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Using Inquiry-Based Laboratory Instruction to Improve Critical Thinking and Scientific Process Skills among Preservice Elementary Teachers

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ABSTRACT

Purpose: Although critical thinking skills (CTS) and scientific process skills (SPS) are the beneficial skills needed in the 21st century learning, the fact is that the acquisition of these two skills is still low. Research with a focus on improving these skills by using inquiry-based approach is also limited. Therefore, this quasi-experimental study aimed to enhance preservice elementary teachers' CTS and SPS by using Inquiry-Based Laboratory Instruction (IBLI). **Method:** A pretest-posttest control group design was executed. A total of 43 students who attended Teaching Science in Elementary School-II Laboratory Course at the Muhammadiyah University of Ponorogo were divided into two groups using cluster random sampling. The experimental group (n=21) was taught by using IBLI, while the control group (n=22) was taught by using traditional laboratory method. The Oliver-Hoyo Rubric for Critical Thinking (OHRCT) and the Observation Checklist for SPS (OCSPS) were administered. The data were then analyzed by using normalized gain score and Mann-Whitney U test at significance level .05.

Findings: There was a significant difference in terms of CTS and SPS between control and experimental groups in favor of experimental group students. It was found out that gained CTS score of control and experimental group students was .58 and .80, while gained SPS score was .60 and .81, respectively. It can be highlighted that IBLI had a significant effect on preservice elementary teachers' performance compared to the conventional group.

Implications for Research and Practice: The findings suggest that IBLI is considered as the effective method to foster CTS and SPS of preservice elementary teachers. According to results, it is recommended that preservice teachers need to be given opportunities to develop hands-on and minds-on experiences in the science laboratory activities. The lecturers should utilize IBLI to develop students' various lifelong learning skills.

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Introduction

Laboratory work is related to scientific skills that should be acquired by preservice teachers in order to improve scientific investigation, laboratory skills, and problem-solving skills (Arabacioglu & Unver, 2016; Feyzioğlu, Demirdağ, Akyıldız & Altun, 2012). Laboratory method is considered as one of the most effective teaching methods in growing lifelong learning skills of the students through various experiments. Wang (1993) revealed some ways of how students obtain information in laboratory activities, which are: (1) the manual, (2) oral instruction from the lecturer, (3) the concept that should be remembered, (4) the technique that should be remembered, (5) the new technique that should be learned, and (6) direct observation in the experiment. In laboratory activity, equipment and tools should not be provided directly, but students should be given the situation of a problem and asked to formulate hypotheses, design the experiment, verify, record the data, and assess and interpret the findings (Gultepe & Kilic, 2015). Wang (1993) also recommended that the lecturer needs to understand how students learn and help them learn more in a student-centered situation through more effective learning strategies. In this case, it is important for preservice teachers to learn how to apply knowledge and connect scientific problems into real-life contexts rather than directly learning concepts, theories, and laws (Konur & Yıldırım, 2016).

One of the crucial skills that support the students in understanding the scientific concept through laboratory work is critical thinking skills (CTS). In the literature, these skills have wide and various definitions. Critical thinking, as part of high-level thinking skills, is a reasonable reflective thinking that focuses on deciding what should be believed or done (Ennis, 2011). Critical thinking is considered as the process of analyzing, applying, conceptualizing, synthesizing, and evaluating information produced by observation, reasoning, experience, communication, or reflection, as the guidelines for belief and action (Allen, 2008; Canziani & Tullar, 2017; National Council for Excellence in Critical Thinking [NCECT], 2013; Scriven & Paul, 1987). It is based on universal intellectual values that cover clarity, precision, accuracy, consistency, good reasons, relevance, breadth, sound evidence, depth, and fairness (Gupta, Burke, Mehta & Greenbowe, 2015; NCECT, 2013; Oliver-Hoyo, 2003; Scriven & Paul, 1987). Furthermore, Facione (2011) also confirmed that critical thinking covers self-regulation, interpretation, analysis, explanation, inference, and ultimate evaluation. From that definition, critical thinking skills are needed by the graduates to practice what they had learned, make decision based on right consideration from available information, apply information in the new situation, and evaluate information that has been collected.

Critical thinking is one important element of scientific thinking skills that can be elicited through scientific process skills (Azar, 2010). Scientific process skills (SPS) are one part of lifelong learning skills that involve critical thinking that is used by students in solving problems, making them more actively involved, and consciously widen their abilities (Darus & Saat, 2014; Karsli & Şahin, 2009). In short, these two beneficial skills have a relationship with one to another. For this reason, we argue that scientific process skills are one relevant tool to manage information about the world around them, obtain new information, and process it critically (Žoldošová & Matejovičová, 2010). These skills can only be achieved if the lecturer considers SPS in each laboratory activity that they design for the students (Molefe, Stears & Hobden, 2016). Generally, Padilla (1990) classified SPS into 2 types; basic process skills (i.e., observing, inferring, predicting, measuring, classifying) and integrated process skills (i.e., formulating hypotheses, designing investigations, identifying and defining variables, experimenting, constructing tables and graphs, interpreting data, and drawing conclusions). Both of them are interrelated and their usage need to be adjusted with the educational level and the stage of students' cognitive development.

Nowadays, improving critical thinking and scientific process skills is one of the most important goals in many higher educational institutions. Nevertheless, surprisingly previous studies reported that acquisition of students' SPS and their CTS tend to be less satisfying (Aktaş & Ünlü, 2013; Aydogdu, 2017; Hardianti & Kuswanto, 2017; Irwanto, Rohaeti & Prodjosantoso, 2018a, in press; Irwanto, Rohaeti, Widjajanti & Suyanta, 2017a; Ongowo, 2017). Furthermore, in Indonesia, research which focused on developing both of these skills is also limited (Muhlisin, Susilo, Amin & Rohman, 2016; Osman & Vebrianto, 2013; Pradina & Suyatna, 2018). If these skills are not properly improved, we predict that students cannot construe knowledge and the concept that they obtained will not help them in understanding their surrounding world (Žoldošová & Matejovičová, 2010). It is necessary to consider some factors that influence students' performance in understanding science concepts. In their research, Boa, Wattanatorn and Tagong (2018), Brahler, Quitadamo and Johnson (2002) agreed that one of the external factors that influence the students' low critical thinking skills lie on the learning method applied by the lecturer.

