Elementary Education Online, 2019; 18(2): pp. 496-507
İlköğretim Online, 2019; 18(2): s.496-507. [Online]: http://ilkogretim-online.org.tr
doi: 10.17051/ilkonline.2019.561896

The Impact of Problem Solving Instruction on Academic Achievement and Science Process Skills among Prospective Elementary Teachers

Problem Çözme Yönteminin Öğretmen Adaylarının Akademik Başarısı ve Bilimsel Süreç Becerilerine Etkileri

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Abstract. Nowadays, it is not enough for future teachers if they are only equipped with abilities and scientific skills, they need to apply their knowledge to real-world inside and outside the classroom. In fact, the previous studies report their low knowledge in understanding science. This research aims to improving students' academic achievement and Science Process Skills (SPS) through Problem Solving Instruction (PSI), and analyzing the correlation between both dependent variables. A quasi-experimental design was conducted for six weeks at Muhammadiyah University of Ponorogo, Indonesia. Forty-eight prospective elementary teachers completed Academic Achievement Test (AAT) and SPS Test (SPST). The reliability coefficient Cronbach's alpha of both tests was .81 and .86, respectively. Data were analyzed by using N-gain score, Mann-Whitney U test and Spearman's rho correlation at significance level .05. The findings indicate that there is significant difference on academic achievement and science process skills between experimental and control groups in favor of experimental group students, and there is a high positive and significant correlation between both dependent variables. We recommend to the lecturers to use PSI as a tool to promote students' scientific skills and abilities to satisfactory performance in order to respond fast changes in 21st century learning.

Keywords: Problem solving instruction, academic achievement, science process skills

Received: 11.06.2018 Accepted: 15.11.2018 Published: 15.04.2019

INTRODUCTION

The transformation to 21st century learning needs big changes in developing thinking habit and learning disposition which will create intellectual skills (Snape, 2012). This is featured by the advance of digital technology that has changed the way we interact with people around us, included interaction among students, students with the materials, and students with lecturers. Lecturers in 21st century learning no longer transmits knowledge to students, however they have to facilitate the acquisition of values, knowledge, and students competence by using inquiry strategy to their classroom teaching practices (Bell, 2016; Dembo, 2001). Because lecturers' domination has been reduced, then students must respond that change quickly and lecturers need to prepare them to be long life learner for following the technology evolution.

One of the most important purposes in higher education is developing science process skills. Science process skills (SPS) are a set of skills used by students to explore science phenomenon. This is the basic for the most effective science investigation in helping students to understand the concept of science and understand how scientists work and think (Akcay & Yager, 2016). That skills need scientific thought support in order to learn the knowledge and find solution towards problems. This skills are divided into two categories, they are; basic and integrated process skills (Can, Yıldız-Demirtaş, & Altun, 2017; Farsakoglu, Sahin, & Karsli, 2012; Feyzioğlu, 2009; Hernawati, Amin, Irawati, Indriwati, & Aziz, 2018; Irwanto, Rohaeti, Widjajanti, & Suyanta, 2017a; Taskin-Can, 2013), covers observing, measuring, classifying, predicting, inferring, communicating, then identifying and controlling variables, formulating and testing hypotheses, experimenting, and drawing graphics. The usage of both of them depends on students' cognitive development and practical experience in building the knowledge. Science process skills correlate to formal reasoning ability used to solve the problem by applying the knowledge that they learned beforehand (Seung, Choi, & Pestel, 2016).

Scientific skills are often related to superior skills in improving investigation ability, until students that acquire that skills can understand complex problem better (Gürses, Çetinkaya, Doğar, & Şahin, 2015). However, the result of the prior studies conducted by some researchers show that students' SPS in Indonesia is still low (Irwanto, Rohaeti, & Prodjosantoso, 2018; Rani, Wiyatmo, & Kustanto, 2017; Savitri, Wusqo, Ardhi, & Putra, 2017; Vebrianto & Osman, 2011; Wahyuni, Indrawati, Sudarti, & Suana, 2017). The weakness in that skills can be seen from students' inability in measuring, applying the concept, interpreting, and communicating data (Irwanto, Rohaeti, Widjajanti, & Suyanta, 2017b). Why did this happen? We assess that generally science teaching in Indonesia still focuses on memorizing the science concept, teacher-centered, until students do not get change to construct their science process skills, as conveyed by Prayitno, Corebima, Susilo, Zubaidah and Ramli (2017). If the knowledge and scientific theory are told to students directly without allowing them to think, then that teaching does not support scientific exploration process (Aktamis & Ergin, 2008). The lack of hands-on experience certainly cause students' failure in acquiring useful scientific knowledge in solving the problem in the global society. Thereby, to anticipate that failure, we assume that students science process skills need to be empowered through problem solving strategy.

