigates the effect of the conversion of green land in urban areas to open areas with paving and asphalt flooring on rising temperatures. They then share assignments and carry out investigations, combine the data, analyse and make a report. These activities are carried out with cognitive and socio-cognitive support from the instructor, such as giving instructions, motivating students to work together, and providing discussion space.

According to Kramarski & Dudai (2009), group feedback is a useful tool for increasing metacognitive awareness. Students become active, and their metacognitive skills are trained with all activities in inquiry-based learning. This shows that metacognitive awareness cannot develop on its own, but requires learning strategies (Naimnule & Corebima, 2018). The increase in metacognitive awareness shows that the recovery of the basic concepts of science with collaborative inquiry learning needs to pay attention to self and socio-cognitive regulation.

Conclusion

The main focus of this research was to investigate the metacognitive awareness of prospective elementary school science teachers. It used first-year students in primary school teacher education courses by implementing collaborative inquiry learning strategies. This is because the current curriculum demands teachers to have the ability to think at a higher level and apply collaborative inquiry learning in schools (Capps & Crawford, 2013). Collaborative learning inquiry can be successful in case it is supported by good scaffolding. There are many variations of inquiry collaborative learning, such as task and tool support. In this study, two different interventions were compared. The study also tested whether the SRL student characteristics involved in collaborative inquiry learning influenced metacognitive awareness. The results showed that there were significant differences between groups of students taught with collaborative inquiry and the conventional learning approach for metacognitive awareness. Students taking collaborative inquiry learning have higher metacognitive awareness. Likewise, high SRL groups have high metacognitive awareness compared to low SRL. The study also showed that there was an interaction between collaborative learning and SRL on metacognitive awareness. These results support several previous studies and provide valuable information showing that self-regulation and socio-cognitive support in collaborative inquiry learning is critical in increasing metacognitive awareness of elementary school prospective teachers. The metacognitive awareness gained motivate them to design and implement the learning that improves the metacognition of students. Future research should focus more on promoting metacognitive potential science teachers by organising scripts and scaffolding of collaborative inquiry learning in both online and offline environments. This can be directed at socio-metacognitive settings to encourage higher-order thinking skills, such as problem-solving and metacognition skills.

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