According to the results of observation done by the researchers in science laboratory course at tertiary level, the lecturer tends to use conventional method (cookbook procedures). That finding is in line with what had been mentioned by Chairam, Somsook and Coll (2009), Koç, Doymuş, Karaçöp and Şimşek (2010) and Sari, Jasmidi, Kembaren and Sudrajat (2018). In this context, students only run the laboratory procedure prepared by the lecturer without instruction to inquire. Whereas in traditional learning, critical thinking skills are not improved optimally (Mahanal, Zubaidah, Bahri & Dinnurriya, 2016). Based on that reason, we contend that paradigm shift from a lecturer-centered to student-oriented is necessary in which the students investigate and conduct team work actively. Similarly, Brahler et al. (2002) also stated that student-centered non-traditional teaching method can improve critical thinking skills and higher learning outcomes. One of the proactive teaching methods that can facilitate students' achievement is Inquiry-based Laboratory Instruction (IBLI).

Inquiry-based laboratory is believed as the most relevant teaching method for promoting scientific concepts and scientific processes and developing research skills, covering asking research questions, formulating hypotheses, and arranging the test from the hypotheses (Casem, 2006; Tatar, 2012). In this approach, students investigate and evaluate critically the things around them and participate in learning to build the concept and long-term understanding like scientists (Löfgren, Schoultz, Hultman & Björklund, 2013; Lord & Orkwiszewski, 2006; Sağlam & Şahin, 2017). Inquiry-based learning environments emphasize active usage of critical thinking and scientific process skills compared to memorizing the concept (Gehring & Eastman, 2008; Özgür & Yılmaz, 2017). In inquiry laboratory, students are not guided to conduct step-by-step instructions; however, they are provided with opportunities to understand science concepts, improve scientific process skills, and enhance their problem-solving skills (Irwanto, Rohaeti, Widjajanti & Suyanta, 2017b; Mutlu & Acar-Şeşen, 2018). Thereby, this method is considered to provide a positive impact on improving high-level thinking skills.

At tertiary level, inquiry becomes a very important approach in order to prepare the graduates to face the real world. Lord and Orkwiszewski (2006) reported that students that are taught by using inquiry teaching have higher achievement, scientific attitudes, and reasoning skills than control group students. Özgür and Yılmaz (2017) proposed that inquiry-based learning improved students' motivation and their conceptual understanding. Artayasa, Susilo, Lestari and Indriwati (2016) claimed the significance of different scientific process skills compared to conventional group. In USA, Maxwell, Lambeth and Cox (2015) explored the impact of inquiry learning towards fifth-grade students and reported that experimental group students showed improvement in their academic achievement, attitudes, and higher engagement compared to students who accepted conventional instruction. In Thailand, Chairam, Klahan and Coll (2015) found an increase in students' understanding of the chemical concepts between pre- and post-diagnostic tests. At the end of the intervention, students showed significant progress in phrasing scientific questions, designing experiments, identifying variables, drawing the concept list, presenting data, and analyzing results. These beneficial findings are also supported by Başer and Durmuş (2010), Duran and Dökme (2016), Ketpichainarong, Panijpan and Ruenwongsa (2010), Mutlu and Acar-Şeşen (2018), and Yakar and Baykara (2014). Based on various previous research findings, we conclude that IBLI method can improve students' cognitive, psychomotor, and affective learning outcomes even though their critical thinking and scientific process skills are not investigated yet.

As discussed previously, laboratory instruction has a vital role in science education because, actually, science concept is the investigation of the product in the laboratory using scientific method. For this reason, the lecturer should facilitate students to obtain factual information from various sources during the investigation and then encourage them to find new concepts and construct knowledge (Chiappetta, 1997). This research aimed to foster critical thinking and scientific process skills among preservice elementary teachers by using inquiry-based laboratory instruction. The research question underlying this study were:

1. Is there any significant difference on critical thinking skills score between control and experimental group students?
2. Is there any significant difference on scientific process skills score between control and experimental group students?
3. How is the improvement of students' performance between control and experimental groups after the laboratory course?

Method

Research Design

A quasi-experimental, pretest-posttest, non-equivalent control group design was employed in this research. It was conducted to investigate causal hypotheses about the causes that can be manipulated by comparing one or more experimental groups which were given treatment with one comparison group that was not given treatment (Creswell, 2009; Shadish, Cook & Campbell, 2002). Control group was taught by using traditional laboratory method, while the experimental group was taught by using Inquiry-Based Laboratory Instruction (IBLI). It was used to compare the impact of both teaching methods on critical thinking and scientific process skills. In brief, pretest-posttest control group design was presented in Table 1.

Table 1

Non-equivalent Pretest and Posttest Control Group Design

Groups	Pretest	Treatment	Posttest
Experimental	O_1	Inquiry-based laboratory	O_2
Control	O_3	Traditional laboratory	O_4

Research Sample

The sample consisted of 43 preservice elementary teachers (23 females, 20 males) who attended Teaching Science in Elementary School-II Laboratory Course in the Department of Elementary School Education, Muhammadiyah University of Ponorogo, in the fifth- semester academic year of 2017/2018. All participants were classified into two groups. A total of 21 students in the experimental group (13 females, 8 males) were randomly selected as the treatment group, and 22 students were in the control group (10 females, 12 males). They completed 5 experiment topics in one semester. The pariticipants were approximately aged 20-22 years old, chosen by using cluster random sampling. Given that this research selects groups rather than individuals, cluster random sampling is more appropriate (Fraenkel, Wallen & Hyun, 2012). All students in both groups followed the pretest, treatment, and posttest. 53.49% of the participants were females and the rest were male students.

Data Collection Instruments

The data were collected from students' practical work activities and their written reports during the laboratory course. Their performance in both groups was assessed by using the Oliver-Hoyo Rubric for Critical Thinking (OHRCT) and the Observation Checklist for Scientific Process Skills (OCSPS) as pretest and posttest. The OHRCT was developed by Oliver-Hoyo (2003), adapted and translated into Indonesian by Irwanto Rohaeti and Prodjosantoso (2018a), and obtained the coefficient of Cronbach's alpha reliability a=.84. The rubric was used to assess students' critical thinking skills based on their written laboratory reports. The instrument consisted of 6 traits; abstract, organization, the source of information, content, relevance, and presentation. Each trait targeted certain cognitive skills, including conceptualizing, analyzing, applying, synthesizing, and evaluating information. It is based on the universal intellectual values (i.e. clarity, precision, accuracy, consistency, good reasons, relevance, breadth, sound evidence, depth, and fairness) that are embedded in the rubric (Oliver-Hoyo, 2003). In addition, each trait had a 5-point Likert scale with a range from 5 (all criteria fulfilled) to 1 (no criteria fulfilled).