The challenges in science learning nowadays are not only about transferring the concept, but also combining the skills, knowledge, and behavior to construct a concept through problem solving. Yee (1994) views problem solving activities as learning situation to introduce the concepts, develop the skills, and use their knowledge to solve all problems. Problem solving is defined as complex and multi-layered skills required to formulate a new answer and create solution (Selcuk, Çalişkan, & Erol, 2008). Prevost and Lemons (2016) underlie problem solving as the process of making decision in which students are presented with challenging task that cannot be solved automatically. The problem presented is not only about routine problem, but it reaches non-routine problems that needs high level thinking skills. Thereby, the purpose of problem solving teaching process is providing environment where students interact with one another and learn how to study and solve problem (Nozari & Siamian, 2014) by using science process skills.

We agree that students who are equipped with problem solving skills can overcome complex problem easily in their daily life (Irwanto, Saputro, Rohaeti, & Prodjosantoso, 2018; Özreçberoğlu & Çağanağa, 2018). Some evidence show positive impact of applying problem solving teaching strategy towards students' achievement. In Iran, Nozari and Siamian (2014) finds out that the implementation of that method increases creativity and its components, such as fluidity, originality, flexibility, and expansion. In Philippines, Cabanilla-Pedro, Acob-Navales and Josue (2004) conducted research towards 26 grade six students and reveals that the usage of problem solving in the classroom can improve their analysis skills significantly. Afterwards, Hu, Xiaohui and Shieh (2017) reveals that problem solving teaching influence the attitude towards learning and students' achievement. Supportively, Aka, Güven and Aydoğdu (2010) also show that after the course, students of experimental group had higher average scores in process skills and achievement than control group. Finally, in Taiwan, Cheng, She and Huang (2018) report that students of problem solving group significantly surpass traditional group in the case of scientific knowledge, scientific concept, and scientific problem solving abilities.

However, few studies reported the effect of problem solving instruction towards science process skills (Aka et al., 2010; Geban, Askar, & Özkan, 1992; Seyhan, 2015). Even, in Indonesia, there is no study about the impact of that method towards students' academic achievement and scientific skills. Whereas, almost four decades ago, Bluhm (1979) and Ostlund (1998) emphasize that the curriculum of science education at the university level needs to facilitate the prospective elementary school teachers to understand how science process skills used in inquiry or problem solving situation. Those skills are transferable skills that can be improved by using constructivist teaching. The right chosen method is lecturers' main reason to improve the process and learning outcome. From those various reasons, this research aims to improve prospective elementary teachers' academic achievement and science process skills between students taught by using problem solving instruction and conventional teaching method, examine whether there is significant difference between those two groups, and analyze the correlation between both dependent variables. As the benefits, lecturers can use various teaching methods, doing innovation in learning and improve the learning that they manage until they have ability and creativity in developing and improving the next more effective teaching program.

METHOD

Research Design

A quasi-experimental control group pretest-posttest design was performed in this study. Experimental research design was employed to evaluate the effectiveness and the impact of the programs that emphasize on the usage of comparative data as the context to interpret the findings (Gribbons & Herman, 1997). This present study compares academic achievement and science process skills between experimental group students taught by using problem solving instruction and control group students taught by using conventional method for six weeks period in one semester. To determine which teaching method that has significant effect towards the performance of the prospective elementary teachers, pretest and posttest control group design was conducted (Table 1).

Table 1. *Pretest and posttest nonequivalent control group design*

Groups	Pretest	Treatment	Posttest
Experimental	O_1	PSI	O_2

Control	O_1	-	O_2

Samples

Samples covered 48 students (13 males, 35 females) on the first year who attended Basic Science Concept course at Department of Elementary School Education, Muhammadiyah University of Ponorogo, Indonesia, in the first semester of academic year 2017/2018. Experimental group consisted of 24 students (4 males, 20 females) and control group consisted of 24 students (9 males, 15 females). The number of male students was 27.08%. The average age of samples were 19 years old, among 18 to 21 years old.

Data Collection Instruments

Two instruments were used in this research, they were Academic Achievement Test (AAT) and Science Process Skills Test (SPST). The AAT was developed by the researchers to measure the students' academic achievement. It consisted of 5 essay questions covered Energy concept and momentum and Forces and motion. This tool was designed in accordance with Bloom's revised taxonomy that covered analyzing, evaluating, and creating levels (Krathwohl, 2002) in the amount of 2, 2, and 1 item, respectively. The minimum and maximum scores that could be obtained by each student were 0 points and 100 points respectively. The reliability coefficient of Cronbach's alpha was calculated in the amount of $\alpha = .81$.

