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Applying The Cognitive Style-Based Learning Strategy in Elementary Schools to Improve Students' Science Process Skills

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ABSTRACT

Science process skills play an important role in the advancement of society because they contribute to the emergence of new knowledge and technology. In this study, researchers analyzed the effectiveness of the cognitive style-based learning strategy (CSBLS) in improving elementary students' science process skills. The CSBLS was implemented over five weeks in science classes at two elementary schools in Indonesia and evaluated using a pre-test-post-test method. The results showed that, overall, the students' science process skills increased from "poor" to "good" level. The weakest science process skill identified in the students was the ability to conduct experiments, including stating hypotheses or operational questions to be tested, identifying and controlling variables, and making operational definitions. The study demonstrates that the CSBLS accommodates students with different levels of cognitive development and cognitive styles (e.g., field dependent and field independent) to optimally improve their science process skills, providing a significant contribution to elementary education.

Keywords: Cognitive style, field dependence, field independence, learning strategy, science process skills.

INTRODUCTION

Complex science process skills are used in conducting scientific investigations; therefore, they play an important role in the advancement of society by contributing to the emergence of new knowledge and technology (Arabacioglu & Unver, 2016; Carin, 1993;

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Dogan & Kunt, 2016; Karsli & Şahin, 2009). In the learning context, students with low science process skills may be unable to fully engage in the learning process (Sudiarman, Soegimin, & Susantini, 2015; Suyidno, Nur, Yuanita, Prahani, & Jatmiko, 2018; Zeidan & Jayosi, 2015). Science process skills allow students to find scientific information, develop critical thinking skills, make decisions, solve problems (Ergül et al., 2011; Irwanto, Rohaeti, & Prodjosantoso, 2019), increase creativity, and strengthen attitudes toward science and learning achievement (Bilgin, 2006). Therefore, science process skills must be introduced in students' education at early stages and continuously developed through the learning process (Limatahu, Suyatno, Wasis, & Prahani, 2018).

Investigation-based learning strategies (e.g., inquiry, discovery, and problem solving) have been used extensively to develop science process skills. Previous studies indicate that investigation-based learning can improve thinking skills, science process skills, critical thinking skills, creative thinking skills, argumentation, conceptual understanding, and learning outcomes, and can reduce learning difficulties for students and prospective teachers (Aktamis, Higde, & Özden, 2016; Bilgin, Yürükel, & Yigit, 2017; Castro & Morales, 2017; Memis & Çevik, 2018; Ozdemir & Isik, 2015; Parmin, Sajidan, Ashadi, Sutikno, & Maretta, 2016; Prayogi, Yuanita, & Wasis, 2018; Zubaidah, Fuad, Mahanal, & Suarsini, 2017; Zulfiani & Herlanti, 2018). As one of the investigation-based learning strategies, inquiry-based learning has been found to improve students' process skills (Mulyeni, Jamaris, & Supriyati, 2019; Simsek & Kabanipar, 2010; Sulistyorini & Permatasari, 2015; Sullivan, 2008; Wu & Hsieh, 2006). In addition, other learning outcomes such as knowledge, problem-solving skills, and attitudes toward science can also be enhanced through hands-on activities in inquiry-based science learning (Aktamiş, Hiğde, & Ozden, 2016; Ergül et al., 2011; Wahyuni, Indrawati, Sudarti, & Suana, 2017).

Investigation-based learning strategies engage students' higher-order thinking skills (Slavin, 2011). Therefore, implementation of these strategies in elementary school students is challenging due to their lack of cognitive development. According to Piaget's stages of cognitive development, children from 6 to 11 years of age are in their concrete cognitive development stage (Slavin, 2011). Children do not think like adults; they are rooted deeply in their environment and find abstract thinking difficult. Allen and Marotz (2008) argue that children are able to construct concepts to see relationships and solve problems that are connected to a real object or known situation.