The OCSPS was developed by Irwanto, Rohaeti and Prodjosantoso (2018b) to assess students' scientific process skills. The instrument consisted of 18 items, covering basic process skills (8 items) and integrated process skills (10 items). Basic process skills were observing, measuring, inferring, and communicating. Integrated process skills were investigating, identifying and controlling variables, formulating hypotheses, experimenting, and interpreting data, 2 items for each. All sub-skills were adapted from Arabacioglu and Unver (2016), Aydogdu (2017), and Padilla (1990). Each item had a 4-point Likert scale with a range from 4 (highly observed) to 1 (unobserved). Before conducting the main research, the instrument was tested with 176 students chosen randomly in Yogyakarta, and obtained the coefficient of Cronbach's alpha reliability a=.88. All students who participated in the pilot research were not involved in the main research.

Procedures

In the present research, research procedure that was implemented covered: (1) choosing control and experimental groups randomly, (2) giving the pretest, (3) conducting the course in both groups, (4) giving the posttest, and (5) analyzing and interpreting the results of the test. Students were instructed to work together in small groups and write laboratory report individually at the end of the experiment. The laboratory report was done outside the course as independent assignment. The course was conducted for 100 minutes per week by the same lecturer to avoid bias of the instructor. In the control group, students conducted the experiment by using cook-book procedure that had been provided by the lecturer. In this context, they proposed the question, and the lecturer explained and summarized the results of the experiment. While in the experimental group, all students were designed to go through each phase in guided inquiry which was adapted from Ješková et al. (2016), as illustrated in Table 2. Both groups completed all experiment topics at the same time.

Table 2

The Syntax of Guided Inquiry-Based Laboratory in Experimental Group

Steps	Activities
Presenting a contextual problem	The students observe and discuss a case given in small groups (4-5 students).
Planning and designing	The students formulate the question, define the problem, formulate the hypotheses, design the experiment, and predict the results of the experiment obviously and accurately.
Implementing	The students investigate, record the results, and make the decision about the experimental techniques.

Table 2 Continue

Steps	Activities
Analyzing and interpreting	The students present the results in the form of pictures, graphics, or table, determine the correlation between variables, compare the experimental data with the hypotheses, and conclude the experimental results.
Communicating	The students, in small groups, present their findings, discuss the results, and elaborate the written laboratory reports about the results obtained.
Conducting follow-up	The students predict the opportunity for future experiments, formulate the hypotheses to be followed-up, and apply the experimental techniques to new problems.

Experimental group students that were taught by using inquiry-based laboratory instruction and control group students that were taught by using confirmatory experiments method finished all experiment topics. The activities provided in this research were based on the topics illustrated in Table 3.

Table 3

Topics and Purposes of Experiments in Both Groups

Topics	Purposes
Units and measurement	Conducting measurement by using some measuring instruments and determining derived units based on the base units.
Static electricity	Observing the symptoms of static electricity and analyzing the phenomenon of electron transfer from one material to another material.
Dynamic Electricity	Investigating series, parallel, and mixed circuits; counting the resistance value in the electrical circuit; and determining the potential difference at the series, parallel, and mixed resistance by using a voltmeter.
Magnets and Electromagnets	Analyzing the relation between magnetic fields and electric currents; and analyzing the factors that influence the strength and the weakness of an induced magnetic field.
Conductors and Insulators	Investigating the materials that can and cannot deliver electricity; and explaining the characteristics of those things based on their ability in delivering electricity.

Data Analysis

All data obtained from observation and written laboratory reports were calculated. Descriptive statistics were administered to count the frequency and the percentage of the samples in control and experimental groups. In this research, quantitative data were analyzed by using non-parametric statistics because the sample size was small, which was less than thirty students (Bernard, 2000; Green & Salkind, 2008). Mann-Whitney *U* test was performed to examine the effect of instructional methods on students' critical thinking and scientific process skills. *N*-gain was employed to determine the increase in achievement scores between the pretest and posttest using the Hake's (1999) formula: *n*-gain = (posttest - pretest scores) / (maximum - pretest scores), with low (*n*-gain < .30), medium (.30 < *n*-gain < .70), and high criteria (*n*-gain > .70). This research used SPSS 17.0 at a significance level of .05.

Results

The findings of the research are explained in this section. The results of *U*-test, either pretest or posttest, to show the impact of IBLI on the preservice elementary teachers' critical thinking and scientific process skills were presented as follows (see Tables 4-8).

Table 4

Gap in Pretest Critical Thinking Skills Score between Experimental and Control Groups

Sub-Dimensions	Groups	*n*	Mean Rank	Sum of Ranks	Mann-Whitney *U* Test	
					U	*p*
Abstract	Experimental	21	22.71	477.00	216.000	.667
	Control	22	21.32	469.00		
Sources of Information	Experimental	21	20.38	428.00	197.000	.348
	Control	22	23.55	518.00		
Organization of the Report	Experimental	21	21.10	443.00	212.000	.576
	Control	22	22.86	503.00		
Relevance of the Ideas	Experimental	21	22.33	469.00	224.000	.837
	Control	22	21.68	477.00		
Content of the Report	Experimental	21	23.50	493.50	199.500	.313
	Control	22	20.57	452.50		
The Written Presentation	Experimental	21	22.60	474.50	218.500	.732
	Control	22	21.43	471.50		
Overall CTS	Experimental	21	21.90	460.00	229.000	.960
	Control	22	22.09	486.00		

Based on the mean rank shown in Table 4, pretest scores of experimental group students were slightly higher in terms of abstract, relevance of the ideas, the written presentation, and content of the report. Control group students were slightly higher in terms of sources of information and organization of the report. Nevertheless, overall, we did not find significant difference between both groups (U=229.000; p=.960). It indicated that prior to treatment, all students had similar prior knowledge in the six traits.