While the SPST was developed by the researchers to measure the students' science process skills. It consisted of 5 essay questions covered inferring, predicting, classifying, formulating hypotheses, and drawing graphics skills, adapted from Can et al. (2017), Farsakoglu et al. (2012), and Feyzioğlu (2009). The minimum and maximum scores that could be obtained by each student were 0 points and 20 points respectively. The reliability coefficient of Cronbach's alpha was calculated in the amount of $\alpha = .86$. All instruments were developed by the researchers, and validated by senior science lecturers and instructional experts from Muhammadiyah University of Ponorogo. Based on the results, both instruments were stated reliable because the reliability coefficient of both instruments was above acceptance limits .70 (Hair, Black, Babin, & Anderson, 2010).

Procedures

The researchers asked for permission from The Head of Department of Elementary School Education, Muhammadiyah University of Ponorogo, before conducting the research. Additionally, none of prospective elementary teachers refused to participate as respondents. The research was conducted for 4 months, started from February until May 2018. During the research, students in experimental group were taught by using problem solving instruction, while students in control group were taught by using conventional teaching. Data of academic achievement and science process skills were collected twice, at pretest and posttest. Before starting the research, both instruments were applied in both groups as pretest. Then, students followed face-to-face course for 100 minutes per week. During the treatment, both groups were taught by the same lecturer. After the treatment, posttest was given to both experimental and control group. Table 2 showed the syntax of problem solving instruction adapted from Gok (2010), Polya (1957) and Selcuk et al. (2008).

Table 2. *The syntax of problem solving instruction in experimental group*

Stages	Activities
Understanding the problem	Students read and re-read the problem, identify the obstacles in the problem, determine important information in the problem, and rewrite the problem in various forms (paraphrasing the problem, drawing the picture, diagram, or graphic about the problem).

Devising a plan	Students identified principles, regulations and laws about the problem, looked for the connection between the data and the unknown, and arranged plan to reach the unknown.
Carrying out the plan	Students used the findings at the second stage to solve the problem then examined each correctness of the stages.
Looking back	Students examine the result of problem solving, arguments, and the answers carefully.

Data Analysis

Data analysis was started by assessing each student's answer at each instrument. Because the size of the samples was classified small (less than 30 students), the quantitative data analysis used non-parametric statistics (Bernard, 2000; Green & Salkind, 2008). While descriptive statistics was used to obtain sample characteristics that covered mean, standard deviation, maximum and minimum score. Mann-Whitney U test was done to test the mean difference between two groups, and Spearman's rho correlation was employed to analyze the correlation between academic achievement and science process skills. N-gain was used to measure the difference between pretest and posttest by using Hake's (1999) formula. It was done at significance level .05 by using statistical program SPSS 17.0

RESULTS

The research findings were described in detail in this section. At the beginning of the course, the results of pretest obtained from the research were compared to explain the achievement difference between experimental and control group by using U test (Table 3).

Table 3. *Pretest academic achievement score of experimental and control groups*

Sub-Dimension	Groups	N	Mean Rank	Sum of Ranks	Mann-Whitney U test	
					U	p
Analyzing	Experimental	24	26.44	634.50	241.500	.294
	Control	24	22.56	541.50		
Evaluating	Experimental	24	25.19	604.50	271.500	.701
	Control	24	23.81	571.50		
Creating	Experimental	24	21.46	515.00	215.000	.079
	Control	24	27.54	661.00		
Overall	Experimental	24	24.75	594.00	282.000	.898
	Control	24	24.25	582.00		

Table 3 shows that, overall, pretest academic achievement score of experimental group students was slightly higher than control group, even though mean rank between both groups was not significantly different (U=282.000; p>.05). In detail, there is no significant difference between both groups in all sub-dimensions (p>.05). Thereby, it can be concluded that before the treatment was conducted, students had equal ability.