Furthermore, investigation-based learning strategies often do not account for different students' characteristics. Several studies have investigated how different people process information; this is defined as their cognitive style. Armstrong, Peterson, and Rayner (2012) argue that a cognitive style refers to differences in individuals' preferred ways of processing information (e.g., perceiving, organizing, and analyzing) using cognitive mechanisms and structures. One's cognitive style is considered to be relatively stable and innate, and can be classified as field dependent (FD) or field independent (FI). FD students tend to process information globally, while FI students tend to process more analytically (Davis, 2004). Students' cognitive style can influence their understanding and skills in various subjects (Ardana, 2008; Khodadady, Bagheri, & Charbgoo, 2016; Stamovlasis, Tsitsipis, & Papagergeou, 2010; Tinajero & Paramo, 1997). Students with FI cognitive style tend to be more academically successful than students with FD cognitive style, particularly in the fields of mathematics (Ardana, 2008), science (Stamovlasis et al., 2010), and English (Khodadady et al., 2016). In their study of second grade students (average age = 7.5 years) at a multi-ethnic primary school, Ennis and Chepyator-Thomson (1990) found that students with FD cognitive style had difficulty in analyzing information, focusing on discussions, following instructions, and working independently. They found that FD students preferred to learn by collaboration and sought to be involved in learning through meaningful demonstrations or examples by undertaking concrete tasks.

Zhang (2010) and Yan (2010) state that FD and FI styles are represented in capabilities that require visual separation (e.g., geometry) relating to a person's perceptual competence. This is supported by Boccia, Piccardi, and Marco (2016) who argue that cognitive style influences a person's ability to do tasks related to spatial orientation, such as the mental rotation of an object, and that good spatial orientation capabilities provide opportunities for the development of good perceptual abilities. Other studies consider cognitive style in terms of working memory capacity (Bahar & Hansel, 2000), where visuospatial and executive functioning is required. For example, Richarson and Turner (2000) explained why 11-year old students with FI cognitive style could encode more vocabulary than students of the same age with FD cognitive style.

The cognitive style-based learning strategy (CSBLS) was designed to accommodate differences in students' cognitive development and cognitive style (Sholahuddin, Yuanita, & Kardi, 2014). The CSBLS's characteristics consist of (1) facilitating students at the concrete cognitive development level, (2) developing problem-solving skills in a guided way to balance teachers and students' roles, (3) providing more relaxed learning environments by incorporating games to strengthen students' conceptual understanding, (4) considering students' differences in cognitive styles equally over the learning steps, and (5) using scaffolding strategies to serve students' learning optimally.

The CSBLS was intended to develop students' process skills at earlier stages of the education process through scientific problem-solving in the classroom. It can be categorized as inquiry-based learning based on its learning steps and involves many analytical thinking activities. The purpose of this study was to analyze the effectiveness of the CSBLS in improving students' science process skills by accommodating cognitive styles and cognitive development.

METHODS

The representative state elementary schools (SDN) involved in this study were SDN Pasar Lama 1 and SDN Pasar Lama 3 in Banjarmasin, South Kalimantan, Indonesia. The schools represent very good and good schools, respectively, according to national accreditation. One sixth grade classroom per school was chosen with random sampling consisting of 33 students (13 male and 20 female) from SDN Pasar Lama 1 and 39 students (16 male and 23 female) from SDN Pasar Lama 3. The ages of participating students were 10 and 11. In this study, the group pre-test and post-test design (Fraenkel, Wallen, & Hyun, 2012) was used.

The CSBLS was implemented during a science learning process over five weeks, which included 10 class meetings. The covered topics were conductors-insulators and changes of substances. The learning process was collaborative, with students divided into groups of five to six members. Each group was created to be heterogeneous in terms of students' gender and cognitive style. The collaborative problem-solving approach with heterogeneous groups was expected to facilitate a variety of different student characteristics. The teacher's role was to facilitate students learning according to the activities and needs of students. For example, in exploration activities, teachers must pay particular attention to students with FD cognitive style because they are more likely to have difficulties with analytical work. Additionally, teachers must facilitate and help students with FI cognitive style during group work activities because these students generally prefer to work alone rather than collaborating with others. Table 1 shows the steps of the CSBLS.