Table 5

Gap in Pretest Scientific Process Skills Score between Experimental and Control Groups

Sub-Skills	Groups	*n*	Mean Rank	Sum of Ranks	Mann-Whitney *U* Test	
					U	*p*
Observing	Experimental	21	21.86	459.00	228.000	.932
	Control	22	22.14	487.00		
Inferring	Experimental	21	21.83	458.50	227.500	.917
	Control	22	22.16	487.50		
Measuring	Experimental	21	24.02	504.50	188.500	.221
	Control	22	20.07	441.50		
Communicating	Experimental	21	23.29	489.00	204.000	.468
	Control	22	20.77	457.00		

Table 5 Continue

Sub-Skills	Groups	*n*	Mean Rank	Sum of Ranks	Mann-Whitney *U* Test	
					U	*p*
Identifying and Controlling Variables	Experimental	21	22.40	470.50	222.500	.770
	Control	22	21.61	475.50		
Investigating	Experimental	21	22.86	480.00	213.000	.553
	Control	22	21.18	466.00		
Formulating Hypotheses	Experimental	21	22.90	481.00	212.000	.532
	Control	22	21.14	465.00		
Experimenting	Experimental	21	23.14	486.00	207.000	.467
	Control	22	20.91	460.00		
Interpreting	Experimental	21	21.71	456.00	225.000	.865
	Control	22	22.27	490.00		
Overall SPS	Experimental	21	24.38	512.00	181.000	.217
	Control	22	19.73	434.00		

According to mean rank presented in Table 5, pretest scores of experimental group students were slightly higher in terms of identifying and controlling variables, measuring, formulating hypotheses, investigating, communicating, and experimenting skills. Control group students were slightly higher in terms of observing, inferring, and interpreting data skills. Similarly, overall, we also did not find significant difference between the scores of both groups (U=181.000; p=.217). It reflected that before the instruction, all students had equal prior scientific skills.

Table 6

Gap in Posttest Critical Thinking Skills Score between Experimental and Control Groups

Sub-Dimensions	Groups	*n*	Mean Rank	Sum of Ranks	Mann-Whitney *U* Test	
					U	*p*
Abstract	Experimental	21	27.33	574.00	119.000	.003
	Control	22	16.91	372.00		
Sources of Information	Experimental	21	26.90	565.00	128.000	.003
	Control	22	17.32	381.00		
Organization of the Report	Experimental	21	26.14	549.00	144.000	.019
	Control	22	18.05	397.00		
Relevance of the Ideas	Experimental	21	27.21	571.50	121.500	.002
	Control	22	17.02	374.50		
Content of the Report	Experimental	21	26.21	550.50	142.500	.002
	Control	22	17.98	395.50		
The Written Presentation	Experimental	21	27.00	567.00	126.000	.003
	Control	22	17.23	379.00		
Overall CTS	Experimental	21	32.43	681.00	12.000	.000
	Control	22	12.05	265.00		

At the end of the experiment, posttest was implemented. According to mean rank presented in Table 6, it showed that experimental group students were more superior in all sub-dimensions compared to control group students. Overall, we found out significant difference between the scores of both groups after the treatment (U=12.000;

p=.000). It indicated that implementation of IBLI had a significant effect on students' CTS. Furthermore, experimental group students obtained the highest mean rank in Abstract (M=27.33) and the lowest in Organization of the Report (M=26.14). Control group students obtained the highest mean rank in Organization of the Report (M=18.05) and the lowest in Abstract (M=16.91).

Table 7

Gap in Posttest Scientific Process Skills Score between Experimental and Control Groups

Sub-Skills	Groups	n	Mean Rank	Sum of Ranks	Mann-Whitney U Test	
					U	p
Observing	Experimental	21	26.00	546.00	147.000	.018
	Control	22	18.18	400.00		
Inferring	Experimental	21	27.29	573.00	120.000	.002
	Control	22	16.95	373.00		
Measuring	Experimental	21	26.36	553.50	139.500	.010
	Control	22	17.84	392.50		
Communicating	Experimental	21	26.40	554.50	138.500	.008
	Control	22	17.80	391.50		
Identifying and Controlling Variables	Experimental	21	26.12	548.50	144.500	.003
	Control	22	18.07	397.50		
Investigating	Experimental	21	27.40	575.50	117.500	.001
	Control	22	16.84	370.50		
Formulating Hypotheses	Experimental	21	27.88	585.50	107.500	.001
	Control	22	16.39	360.50		
Experimenting	Experimental	21	26.33	553.00	140.000	.011
	Control	22	17.86	393.00		
Interpreting	Experimental	21	27.10	569.00	124.000	.004
	Control	22	17.14	377.00		
Overall SPS	Experimental	21	32.57	684.00	9.000	.000
	Control	22	11.91	262.00		

According to mean rank presented in Table 7, it showed that experimental group students were more dominant in all sub-skills compared to control group students. Overall, we found out significant difference between the scores of both groups (U=9.000; p=.000). It confirms that implementation of IBLI had a significant impact on students' SPS. Moreover, experimental group students obtained the highest mean rank in Formulating Hypotheses (M=27.88) and the lowest in Observing (M=26.00). Meanwhile, control group students obtained the highest mean rank in Observing (M=18.18) and the lowest in Formulating Hypotheses (M=16.39).

Table 8

The Difference of N-Gain Scores between Experimental and Control Groups

Groups	Critical Thinking Skills		Scientific Process Skills	
	Control	Experimental	Control	Experimental
Pretest	16.32	16.24	15.91	16.62
Posttest	24.23	27.29	28.05	32.24
N-gain	.58	.80	.60	.81
Category	Medium	High	Medium	High

According to *n*-gain presented in Table 8, it showed that experimental group students had score improvement in high category, while control group students had score improvement in medium category. It can be concluded that there was enhancement of pretest to posttest in both groups, although experimental group students who were taught by using IBLI showed better performance compared to control group students that were taught by using traditional laboratory method in both dependent variables.

Discussion, Conclusion and Recommendations

In the context of 21st century learning, critical thinking and scientific process skills are considered as two superior skills that become the main purpose of teaching science at college or university level (Ahrari, Samah, Hassan, Wahat & Zaremohzzabieh, 2016; Boa et al., 2018; Irwanto, Rohaeti & Prodjosantoso, 2018c; Karsli & Şahin, 2009; Molefe et al., 2016). In order to develop both, we claim that science learning need to be designed to give opportunities to the students through inquiry activities. For this reason, this research aimed to improve students' cognitive and psychomotor domains by using IBLI method. Five practical works were done by control and experimental group students in one semester. Afterwards, we investigated students' performance at the beginning and at the end of the experiment by using two valid and reliable instruments.