Table 4. *Pretest SPS score of experimental and control groups*

Sub-Dimension	Groups	N	Mean Rank	Sum of Ranks	Mann-Whitney U test	
					U	p
Inferring	Experimental	24	22.75	546.00	246.000	.237
	Control	24	26.25	630.00		
Predicting	Experimental	24	24.42	586.00	286.000	.963
	Control	24	24.58	590.00		
Classifying	Experimental	24	23.29	559.00	259.000	.501

Sub-Dimension	Groups	N	Mean Rank	Sum of Ranks	Mann-Whitney U test	
					U	p
	Control	24	25.71	617.00		
Formulating Hypotheses	Experimental	24	26.06	625.50	250.500	.290
	Control	24	22.94	550.50		
Drawing Graphics	Experimental	24	25.50	612.00	264.000	.566
	Control	24	23.50	564.00		
Overall	Experimental	24	23.67	568.00	268.000	.675
	Control	24	25.33	608.00		

Table 4 showed that, overall, pretest SPS score of control group students was slightly higher than experimental group. In detail, we also found the similar trend in all sub-dimensions. However, mean rank between both groups was not significantly different (U=268.000; p>.05). It can be concluded that at the beginning of the course, students had equal scientific skills.

Table 5. *Posttest achievement score of experimental and control groups*

Sub-Dimension	Groups	N	Mean Rank	Sum of Ranks	Mann-Whitney U test	
					U	p
Analyzing	Experimental	24	32.21	773.00	103.000	.000
	Control	24	16.79	403.00		
Evaluating	Experimental	24	33.46	803.00	73.000	.000
	Control	24	15.54	373.00		
Creating	Experimental	24	30.90	741.50	134.500	.000
	Control	24	18.10	434.50		
Overall	Experimental	24	35.23	845.50	30.500	.000
	Control	24	13.77	330.50		

Table 5 showed that posttest academic achievement score between experimental and control group was significantly different (U=30.500; p<.05). In detail, there was significant difference between both groups in all sub-dimensions (p<.05). Experimental group students had higher mean rank compared to control group (the difference was 21.46). Achievement score difference at the end of the course indicates the existence of the instruction method intervention during the application. It can be concluded that problem solving method significantly influence students' academic achievement.

Table 6. *Posttest SPS score of experimental and control groups*

Sub-Dimension	Groups	N	Mean Rank	Sum of Ranks	Mann-Whitney U test	
					U	p
Inferring	Experimental	24	30.00	720.00	156.000	.002
	Control	24	19.00	456.00		
Predicting	Experimental	24	28.50	684.00	192.000	.020
	Control	24	20.50	492.00		
Classifying	Experimental	24	28.50	684.00	192.000	.022
	Control	24	20.50	492.00		
Formulating Hypotheses	Experimental	24	29.25	702.00	174.000	.010
	Control	24	19.75	474.00		

Sub-Dimension	Groups	N	Mean Rank	Sum of Ranks	Mann-Whitney U test	
					U	p
Drawing Graphics	Experimental	24	32.29	775.00	101.000	.000
	Control	24	16.71	401.00		
Overall	Experimental	24	34.56	829.50	46.500	.000
	Control	24	14.44	346.50		

Table 6 showed that posttest SPS score between experimental and control group was significantly different (U=46.500; p<.05). Experimental group students had higher mean rank compared to control group (the difference was 20.12). SPS score difference at the end of the treatment showed the existence of students' cognitive skills development in experimental group. It can be concluded that problem solving method significantly influence their scientific skills.

Table 7. *N-gain scores of experimental and control groups*

	Academic Achievement		Science Process Skills	
Groups	Experimental	Control	Experimental	Control
Posttest	88.13	70.42	18.04	15.46
Pretest	55.63	55.42	10.71	10.88
N-Gain	.73	.34	.79	.50
Category	High	Moderate	High	Moderate

In order to explain how much was the improvement of students' performance in both groups, N-gain was employed. Experimental group students showed more superior gain score in both dependent variables compared to control group. They noted improvement in the amount of .73 and .79 on academic achievement and science process skills, respectively.

Table 8. *Spearman's rho correlation between academic achievement and science process skills*

	Academic Achievement	N	p
Science Process Skills	r=.553**	48	.005

Note: ** p < .01

The last research purpose was to analyze the correlation between academic achievement and science process skills among prospective elementary teachers in experimental group. Based on data analysis (see Table 8), we found out the existence of strongly positive and significant correlation between students' academic achievement and science process skills (r=.553; p<.05). It can be concluded that students' SPS improvement taught by using problem solving method can increase their academic achievement.

DISCUSSION

Problem solving covers scientific thinking process that involves scientific process (e.g., findings, investigation, and critical thinking) that does not only need content information but also using the right method (Aka et al., 2010). This present study aims to identify significant difference between academic achievement and science process skills of prospective elementary teachers taught by using problem solving and conventional teaching methods, then investigates the correlation between those two dependent variables. The findings in this research are explained in detail as follows. The first, based on the pretest score, students in experimental and control group had equal achievement. The reason for that finding, we observed that before the treatment, the course tended to be conducted by using traditional lecture approach. This result is in line with Aka et al. (2010), Çalışkan, Selçuk and Erol (2010) and Gok (2014) who conclude that students taught by using conventional method tend to have low achievement. Students' low performance can be seen from their inability in absorbing information and lack of mathematical concept understanding presented in the essay test, almost the same like findings by Rohmah and Sutiarso (2018). This is because in traditional didactic teaching, students learn the knowledge passively until they missed much time and ability to build knowledge, as reported by Hu et al. (2017). Thereby, it is not surprising if both groups have similar pretest score.