Table 1. *The steps of the CSBLS*

No	Learning Steps	Learning Activities	Objectives
1	Attention	The teacher attracts students' attention to learning through the delivery of the learning objectives, apperception, and reminding and reinforcing the prerequisite knowledge.	To prepare students physically and mentally to learn and ensure that students have prior knowledge.
2	Understanding the Problem	The teacher conveys a problem and asks the groups to understand the problem and instructions on the worksheet.	To develop the students' ability to analyze information and identify and formulate the problems (FI).
3	Exploration	The teacher encourages and helps the students to gather the appropriate information and conduct a simple experiment or observation to solve the problem. The students are encouraged and guided by the teacher to formulate the hypothesis or prediction, seek information from various sources, or perform observations to gather data, interpret the data, draw conclusions, and evaluate the solution.	To teach students to solve problems by applying process skills and collaboration (FI and FD).
4	Sharing	The students share their ideas between groups about the problem-solving results while the teacher moderates the discussion and provides feedback.	To teach students to communicate their solutions (FD).
5	Game	The teacher invites students to play a ball-throwing game to deepen and strengthen content knowledge. The ball contains questions of key concepts and is thrown from one student to another (accompanied by music). When the music stops, the students with the ball must answer a question.	To deepen and strengthen the retention of content knowledge using an enjoyable activity (FI & FD).
6	Assessment	The students undertake a test, and the teacher evaluates the students' knowledge and problem-solving abilities.	To measure students' conceptual understanding and problem-solving abilities and to motivate learning (FI).
7	Individual Task	The teacher gives each student an individual problem-solving task to complete at home.	To strengthen students' problem-solving abilities and to facilitate the transfer of knowledge (FI).

FI: Field Independent; FD: Field Dependent
(Sholahuddin et al., 2014).

This study used three measurement tools: a science process skills test, a cognitive style test, and a cognitive development test. Previous research has demonstrated the validity of the science process skills test as follows: (1) the biserial index point is 0.38, which is categorized as valid; (2) the difficulty index is 0.6, which is classified as moderate; (3) the differentiation index is 0.34, which is categorized as good; and (4) the KR-20 index is 0.81, which shows good reliability (Sholahuddin et al., 2014). This instrument includes seven indicators: observing, classifying, measuring, communicating, inferring, predicting, and experimenting. The instrument consists of 30 multiple choice items, each with four alternative answers.

Evaluation of the students' cognitive style was conducted using the Group Embedded Figures Test (Ardana, 2008; Witkin, Oltman, Raskin, & Karp, 1971), a timed test that requires the test-taker to find certain simple images from a complex image. The test provides two items as examples of questions and answers and is then divided into three parts. The first part is not graded consisting of seven test items to be answered in a 2-minute duration, while the second and third parts are graded consisting of 9 items each to be completed within 5 minutes per part. Students with a score from 0 to11 are categorized as having FD cognitive style, and those who score from 12 to 18 are considered to have FI cognitive style.

The evaluation of cognitive development was conducted using the test of formal reasoning skills, adapted from the Test of Logical Thinking by Tobin and Capie and retested by Nur (2011). This test consists of 10 multiple choice question items accompanied by choice of reasons. A score from 0 to 1 is categorized as concrete, 2 to 3 as transition, 4 to 5 as early formal, and 6 to 10 as formal.