According to the results, at the beginning of the instruction, all students showed less satisfying performance. Based on the analysis, we found out that there was no significant difference in pretest CTS scores of control and experimental groups. It indicated that prior to treatment, all students had similar prior knowledge. In addition, we also did not find out any significant differences among pretest SPS scores of both groups. It reflected that before the instruction, all students had equal prior scientific skills. Related to students' low skills, we found that they encountered difficulty in designing the experimental procedures, as reported by Yang and Park (2017). According to results of observation that we did before conducting the research, it was caused by the lecturer who just utilized traditional method during the laboratory instruction. Finally, we assumed that students taught by using conventional method tend to obtain less optimal achievement (Duran & Dökme, 2016; Quitadamo, Faiola, Johnson & Kurtz, 2008; Wartono, Hudha & Batlolona, 2018). The reason, as mentioned by Quitadamo et al. (2008), is that traditional method is not built from students' prior knowledge, it does not bridge how science was practiced in the real world, and it does not promote students' awareness to learn.

In order to compare the effectiveness of teaching methods, students in both groups were given different treatment. At the end of the instruction, all students showed better performance improvement compared to the pretest. Based on the findings, preservice teachers in the experimental group were more superior in all sub-dimensions of CTS compared to control group students. The fact is that students did not encounter any trouble in arranging written laboratory reports. It indicates that each step in inquiry can lead students to conceptualize, analyze, apply, synthesize, and evaluate the information at once to decide what to trust and do. Overall, we concluded that there was significant difference in posttest scores of both groups. It can be claimed that IBLI has positive impact on students' CTS. Supportively, Maxwell et al. (2015) revealed that critical thinking can be developed through inquiry approach. In this regard, inquiry process is believed to facilitate students in explaining the concept, sharing the knowledge, explaining the opinion, listening to alternative opinion, discussing with others, and maintaining their ideas, as revealed by Tatar (2012). By participating in inquiry-based activities, students can recognize the nature of science, the phenomenon, and scientific concept; develop their ability in evaluating scientific data critically and participate in scientific community (Löfgren et al., 2013). This is the reason why IBLI can promote students' CTS in the current research.

We also underline that students' involvement in the inquiry process stimulate them to be active learners physically and mentally, help them acquire science and consolidate those processes with scientific knowledge, critical thinking, and scientific reasoning (Hsiao et al., 2017; Ozdem-Yilmaz & Cavas, 2016). Previous research also supports current findings. In Slovenia, Avsec and Kocijancic (2014) reported that inquiry-based learning had a large and positive effect on critical thinking skills. In Israel, Hugerat and Kortam (2014) investigated 28 undergraduate biology and chemistry students, and found out that inquiry had a significant effect on improving critical thinking skills. Furthermore, critical thinking skills of experimental group students that were taught by using inquiry-based learning were higher in all sub-skills than control group students who were taught by using traditional method (Duran & Dökme, 2016; Wartono et al., 2018). It is believed that the most effective way to promote critical thinking skills is through active participation in the laboratory experiments (Irwanto, Saputro, Rohaeti & Prodjosantoso, 2018; Lujan & DiCarlo, 2006). Thereby, we suggest the lecturers apply inquiry approach in laboratory instruction. In essence, the lecturer is not considered as the mentor but as the facilitator, and the students are not passive recipients but active learners in the instruction process (Škoda, Doulík, Bílek & Šimonová, 2015).

As another finding, we reported that experimental group students were more dominant in all sub-skills, either basic or integrated process skills compared to control group students. Overall, we found out significant difference between the scores of both groups. It can be claimed that IBLI had positive impact on students' SPS. Encouragingly, Gehring and Eastman (2008) and Sağlam and Şahin (2017) revealed that scientific process skills can be promoted through inquiry-based learning. For this reason, we emphasized that in inquiry, students also learn how to propose questions and find out the answer at once when they are involved in the intellectual activities covering observing, thinking, generalizing, and creating like a scientist (Hsiao et al., 2017; Maxwell et al., 2015). In this stage, all students are directed to collect and analyze the data and report their findings in scientific format, as expressed by Casem (2006). Various IBLI advantages stimulate the students to actively generate scientific ideas, conduct scientific investigation, and construct scientific concept. This is another reason why IBLI can promote students' SPS in the current research. The expected learning purpose in this research was promoting students' long-term knowledge.

As a result, experimental group students had CTS and SPS scores enhancement in high category, while control group students had score enhancement in medium category. In this case, the fact is that experimental group students were not focused only on hands-on experiences but also minds-on activities to improve their way of thinking, as informed by Žoldošová and Matejovičová (2010). According to that explanation, we consider IBLI as the most effective method to enhance students' achievement. In the laboratory, students can plan, design, and implement the experimental procedure. Furthermore, students analyze, interpret, and communicate the data much better than control group students. How can this happen? We assert that through inquiry-based laboratory instruction, all students learn how to optimize their problem-solving skills, foster their attitudes and skills, and also associate the knowledge in their daily experiences (Yakar & Baykara, 2014). All these activities possibly become the reasons why students' scientific skills in experimental group increased rapidly. Therefore, this is obvious that the students who were taught by using inquiry method had better performance enhancement. It can be asserted that there was an improvement in pretest and posttest scores of both groups although experimental group students showed better performance compared to control group students in both dependent variables.

Various evidence that support these current findings has been reported. In Indonesia, Hardianti and Kuswanto (2017) analyzed the achievement of 77 senior high school students, and reported that their SPS could be promoted by using inquiry-based learning. In Turkey, Şen and Vekli (2016) investigated activities of 24 preservice science teachers in biology laboratory and found out that scientific process skills can be developed through inquiry-based teaching. In another research that involved 30 preservice classroom teachers, Akben (2015) reported similar findings. Furthermore, students who are exposed to inquiry instruction also show more improvement in their critical thinking scores compared to conventional group students (Ekahitanond, 2013; Greenwald & Quitadamo, 2014). Moreover, students in inquiry laboratory group also showed better achievement and they enjoyed investigation compared to students in step-by-step directions group (Demircioglu & Ucar, 2015; Lord & Orkwiszewski, 2006; Rissing & Cogan, 2009). In brief, current research confirms that IBLI is a constructivist approach that provides a great impact on the development of the cognitive and psychomotor domains.