The second, the application of problem solving instruction has significant impact towards students' academic achievement and science process skills in experimental group. Our results demonstrate that problem solving group show significantly better posttest score than conventional group in both dependent variables. Furthermore, we also investigate the improvement of students' pretest and posttest score in both groups. The result of the analysis show gain score of students in control group tend to experience little improvement, however either their pretest or posttest was moderate, while students in experimental group experience improvement from moderate to high after the instruction. Why are students in experimental group more superior? This is because problem solving involves actionable knowledge that propels the transfer of knowledge across domain and different context, until students more recognize the type of the problem and easier in applying the solution related to that problem (Cheng et al., 2018; Özreçberoğlu & Çağanağa, 2018).

We also believe that students' high posttest score is related to problem solving task presented during the instruction. Problem solving task is assumed to be able to develop higher thinking level such as justifying, generalizing, comparing, synthesizing, and analyzing through inquiry investigation and situation analysis (Cabanilla-Pedro et al., 2004). In addition, in this instruction, lecturer act as a facilitator that stimulate students' initiative, focus on learning process, construct their thinking ability and non-routine problem solving skills. Consequently, students who are equipped with problem solving skills can interpret problem statement correctly, plan the solution in detail, and use more metacognitive process (Yee, 1994; Hassan & Rahman, 2017). Therefore, in line with that principle, students exposed to problem solving instruction show more dominant performance compared to students in conventional group.

Consistent with our findings, Tosun and Taskesenligil (2013) investigate 84 freshmen who took General Chemistry-II course and find out that problem-oriented instruction is more effective than conventional teaching in improving scientific process skills, access and use knowledge, work in collaboratively in group and study independently. Günter and Alpat (2017) revealed that experimental group of prospective chemistry teachers had higher academic potency, few misconceptions and had better understanding about electrochemistry concept. Afterwards, Tatar and Oktay (2011) involved 48 third-grade university students on teaching the first law of thermodynamics and reported that learning that facilitated students to overcome the problem had positive effect towards learning abilities and science process skills. Even, Yalcin, Karahan, Karadenizli and Sahin (2006) agreed that problem-based instruction positively influenced scientific process skills and problem solving of the students in short time. Lastly, Seyhan (2015) also reported that the application of problem solving had significant impact towards scientific process skills and logical thinking abilities of prospective science teachers. From those various findings, it is necessary to remember that problem solving instruction can propel content knowledge development and various skills needed by students in learning science efficiently, as mentioned by Wilder (2015).

In the contrary to these findings, Kızkapan and Bektaş (2017) reported that there was no significant effect of posttest achievement score of grade seven students who were exposed to problem-oriented instruction and students who were exposed to traditional instruction. Further, Armağan, Sağir and Çelik (2009) also reported that there was no significant difference of posttest score between experimental group taught by using problem solving instruction and control group taught by using traditional method after learning chemical reaction rates. We predict the different findings probably caused by different environment, learning style, prior knowledge, characteristics of teachers and students, curriculum, work experiences, and age (Akyüz, 2006; Ari & Bayram, 2011; Erdogan, Bayram, & Deniz, 2008; Lin, Yen, Liang, Chiu, & Guo, 2016; Tatar, Tüysüz, Tosun, & İlhan, 2016; Yazıcılar & Güven, 2009). Thereby, it is important for lecturers to understand the factors that can influence students' performance in learning and solving the problem. This aims to make an effective process and optimizing the learning outcomes.

Finally, we found out strongly positive and significant correlation between academic achievement and science process skills in experimental group. Our finding is supported by Feyzioğlu (2009) who reports that there is positive correlation and significantly linear between science process skills and academic achievement among students who take General Chemistry course. In other studies, (Başer & Durmuş, 2010; Durmaz & Mutlu, 2014; Özgelen, 2012; Yildirim, Çalik, & Özmen, 2016) also reveal that there is a strong correlation between students' achievement and their science process skills. Even though in the previous research, Aydogdu and Ergin (2008) report the correlation between science process skills and academic achievement of prospective science teachers is positive moderate. In this context, we conclude that students' science process skills improvement influence their achievement. Cabanilla-Pedro et al. (2004) emphasize that the usage of problem solving strategy statistically can improve students' analyzing skills. As we know, "analyzing" is one of cognitive domain in higher order thinking skills in accordance with Bloom's taxonomy (Krathwohl, 2002). Thereby, students' achievement can be improved through problem solving strategy. We suggest that problem solving instruction is used intensively to improve students' science learning achievement thoroughly.