Improvements in students' science process skills were measured by testing both before and after the five weeks of teaching via the CSBLS. The effect of applying the CSBLS was determined based on the n-gain scores of science process skills. To justify the significance of the learning strategy effect, pre-test and post-test scores were analyzed with a dependent t-test using SPSS version 17 software after normality tests of the data (see Table 2). An independent test was also conducted to examine the difference between FD and FI students' achievements. The rating categories of science process skills scores were as follows: 80 to 100 = excellent, 70 to79 = good, 60 to 69 = moderate, and 0 to 59 = poor. Additionally, the categories for n-gain score ratings using Hake's (1998) criteria were 0.70 < n-gain = high, 0.30 ≤ n-gain ≤ 0.70 = moderate, and n-gain < 0.30 = low.

Table 2. *Normality tests of students' science process skills data*

School	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SDN P. Lama 1[b]	.087	33	.200*	.974	33	.583
SDN P. Lama 3[c]	.079	39	.200*	.973	39	.464

[a] Lilliefors Significance Correction

[b] The p value of Lilliefors and Shapiro-Wilk ($\alpha = 0.05$) is 0.200> 0.05 and 0.583> 0.05, respectively. This indicates that the data of SDN P. Lama 1 Students' science process skills are normally distributed.

[c] The p value of Lilliefors and Shapiro-Wilk ($\alpha = 0.05$) is 0.200> 0.05 and 0.464> 0.05, respectively. This indicates that the data of SDN P. Lama 3 Students' science process skills are normally distributed.

FINDINGS

The formal tests on reasoning ability confirmed that all participating students were in the concrete cognitive development stage. Furthermore, in the learning process, they were grouped heterogeneously by considering the distribution of their cognitive styles. Figure 1 and Figure 2 show the science process skills of SDN Pasar Lama 1 and SDN Pasar Lama 3 students, respectively, measured before and after the 5-week program.

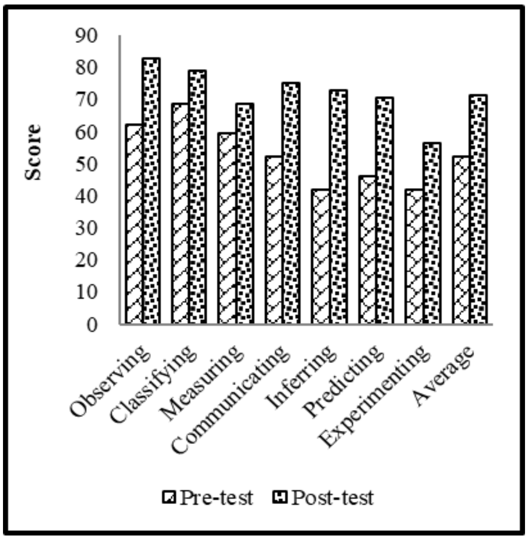

Figure 1. Students' science process skills: SDN Pasar Lama 1

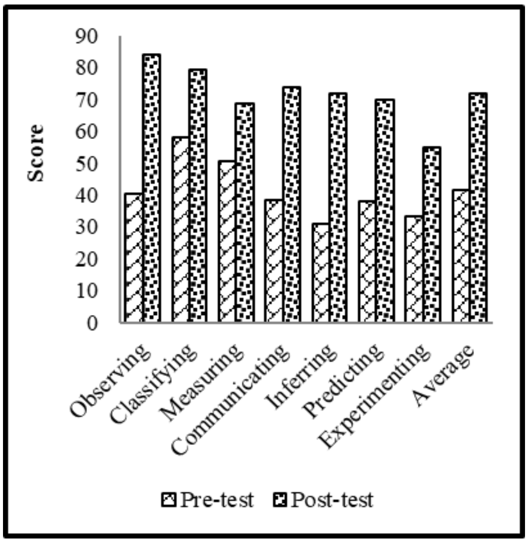

Figure 2. Students' science process skills: SDN Pasar Lama 3

Using a dependent t-test statistical analysis, the data were found to be normal and homogeneous. The pre-test and post-test results of the dependent t-test of students' science process skills are presented in Table 3, while the independent t-test of n-gain values between FI and FD students' science process skills are presented in Table 4. The n-gain values reflect the improvement of students' science process skills.