In this research, pretest-posttest critical thinking and scientific process skills scores of preservice elementary teachers were compared. Based on the *U*-test, there was a statistically significant difference in terms of CTS and SPS between experimental group students who were taught by using IBLI and control group students who were taught by using traditional laboratory instruction. At the end of the instruction, experimental group students showed domination on posttest scores in all sub-skills of critical thinking and scientific process skills. Subsequently, it was found out that gain CTS score of control and experimental group students were obtained .58 and .80 (difference .22), while gain SPS score of the students were obtained .60 and .81 (difference .21), respectively. It can be concluded that IBLI has a positive impact on the preservice elementary teachers' achievement compared to conventional group. The findings indicated that laboratory activities significantly improve practical and generic skills. Through laboratory work, students are seen solving problems collaboratively and participating in the inquiry process actively in order to develop cognitive skills.

According to the findings, it can be further suggested that preservice elementary teachers need to be given opportunities to develop hands-on and minds-on experiences in the laboratory activities. The lecturer should lead the usage of various constructivist teaching methods that can propel the students to enhance various lifelong learning skills. As we know, teaching methods are one of the factors that influence students' achievement (Abdullah & Shariff, 2008; Akınoğlu & Tandoğan, 2007; Budsankom, Sawangboon, Damrongpanit & Chuensirimongkol, 2015). Furthermore, impact of IBLI on students' critical thinking and scientific process skills need to be investigated in other laboratory courses related to science learning at tertiary level.

This research has several limitations; First, we only involved preservice elementary teachers in the fifth semester as participants, thereby the findings could not be generalized. As such, we recommend further research to investigate the effectiveness of this method in branches, laboratory courses, gender, and other grade levels in order to strengthen claims. Second, current research involved limited samples, thereby that it can be improved by involving a wider sample in order to obtain detailed and comprehensive information. Moreover, we recommend that future researchers need to compare impact of different levels of inquiry (i.e., confirmation, structured, guided, and open) on preservice elementary teachers' performance. Equally important, it is also necessary to explore the effect of IBLI on other dependent variables.

References

Abdullah, S., & Shariff, A. (2008). The effects of inquiry-based computer simulation with cooperative learning on scientific thinking and conceptual understanding of gas laws. *Eurasia Journal of Mathematics, Science & Technology Education*, 4(4), 387–398.

Ahrari, S., Samah, B. A., Hassan, M. S., Wahat, N. W., & Zaremohzzabieh, Z. (2016). Deepening critical thinking skills through civic engagement in Malaysian higher education. *Thinking Skills and Creativity*, *22*, 121–128.

Akben, N. (2015). Improving science process skills in science and technology course activities using the inquiry method. *Education and Science*, *40*(179), 111–132.

Akınoglu, O., & Tandoğan, R. Ö. (2007). The effects of problem-based active learning in science education on students' academic achievement, attitude and concept learning. *Eurasia Journal of Mathematics, Science & Technology Education*, 3(1), 71–81.

Aktas, G. S., & Ünlü, M. (2013). Critical thinking skills of teacher candidates of elementary mathematics. *Procedia - Social and Behavioral Sciences*, *93*, 831–835.

Allen, M. (2008). Promoting critical thinking skills in online ınformation literacy instruction using a constructivist approach. *College & Undergraduate Libraries, 15*(1-2), 21–38.

Arabacioglu, S., & Unver, A. O. (2016). Supporting inquiry based with mobile learning to enhance students' process skills in science education. *Journal of Baltic Science Education*, *15*(2), 216–231.

Artayasa, I. P., Susilo, H., Lestari, U., & Indriwati, S. E. (2016). The effectiveness of the three levels of inquiry in improving teacher training students' science process skills. *Journal of Baltic Science Education*, *16*(6), 908–919.

Avsec, S., & Kocijancic, S. (2014). The effect of the use of an inquiry-based approach in an open learning middle school hydraulic turbine optimisation course. *World Transactions on Engineering and Technology Education*, *12*(3), 329–337.

Aydogdu, B. (2017). A study on basic process skills of Turkish primary school students. *Eurasian Journal of Educational Research*, *67*, 51–69.

Azar, A. (2010). The effect of critical thinking dispositions on students achievement in selection and placement exam for university in Turkey. *Journal of Turkish Science Education*, *7*(1), 61–73.

Baser, M., & Durmuş, S. (2010). The effectiveness of computer supported versus real laboratory inquiry learning environments on the understanding of direct current electricity among pre-service elementary school teachers. *Eurasia Journal of Mathematics, Science and Technology Education*, *6*(1), 47–61.

Bernard, H. R. (2000). *Social research methods: Qualitative and quantitative approaches*. California: Sage Publications, Inc.

Boa, E. A., Wattanatorn, A., & Tagong, K. (2018). The development and validation of the blended socratic method of teaching (BSMT): An instructional model to enhance critical thinking skills of undergraduate business students. *Kasetsart Journal of Social Sciences*, *39*(1), 81–89.

Brahler, C. J., Quitadamo, I. J., & Johnson, E. C. (2002). Student critical thinking is enhanced by developing exercise prescriptions using online learning modules. *Advances in Physiology Education*, *26*(3), 210–221.

Budsankom, P., Sawangboon, T., Damrongpanit, S., & Chuensirimongkol, J. (2015). Factors affecting higher order thinking skills of students: A meta-analytic structural equation modeling study. *Educational Research and Review*, *10*(19), 2639–2652.

Canziani, B., & Tullar, W. L. (2017). Developing critical thinking through student consulting projects. *Journal of Education for Business, 92*(6), 271–279.

Casem, M. L. (2006). Student perspectives on curricular change: Lessons from an undergraduate lower-division biology core. *CBE - Life Science Education*, *5*, 65–75.

Chairam, S., Klahan, N., & Coll, R. K. (2015). Exploring secondary students' understanding of chemical kinetics through inquiry-based learning activities.

Eurasia Journal of Mathematics, Science and Technology Education, *11*(5), 937–956.