CONCLUSIONS and SUGGESTIONS

In this study, the impact of problem solving instruction towards academic achievement and science process skills has been compared to conventional teaching method. Based on the analysis at the end of the course, problem solving gives positive impact towards the performance of prospective elementary teachers. There is greater increase on experimental than control group. It is found out that the gain achievement score of experimental and control group students obtained in the amount of .73 and .34 (.39 higher), while students' gain scientific skills score obtained in the amount of .79 and .50 (.29 higher), respectively. Additionally, the results of Spearman's rho correlation show that there is highly positive and significant correlation between achievement and science process skills. It means, the higher students' achievement, the higher their scientific skills. Thereby, problem solving method has significant effect towards students' learning abilities compared to conventional teaching group.

Further research is needed to examine the effects of problem solving towards students' achievement and scientific skills in terms of educational level, academic majors, and other courses. In this research, there was no method applied in control group. The next similar research can compare these with other constructivist learning method, such as problem-based learning, inquiry-based learning, process-oriented guided-inquiry learning, project-based learning, research-based learning or other methods that have potency to give big impact. This is because the instructional method is one of the most important factors in improving student achievement and the key to promote their conceptual change, as explained by Lin et al. (2016). Arguably, the effect of problem solving instruction towards attitude, interest, motivation, and students' thinking habits need to be investigated.

REFERENCES

Aka, E. I., Güven, E., & Aydoğdu, M. (2010). Effect of problem solving method on science process skills and academic achievement. *Journal of Turkish Science Education*, *7*(4), 13–25.

Akcay, H., & Yager, R. E. (2016). Students learning to use the skills used by practicing scientists. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(3), 513–525.

Aktamis, H., & Ergin, Ö. (2008). The effect of scientific process skills education on students' scientific creativity, science attitudes and academic achievements. *Asia-Pacific Forum on Science Learning and Teaching*, *9*(1), 1–21.

Akyüz, G. (2006). Investigation of the effect of teacher and class characteristics on mathematics achievement in Turkey and European Union Countries. *Elementary Education Online*, *5*(2), 75–86.

Ari, E., & Bayram, H. (2011). The influence of constructivist approach and learning styles on achievement