Table 3. *The results of the dependent t-test of students' pre-test and post-test science process skills*

School	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
1	-18.89	2.96	0.51	-17.83	-19.94	-36.59	32	0.00*
2	-30.00	13.04	2.08	-34.22	-25.77	-14.36	38	0.00*

Note: 1 = SDN P. Lama 1 Banjarmasin; 2 = SDN P. Lama 3 Banjarmasin
*p<0.05 or 0.00

The results of the dependent t-test between pre-test and post-test science process skills of students in the SDN Pasar Lama 1 showed that the mean of the pre-test scores was not different from the mean post-test scores. Therefore, it can be concluded that there was a significant difference between the pre-test and post-test scores of the science process skills of students at SDN Pasar Lama 1. The mean of the post-test scores was higher than the pre-test scores, indicating an increase in science process skills after attending science classes using the CSBLS. The same analysis was conducted for the students at SDN Pasar Lama 3, with the results indicating that the mean of the post-test scores of science process skills was significantly different (higher) than the mean of the pre-test scores. The students in both schools showed an improvement in science process skills after the learning activities using the CSBLS, on average, moved from a poor rating to a good rating.

Table 4. *The independent t-test of n-gain scores of science process skills of FI and FD students*

Independent Samples Test									
School	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
1	1.68	0.20	4.37	31	0.00*	0.20	0.04	0.11	0.30
2	1.91	0.17	1.89	37	0.06	0.11	0.06	-0.01	0.23

Note: 1 = SDN P. Lama 1 Banjarmasin; 2 = SDN P. Lama 3 Banjarmasin
*P<0.05

The results of the independent t-test of n-gain values of science process skills of FI and FD students at SDN Pasar Lama 1 showed that the mean n-gain value of science process skills of FI students was not statistically different from the mean n-gain value of science process skills of FD students. It can, therefore, be concluded that there was a significant difference between the n-gain values of the science process skills of FI and FD students of

SDN Pasar Lama 1. The results indicated greater improvement in science process skills in FI students after attending science class using the CSBLS. The same analysis was conducted for the students at SDN Pasar Lama 3, indicating that there was no significant difference between the n-gain values of the science process skills of FI and FD students. The students in both schools showed an improvement in process skills after the learning activities using the CSBLS. Both FI and FD students moved into the moderate category, although FI students scored slightly higher than FD students, as presented in Figure 3.