Chairam, S., Somsook, E., & Coll, R. K. (2009). Enhancing Thai students' learning of chemical kinetics. *Research in Science & Technological Education*, *27*(1), 95–115.

Chiappetta, E. L. (1997). Inquiry-based science: Strategies and techniques for encouraging inquiry in the classroom. *The Science Teacher*, *64*(7), 22–26.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches.* California: Sage Publications, Inc.

Darus, F. B., & Saat, R. M. (2014). How do primary school students acquire the skill of making hypothesis. *The Malaysian Online Journal of Educational Science*, *2*(2), 20–26.

Demircioglu, T., & Ucar, S. (2015). Investigating the effect of argument-driven inquiry in laboratory instruction. *Educational Sciences: Theory & Practice*, *15*(1), 267–283.

Duran, M., & Dökme, I. (2016). The effect of the inquiry-based learning approach on student's critical-thinking skills. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(12), 2887–2908.

Ekahitanond, V. (2013). Promoting university students' critical thinking skills through peer feedback activity in an online discussion forum. *Alberta Journal of Educational Research*, *59*(2), 247–265.

Ennis, R. H. (2011). *The nature of critical thinking: An outline of critical thinking dispositions.* Retrieved from http://faculty.education.illinois.edu/rhennis/documents/TheNatureofCriticalThinking_51711_000.pdf

Facione, P. A. (2011). *Critical thinking: What it is and why it counts.* Millbrae, CA: Measured Reasons and The California Academic Press.

Feyzioglu, B., Demirdağ, B., Akyıldız, M., & Altun, E. (2012). Developing a science process skills test for secondary students: Validity and reliability study. *Educational Science Theory and Practice*, *12*(3), 1899–1906.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education (8th ed.).* New York, NY: McGraw-Hill.

Gehring, K. M., & Eastman, D. A. (2008). Information fluency for undergraduate biology majors: Applications of inquiry-based learning in a developmental biology course. *CBE Life Sciences Education*, *7*, 54–63.

Green, S. B., & Salkind, N. J. (2008). *Using SPSS for windows and macintosh (Analyzing and understanding data).* New Jersey: Pearson Prentice Hall.

Greenwald, R. R., & Quitadamo, I. J. (2014). A mind of their own: Using inquiry-based teaching to build critical thinking skills and intellectual engagement in an undergraduate neuroanatomy course. *The Journal of Undergraduate Neuroscience Education*, *12*(2), A100–A106.

Gultepe, N., & Kilic, Z. (2015). Effect of scientific argumentation on the development of scientific process skills in the context of teaching chemistry. *International*

Journal of Environmental and Science Education, *10*(1), 111–132.

Gupta, T., Burke, K. A., Mehta, A., & Greenbowe, T. J. (2015). Impact of guided-inquiry-based instruction with a writing and reflection emphasis on chemistry students' critical thinking abilities. *Journal of Chemical Education*, *92*(1), 32–38.

Hake, R. R. (1999). *Analyzing change/gain scores*. Retrieved from http://www.physics.indiana.edu/~sdi/AnalyzingChange-Gain.pdf

Hardianti, T., & Kuswanto, H. (2017). Difference among levels of inquiry: Process skills improvement at senior high school in Indonesia. *International Journal of Instruction*, *10*(2), 119–130.

Hsiao, H.-S., Chen, J.-C., Hong, J.-C., Chen, P.-H., Lu, C.-C., & Chen, S. Y. (2017). A five-stage prediction-observation-explanation inquiry-based learning model to improve students' learning performance in science courses. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3393–3416.

Hugerat, M., & Kortam, N. (2014). Improving higher order thinking skills among freshmen by teaching science through inquiry. *Eurasia Journal of Mathematics, Science and Technology Education*, *10*(5), 447–454.

Irwanto, Rohaeti, E., & Prodjosantoso, A. K. (2018a). A survey analysis of pre-service chemistry teachers' critical thinking skills. *MIER Journal of Educational Studies, Trends & Practices*, *8*(1), 57–73.

Irwanto, Rohaeti, E., & Prodjosantoso, A. K. (2018b). Undergraduate students' science process skills in terms of some variables: A perspective from Indonesia. *Journal of Baltic Science Education, 17*(5), 751–764.

Irwanto, Rohaeti, E., & Prodjosantoso, A. K. (2018c). The investigation of university students' science process skills and chemistry attitudes at the laboratory course. *Asia-Pacific Forum on Science Learning and Teaching, 19*(2), [7].

Irwanto, Rohaeti, E., & Prodjosantoso, A. K. (in press). Analyzing the relationships between pre-service chemistry teachers' science process skills and critical thinking skills. *Journal of Turkish Science Education*.

Irwanto, Rohaeti, E., Widjajanti, E., & Suyanta. (2017a). Students' science process skill and analytical thinking ability in chemistry learning. In *AIP Conference Proceedings* (Vol. 1868, pp. 1–5). https://doi.org/10.1063/1.4995100.

Irwanto, Rohaeti, E., Widjajanti, E., & Suyanta. (2017b). The development of an integrated assessment instrument for measuring analytical thinking and science process skills. In *AIP Conference Proceedings* (Vol. 1847, pp. 1–6). https://doi.org/10.1063/1.4983907.

Irwanto, Saputro, A. D., Rohaeti, E., & Prodjosantoso, A. K. (2018). Promoting critical thinking and problem solving skills of pre-service elementary teachers through process-oriented guided-inquiry learning (POGIL). *International Journal of Instruction, 11*(4), 777–794.

Ješková, Z., Lukáč, S., Hančová, M., Šnajder, Ľ., Guniš, J., Balogová, B., & Kireš, M.

(2016). Efficacy of inquiry-based learning in mathematics, physics and informatics in relation to the development of students' inquiry skills. *Journal of Baltic Science Education*, *15*(5), 559–574.

Karsli, F., & Şahin, Ç. (2009). Developing worksheet based on science process skills: Factors affecting solubility. *Asia-Pacific Forum on Science Learning and Teaching*, *10*(1), [15].

Ketpichainarong, W., Panijpan, B., & Ruenwongsa, P. (2010). Enhanced learning of biotechnology students by an inquiry-based cellulase laboratory. *International Journal of Environmental & Science Education*, *5*(2), 169–187.

Koc, Y., Doymus, K., Karacop, A., & Simşek, Ü. (2010). The effects of two cooperative learning strategies on the teaching and learning of the topics of chemical kinetics. *Journal of Turkish Science Education*, *7*(2), 52–65.