and science process skills in the laboratory. *Elementary Education Online*, *10*(1), 311–324.
Armağan, F. Ö., Sağir, Ş. U., & Çelik, A. Y. (2009). The effects of students' problem solving skills on their understanding of chemical rate and their achievement on this issue. *Procedia - Social and Behavioral Sciences*, *1*(1), 2678–2684.
Aydogdu, B., & Ergin, O. (2008). The relationship between science process skills and academic achievements of pre-service science teachers. In *IOSTE Symposium, The Use of Science and Technology Education for Peace and Sustainable Development* (pp. 899–905).
Başer, 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.
Bell, D. V. J. (2016). Twenty-first century education: Transformative education for sustainability and responsible citizenship. *Journal of Teacher Education for Sustainability*, *18*(1), 48–56.
Bernard, H. R. (2000). *Social research methods: Qualitative and quantitative approaches*. California: SAGE Publications, Inc.
Bluhm, W. J. (1979). The effects of science process skill instruction on preservice elementary teachers' knowledge of, ability to use, and ability to sequence science process skills. *Journal of Research in Science Teaching*, *16*(5), 427–432.
Cabanilla-Pedro, L. A., Acob-Navales, M., & Josue, F. T. (2004). Improving analyzing skills of primary students using a problem solving strategy. *Juournal of Science and Mathematics Education in S.E Asia*, *27*(1), 33–53.
Çalışkan, S., Selçuk, G. S., & Erol, M. (2010). Instruction of problem solving strategies: Effects on physics achievement and self-efficacy beliefs. *Journal of Baltic Science Education*, *9*(1), 20–34.
Can, B., Yıldız-Demirtaş, V., & Altun, E. (2017). The effect of project-based science education programme on scientific process skills and conceptions of kindergarten students. *Journal of Baltic Science Education*, *16*(3), 395–413.
Cheng, S.-C., She, H.-C., & Huang, L.-Y. (2018). The impact of problem-solving instruction on middle school students' physical science learning: Interplays of knowledge, reasoning, and problem solving. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(3), 731–743.
Dembo, M. H. (2001). Learning to teach is not enough—Future teachers also need to learn how to learn. *Teacher Education Quarterly*, *28*(4), 23–35.
Durmaz, H., & Mutlu, S. (2014). The effects of an instructional intervention on 7th grade students' science process skills and science achievement. *Çukurova Üniversitesi Eğitim Fakültesi Dergisi*, *43*(2), 155–168.
Erdogan, Y., Bayram, S., & Deniz, L. (2008). Factors that influence academic achievement and attitudes in web based education. *International Journal of Instruction*, *1*(1), 31–47.
Farsakoglu, Ö. F., Sahin, Ç., & Karsli, F. (2012). Comparing science process skills of prospective science teachers: A cross-sectional study. *Asia-Pacific Forum on Science Learning and Teaching*, *13*(1), 1–21.
Feyzioğlu, B. (2009). An investigation of the relationship between science process skills with efficient laboratory use and science achievement in chemistry education. *Journal of Turkish Science Education*, *6*(3), 114–132.
Geban, Ö., Askar, P., & Özkan, İ. (1992). Effects of computer simulations and problem-solving approaches on high school students. *The Journal of Educational Research*, *86*(1), 5–10.
Gok, T. (2010). A new approach: Computer-assisted problem-solving systems. *Asia-Pacific Forum on Science Learning and Teaching*, *11*(2).
Gok, T. (2014). Students' achievement, skill and confidence in using stepwise problem-solving strategies. *Eurasia Journal of Mathematics, Science and Technology Education*, *10*(6), 617–624.
Green, S. B., & Salkind, N. J. (2008). *Using SPSS for windows and macintosh (Analyzing and understanding data)* (5th editio). New Jersey: Pearson Prentice Hall.
Gribbons, B., & Herman, J. (1997). True and quasi-experimental designs. *Practical Assessment, Research & Evaluation*, *5*(14), 1–3.
Günter, T., & Alpat, S. K. (2017). The effects of problem-based learning (PBL) on the academic achievement of students studying "Electrochemistry." *Chemistry Education Research and Practice*, *18*(1), 78–98.
Gürses, A., Çetinkaya, S., Doğar, Ç., & Şahin, E. (2015). Determination of levels of use of basic process skills of high school students. *Procedia - Social and Behavioral Sciences*, *191*, 644–650.
Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th editio). New Jersey: Prentice Hall, Upper Saddle River.
Hake, R. R. (1999). *Analyzing change/gain scores*. Retrieved from http://www.physics.indiana.edu/~sdi/AnalyzingChange-Gain.pdf
Hassan, N. M., & Rahman, S. (2017). Problem solving skills, metacognitive awareness, and mathematics