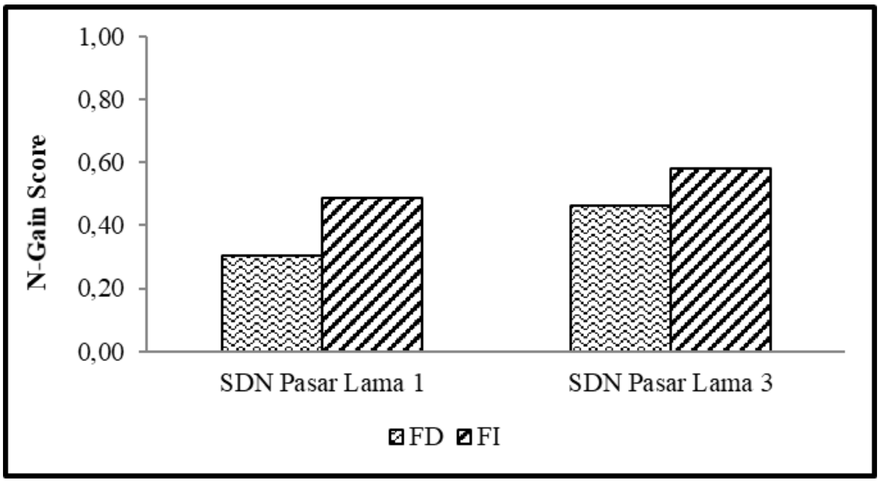

Figure 3. Improvement of the students' science process skills

DISCUSSION

Low levels of scientific literacy in 15-year-old students (OECD, 2016) in several countries (as external factors) and lack of appropriate classroom activities (as technical aspects) have encouraged fundamental changes in the Indonesian national curriculum. The CSBLS is one of the solutions to improve students' science process skills as an essential component of scientific literacy. The main goal of the CSBLS is the early development of students' process skills by considering their cognitive development and cognitive styles at a concrete cognitive development stage. Therefore, teacher guidance and scaffolding of reasoning activities are provided in the learning process. In addition, it is necessary to support students' cognitive styles for optimal learning. Previous studies (Prayogi et al., 2018; Rokhmat, Marzuki, Wahyudi, & Putrie, 2019) proved that scaffoldings successfully helped students to solve the complex scientific tasks.

Figures 1 and 2 show that the sixth-grade students who participated in the study had science process skills in the moderate category before implementing the strategy. This may be due to the cumulative effect of the educational sequence. However, after attending five weeks of science classes using the CSBLS, the average of students' science process skills improved from poor to good. Similar findings were reported by Simsek and Kabanipar (2010), who concluded that most elementary school students' process skills enhanced after attending inquiry-based learning, particularly in the areas of measuring, correlating and classifying, and forming hypotheses.

The findings above demonstrate the influence of the learning process using the CSBLS. The strategy allowed students to develop their problem-solving skills in a guided manner through scientific steps. The learning steps were stated in the student worksheet by systematic scaffolding consisting of nine elements: (1) a problem for understanding, (2) the purpose of the investigation, (3) tools and materials required, (4) a prediction, (5) working procedures, (6) data collection, (7) data interpretation, (8) conclusion and solutions, and (9) evaluation. Elements 1 to 3 and 5 were presented directly by the teacher through the worksheet, while elements 4 and 6 to 9 were provided by the students in a collaborative group setting with guidance from the teacher. The students were not only able to apply various process skills but were also guided to explain the reasons for a particular step and why certain data were obtained. Thus, the students indirectly improved their metacognitive skills.

The results indicate that the science process skill of experimenting was not well developed, even after attending the learning activities using the CSBLS. This may be due to limited reasoning development in this age group (Allen & Marotz, 2008; Slavin, 2011); the CSBLS emphasizes the development of basic process skills in accordance with the level of cognitive development of the students. This strategy was designed based on concrete cognitive development by considering cognitive style factors; therefore, the teacher provided significant assistance at the learning stages that required analytical skills, such as data interpretation. In addition, FD students required more attention from the teacher because, as shown empirically, they have a lower analytical ability, perceptual ability, and working memory capacity than those with FI cognitive style (Bahar & Hansel, 2000; Boccia et al., 2016; Davis, 2004; Yan, 2010; Zhang, 2010).

The experimenting process skills that were evaluated in this study included stating hypotheses or operational questions, identifying and controlling variables, and making operational definitions. The following is an example from the study:

> An agriculture scholar wants to investigate the effect of temperature on the growth rate of tomato plants in his garden and uses the following steps: (1) He planted tomato seedlings in four equal pots, same soil type, and watered with the same amount of water. (2) Pots were placed in glass boxes of different temperatures. The temperatures of boxes 1, 2, 3, and 4 were 0, 10, 25, and 50°, respectively. (3) The growth rates of the tomato plants were recorded at the end of day 14.