Konur, K. B., & Yıldırım, N. (2016). Pre-service science and primary school teachers' identification of scientific process skills. *Universal Journal of Educational Research*, *4*(6), 1273–1281.

Löfgren, R., Schoultz, J., Hultman, G., & Björklund, L. (2013). Exploratory talk in science education: Inquiry-based learning and communicative approach in primary school. *Journal of Baltic Science Education*, *12*(4), 482–496.

Lord, T., & Orkwiszewski, T. (2006). Moving from didactic to inquiry-based instruction in a science laboratory. *American Biology Teacher*, *68*(6), 342–345.

Lujan, H. L., & DiCarlo, S. E. (2006). Too much teaching, not enough learning: What is the solution? *Advances in Physiology Education*, *30*(1), 17–22.

Mahanal, S., Zubaidah, S., Bahri, A., & Dinnurriya, M. S. (2016). Improving students' critical thinking skills through remap NHT in biology classroom. *Asia-Pacific Forum on Science Learning and Teaching*, *17*(1), [11].

Maxwell, D. O., Lambeth, D. T., & Cox, J. T. (2015). Effects of using inquiry-based learning on science achievement for fifth-grade students. *Asia-Pacific Forum on Science Learning and Teaching*, *16*(1), [2].

Molefe, L., Stears, M., & Hobden, S. (2016). Exploring student teachers' views of science process skills in their initial teacher education programmes. *South African Journal of Education*, *36*(3), 1–12.

Muhlisin, A., Susilo, H., Amin, M., & Rohman, F. (2016). Improving critical thinking skills of college students through RMS model for learning basic concepts in science. *Asia-Pacific Forum on Science Learning and Teaching*, *17*(1), [12].

Mutlu, A., & Acar-Şeşen, B. (2018). Pre-service science teachers' understanding of chemistry: A factorial design study. *Eurasia Journal of Mathematics, Science & Technology Education*, *14*(7), 2817–2837.

National Council for Excellence in Critical Thinking [NCECT]. (2013). *Critical thinking*. Retrieved from http://www.criticalthinking.org/pages/thenational-council-for-excellence-in-critical-thinking/406.

Oliver-Hoyo, M. T. (2003). Designing a written assignment to promote the use of critical thinking skills in an introductory chemistry course. *Journal of Chemical Education*, *80*(8), 899–903.

Ongowo, R. O. (2017). Secondary school students' mastery of integrated science process skills in Siaya county, Kenya. *Creative Education*, *8*, 1941–1956.

Osman, K., & Vebrianto, R. (2013). Fostering science process skills and improving achievement through the use of multiple media. *Journal of Baltic Science Education*, *12*(2), 191–204.

Ozdem-Yilmaz, Y., & Cavas, B. (2016). Pedagogically desirable science education: Views on inquiry-based science education in Turkey. *Journal of Baltic Science Education*, *15*(4), 506–522.

Ozgür, S. D., & Yilmaz, A. (2017). The effect of inquiry-based learning on gifted and talented students' understanding of acids-bases concepts and motivation. *Journal of Baltic Science Education*, *16*(6), 994–1008.

Padilla, M. J. (1990). Science process skills. National association of research in science teaching publication: Research matters - to the science teacher (9004). Retrieved from http://www.narst.org/publications/research/skill.cfm.

Pradina, L. P., & Suyatna, A. (2018). Atom core interactive electronic book to develop self efficacy and critical thinking skills. *The Turkish Online Journal of Educational Technology*, *17*(1), 17–23.

Quitadamo, I. J., Faiola, C. L., Johnson, J. E., & Kurtz, M. J. (2008). Community-based inquiry improves critical thinking in general education biology. *CBE Life Sciences Education*, *7*, 327–337.

Rissing, S. W., & Cogan, J. G. (2009). Can an inquiry approach improve college student learning in a teaching laboratory? *CBE Life Sciences Education*, *8*, 55–61.

Sağlam, M. K., & Şahin, M. (2017). Inquiry-based Professional Development Practices for Science Teachers. *Inquiry-Based Professional Development Practices for Science Teachers*, *14*(4), 66–76.

Sari, S. A., Jasmidi, Kembaren, A., & Sudrajat, A. (2018). The impacts of chemopoly-edutainment to learning activities and responses. *Journal of Education and Learning*, *12*(2), 311–318.

Scriven, M., & Paul, R. (1987). Defining critical thinking. In *The 8th Annual International Conference on Critical Thinking and Education Reform*. Retrieved from http://www.criticalthinking.org/pages/defining-critical-thinking/766

Sen, C., & Vekli, G. S. (2016). The impact of inquiry based instruction on science process skills and self-efficacy perceptions of pre-service science teachers at a university level biology laboratory. *Universal Journal of Educational Research*, *4*(3), 603–612.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. New York: Houghton Mifflin Company.

Škoda, J., Doulík, P., Bílek, M., & Šimonová, I. (2015). The effectiveness of inquiry based science education in relation to the learners' motivation types. *Journal of Baltic Science Education*, *14*(6), 791–803.

Tatar, N. (2012). Inquiry-based science laboratories: An analysis of preservice teachers' beliefs about learning science through inquiry and their performances. *Journal of Baltic Science Education*, *11*(3), 248–267.

Wang, C.-H. (1993). Improving chemistry experimental learning through process-mapping-hydrolysis of p-nitroacetanilide-. *Bull. Nat'l Taiwan Nor. Univ.*, *38*, 157–173.

Wartono, W., Hudha, M. N., & Batlolona, J. R. (2018). How are the physics critical thinking skills of the students taught by using inquiry-discovery through empirical and theorethical overview? *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 691–697.

Yakar, Z., & Baykara, H. (2014). Inquiry-based laboratory practices in a science teacher training program. *Eurasia Journal of Mathematics, Science and Technology Education*, *10*(2), 173–183.

Yang, H., & Park, J. (2017). Identifying and applying factors considered important in students' experimental design in scientific open inquiry. *Journal of Baltic Science Education*, *16*(6), 932–945.

Žoldošová, K., & Matejovičová, I. (2010). Finding out how the elementary school children manipulate with empirical material and how they process the obtained information. *International Electronic Journal of Elementary Education*, *2*(3), 327–347.

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