achievement: A mediation model. *The New Educational Review, 49*(3), 201–212.
Hernawati, D., Amin, M., Irawati, M., Indriwati, S., & Aziz, M. (2018). Integration of project activity to enhance the scientific process skill and self-efficacy in zoology of vertebrate teaching and learning. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(6), 2475–2485.
Hu, R., Xiaohui, S., & Shieh, C.-J. (2017). A study on the application of creative problem solving teaching to statistics teaching. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 3139–3149.
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.
Irwanto, Rohaeti, E., & Prodjosantoso, A. K. (2018). 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., Widjajanti, E., & Suyanta. (2017a). The development of an integrated assessment instrument for measuring analytical thinking and science process skills. In *AIP Conference Proceedings* (Vol. 1847, pp. 50005-1–6). https://doi.org/10.1063/1.4983907.
Irwanto, Rohaeti, E., Widjajanti, E., & Suyanta. (2017b). Students' science process skill and analytical thinking ability in chemistry learning. In *AIP Conference Proceedings* (Vol. 1868, p. 30001). https://doi.org/10.1063/1.4995100
Kızkapan, O., & Bektaş, O. (2017). The effect of project based learning on seventh grade students' academic achievement. *International Journal of Instruction*, *10*(1), 37–54.
Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into Practice*, *41*(4), 212–218.
Lin, J.-W., Yen, M.-H., Liang, J.-C., Chiu, M.-H., & Guo, C.-J. (2016). Examining the factors that influence students' science learning processes and their learning outcomes: 30 years of conceptual change research. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(10), 2617–2646.
Nozari, A. Y., & Siamian, H. (2014). The effects of problem-solving teaching on creative thinking among district 2 high school students in Sari City. *Materia Socio Medica*, *26*(6), 360.
Ostlund, K. (1998). What the research says about science process skills. *Electronical Journal of Science Education*, *2*(4). Retrieved from http://ejse.southwestern.edu/article/view/7589/5356
Özgelen, S. (2012). Students' Science Process Skills within a Cognitive Domain Framework. *Eurasia Journal of Mathematics, Science & Technology Education*, *8*(4), 283–292.
Özreçberoğlu, N., & Çağanağa, Ç. K. (2018). Making it count: Strategies for improving problem-solving skills in mathematics for students and teachers' classroom management. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(4), 1253–1261.
Polya, G. (1957). *How to solve it*. New York: Anchor Books.
Prayitno, B. A., Corebima, D., Susilo, H., Zubaidah, S., & Ramli, M. (2017). Closing the science process skills gap between students with high and low level academic achievement. *Journal of Baltic Science Education*, *16*(2), 266–277.
Prevost, L. B., & Lemons, P. P. (2016). Step by step: Biology undergraduates' problem-solving procedures during multiple-choice assessment. *CBE Life Sciences Education*, *15*(4), 1–14.
Rani, S. A., Wiyatmo, Y., & Kustanto, H. (2017). Concept attainment worksheet to enhance concept knowledge and science process skills in physics instruction. *Jurnal Pendidikan IPA Indonesia*, *6*(2), 326–334.
Rohmah, M., & Sutiarso, S. (2018). Analysis problem solving in mathematical using theory Newman. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 671–681.
Savitri, E. N., Wusqo, I. U., Ardhi, M. W., & Putra, P. D. (2017). Enhancement of science students' process skills through implementation of green learning method (Gelem) with conservation-based inquiry approach. *Jurnal Pendidikan IPA Indonesia*, *6*(2), 237–244.
Selcuk, G., Çalişkan, S., & Erol, M. (2008). The effects of problem solving instruction on physics achievement, problem solving performance and strategy use. *Latin American Journal of Physics Education*, *2*(3), 161–166.
Seung, E., Choi, A., & Pestel, B. (2016). University students' understanding of chemistry processes and the quality of evidence in their written arguments. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(4), 991–1008.
Seyhan, H. G. (2015). The effects of problem solving applications on the development of science process skills, logical thinking skills and perception on problem solving ability in the science laboratory. *Asia-Pacific Forum on Science Learning and Teaching*, *16*(2), 1–31.
Snape, P. (2012). Twenty-first century learning in the senior secondary school: A New Zealand teacher's innovation. In *PATT 26 Conference; Technology Education in the 21st Century* (pp. 415–424).

Taskin-Can, B. (2013). The effects of using creative drama in science education on students' achievements and scientific process skills. *Elementary Education Online*, *12*(1), 120–131.
Tatar, E., & Oktay, M. (2011). The effectiveness of problem-based learning on teaching the first law of thermodynamics. *Research in Science & Technological Education*, *29*(3), 315–332.
Tatar, E., Tüysüz, C., Tosun, C., & İlhan, N. (2016). Investigation of factors affecting students' science achievement according to student science teachers. *International Journal of Instruction*, *9*(2), 153–166.
Tosun, C., & Taskesenligil, Y. (2013). The effect of problem-based learning on undergraduate students' learning about solutions and their physical properties and scientific processing skills. *Chemistry Education Research and Practice*, *14*(1), 36–50.
Vebrianto, R., & Osman, K. (2011). The effect of multiple media instruction in improving students' science process skill and achievement. *Procedia - Social and Behavioral Sciences*, *15*(1), 346–350.
Wahyuni, S., Indrawati, Sudarti, & Suana, W. (2017). Developing science process skills and problem-solving abilities based on outdoor learning in junior high school. *Jurnal Pendidikan IPA Indonesia*, *6*(1), 165–169.
Wilder, S. (2015). Impact of problem-based learning on academic achievement in high school: A systematic review. *Educational Review*, *67*(4), 414–435.
Yalcin, B. M., Karahan, T. F., Karadenizli, D., & Sahin, E. M. (2006). Short-term effects of problem-based learning curriculum on students' self-directed skills development. *Croatian Medical Journal*, *47*(3), 491–498.
Yazıcılar, Ö., & Güven, B. (2009). The effects of learning style activities on academic achievement, attitudes and recall level. *Elementary Education Online*, *8*(1), 9–23.
Yee, F. P. (1994). Differences in the processes of solving mathematical problems between successful and unsuccessful solvers. *Teaching and Learning*, *14*(2), 61–72.
Yildirim, M., Çalik, M., & Özmen, H. (2016). A meta-synthesis of Turkish studies in science process skills. *International Journal of Environmental & Science Education*, *11*(14), 6518–6539.