1. Which of the following statements is the hypothesis (tentative answer before being proven by experiment) of the investigation?
   A. If I am lucky, my tomato plant will grow as well as other farmers' plants.
   B. The growth of tomato plants is influenced by the type of soil and glass box used.
   C. Planting tomato plants in aqueous media (hydroponics) will not develop in the future.
   D. The growth of tomato plants is influenced by temperature.
2. How to appropriately measure the growth rate of the tomato plants in this investigation?
   A. Measure the change in the amount of soil that is planted with tomatoes after 14 days.
   B. Measure the height of tomato plant stems after 14 days.
   C. Count the number of plant roots after 14 days.
   D. Calculate the amount of water that plants need after 14 days.

Question 1 is an example of a question that measures the skill of hypothesizing, while Question 2 measures the skill of making operational definitions. Both questions included integrated process skill indicators, and most students were unable to answer either question. Previous research showed that even junior high school students integrated process skills in the poor category with an average score of 49.70 (Sholahuddin, 2015); however, students with higher grade levels tended to demonstrate better science process skills. Six grade students integrated process skills which were lower than those in seventh and eighth grades; even, science process skills of higher education students indicating that continual learning using the appropriate strategy can improve process skills (Aydinli et al., 2011; Irwanto, Rohaeti, & Prodjosantoso, 2019; Sukardiyono, Rosana, & Dwandaru, 2019).

In this study, the results of the dependent t-test statistical analysis documented that the implementation of CSBLS improved students’ science process skills significantly for both schools. This highlights the effective application of the CSBLS in facilitating science learning in all elementary school students. The results of the independent t-test of n-gain scores of science process skills between the students with different cognitive styles showed little difference in the advanced school but differed significantly in the developing school. Although this requires further research, this study indicates that both FD and FI cognitive styles can be well facilitated in the learning process using the CSBLS. Figure 3 shows that the students in both schools improved their process skills to achieve a moderate level, based on Hake’s (1998) criteria.

The results of this study demonstrated the effectiveness of the CSBLS to improve sixth grade students’ science process skills significantly. This result support other studies (Gormally, Brickman, Hallar, & Armstrong, 2009; Simsek & Kabanipar, 2010; Sulistyorini & Permatasari, 2015) that students’ process skills, particularly measuring, classifying and correlating, and hypothesizing, were improved after students engaged in science learning through inquiry-based learning activities. This study also shows that the CSBLS effectively improved students’ science process skills by accommodating learning styles and cognitive development. It means that teachers were able to apply stages of the CSBLS well, including provide scaffolding strategies due to the needs of students who have different cognitive styles.

Based on observations during the learning process using the CSBLS, the students’ interacted well in their collaborative groups. However, the teacher faced with some difficulties in managing the students’ activities during the exploration and game learning steps. This was due to the large class sizes (i.e., 33 and 39 students). Several studies reported that smaller class sizes would be more conducive to learning, allowing easier classroom management, more time to learn, and more intensive student-teacher interaction (Blatchford, Bassett, & Brown, 2011; Blatchford, Russell, Bassett, Brown, & Martin, 2007). Yigit, Alpaslan, Cinemre, and Balcin (2017) found that students in small classes rated their learning environment as more constructive than those in large classes. Therefore, the reliability of the CSBLS could be tested in future studies by considering factors such as varied grade levels, the characteristics of students or schools, and class size.

CONCLUSION

The CSBLS was implemented in science learning in two different elementary schools. The results of this study indicate that the effectiveness of the CSBLS in improving almost all science process skills of elementary school students. In this study, researchers identified that the weakest science process skills are experimental skills consisting of indicators to state hypotheses or operational questions to be tested, identify and control variables, and make operational definitions (classified as integrated science process skills). This learning strategy can facilitate students of both developing and advanced schools and accommodate the different cognitive styles of both FD and FI students to enable the optimal development of their science process skills. The results also demonstrate that science process skills can be developed early in a student’s education by using an appropriate learning strategy. The fundamental implication of this research is that the CSBLS can be used to address key issues in education, including (1) improving students’ science process skills, (2) accommodating students’ cognitive styles and cognitive development, and (3) optimizing scientific problem solving-based learning.

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