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THE IMPACT OF RESEARCH-ORIENTED COLLABORATIVE INQUIRY LEARNING ON PRE-SERVICE TEACHERS' SCIENTIFIC PROCESS SKILLS AND ATTITUDES

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Abstract

In the past decade, scientific process skills and scientific attitudes are widely regarded as essential factors influencing students' achievement and their future career choices. Unfortunately, previous literature found that students' scientific skills and attitudes tend to be unsatisfactory. Thus, cultivating students' skills and attitudes is seen as a fundamental goal in science education. This research sought to promote scientific process skills and scientific attitudes of pre-service chemistry teachers using REORCILEA (Research-Oriented Collaborative Inquiry Learning). In this quasi-experimental research, a one-group pretest and posttest design was utilized. A total of 50 pre-service teachers (6 males and 44 females) at a medium-sized public university in Indonesia were recruited in this study. In order to gather data, the Scientific Process Skills Observation Checklist (SPSOC) and the Scientific Attitude Survey (SAS) were administered before and after the intervention. The data obtained in this study were analyzed through paired-samples *t*-test and Cohen's *d*. The results showed a significant increase from pretest to posttest in scientific process skills and scientific attitude scores during treatment, each with a high effect size. It can be summarized that REORCILEA is effective in fostering scientific skills and positive attitudes of pre-service chemistry teachers to a satisfactory level. It is recommended for educators to apply REORCILEA to other college chemistry courses to improve their performance.

***Keywords* –** Collaborative inquiry learning, Research-oriented learning, Scientific attitudes, Scientific process skills.

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1. Introduction

Numerous studies claimed that a lot of students enter the university with inadequate prior knowledge and laboratory skills (Veiga, Luzardo, Irving, Rodriguez-Ayan & Torres, 2019). In addition, previous literature (e.g., Goodey & Talgar, 2016; Knox, Gillis & Dake, 2019; Runquist & Kerr, 2005) reported that chemistry graduates lack communication skills, the ability to analyze data efficiently, work ethos, and critical thinking, problem-solving, and teamwork skills. It may be due to the fact that lectures generally do not develop practical work experience and attitudes towards chemistry (Calik, Ultay, Kolomuc & Aytar, 2015; Goodey & Talgar, 2016). Responding to these issues, many studies suggest that chemistry teaching and learning in the 21st century is designed in such a way as to create a student-centered collaborative environment and enhance students' knowledge, conceptual understanding, problem-solving, critical thinking, laboratory skills, and various transferable skills (Aka, Guven & Aydogdu, 2010; Boesdorfer & Livermore, 2018; Gurses, Acikyildiz, Dogar & Sozbilir, 2007; Shieh & Chang, 2014; van Brederode, Zoon & Meeter, 2020).

One of the most relevant skills in facilitating teamwork is Scientific Process Skills (SPSs) (Tosun & Taskesenligil, 2013). SPSs are a set of fundamental skills that can be applied to the domain of inquiry, such as solving scientific problems, understanding content in-depth, cultivating an attitude of responsibility, and fostering learning experiences (Gurses, Cuya, Gunes & Dogar, 2014; Jirout & Zimmerman, 2015). Undoubtedly, SPSs are considered a prerequisite for students to understand the nature of science and solve scientific problems (Tosun, 2019). Previous literature confirmed the correlation between SPSs and critical thinking (Koray, Koksal, Ozdemir & Presley 2007), formal reasoning ability (Shaibu & Mari, 2003), achievement (Prayitno, Corebima, Susilo, Zubaidah & Ramli, 2017), self-efficacy (Ketelhut, 2007), creativity (Koray et al., 2007), and scientific attitudes (Juhji & Nuangchalerm, 2020). This implies that SPSs are related to mental and physical skills to construct knowledge, solve daily-life problems, and draw conclusions (Karsli & Sahin, 2009). Using scientific process skills, students can build scientific concepts directly as they solve complex problems using a practical approach in the laboratory. This means that SPSs are seen as a set of skills that cannot be separated from laboratory activities.

However, Irwanto, Rohaeti and Prodjosantoso (2018a) reported that the scientific process skills of first- and second-year students in Indonesia needed to be improved. They suggested the majority of undergraduate students only mastered basic scientific process skills. In a similar context, previous evidence suggested that students' scientific process skills were unsatisfactory (e.g., Hardianti & Kuswanto, 2017; Setiawan & Sugiyanto, 2020). In Turkey, Demirdogen and Uzuntiryaki-Kondakci (2016) also reported that the majority (11 out of 18) of pre-service chemistry teachers did not succeed in integrating scientific process skills into their planned lessons. The researcher assumes that laboratory activities so far may be limited to practicing recipe books (Goodey & Talgar, 2016; Smith & Sepulveda, 2018); thus, it does not engage students in scientific practice and provide opportunities to foster higher-order thinking (Boesdorfer & Livermore, 2018; Wheeler, Maeng & Whitworth, 2015). In order to strengthen SPSs, Akkuzu and Uyulgan (2016) suggested students do various laboratory work to explore and explain concepts, and then apply them to different situations. Explicitly, George-Williams, Karis, Ziebell, Kitson, Coppo, Schmid et al. (2019) also emphasized the need for laboratory learning that can support students to learn and develop their scientific skills. Thus, educators and researchers should encourage students to cultivate scientific process skills through a constructive learning environment (Koksal & Berberoglu, 2014).

In addition to scientific process skills, an important goal in science education is to develop a positive scientific attitude, in general, and attitude towards chemistry, in particular (Hofstein & Mamlok-Naaman, 2011). Ajzen (2001) defined scientific attitude as a student's tendency to think and judge an object based on his/her beliefs, for example, good or bad, interesting or uninteresting, pleasant or unpleasant, harmful or beneficial, and liked or disliked. In addition, Brown, White, Sharma, Wakeling, Naiker, Chandra et al. (2015) argued that attitude refers to the tendency of students to respond to certain stimuli based on their perception of chemistry, whose responses include cognitive, affective, and behavioral domains. Since attitudes include all three components, Rajecki (1990) agreed that attitudes not only include students' feelings and beliefs about a particular object but also affect their behavior towards the object. It can be supposed that scientific attitudes are students' ways of thinking in responding to specific stimuli based on scientific ethics and rejecting any information that is not supported by authentic evidence.

Previous research has summarized that attitudes towards chemistry have an impact on student academic performance (Xu, Villafane & Lewis, 2013; Villafane & Lewis, 2016), reasoning abilities (Vilia, Candeias, Neto, Franco & Melo, 2017), achievement (Brown et al., 2015; Vilia et al., 2017), and career interests (Wiebe, Unfried & Faber, 2018). This implies that a positive scientific attitude leads to students' positive commitment to a subject that influences their career choices and lifelong learning in science, particularly chemistry (Simpson & Oliver, 1990). Unfortunately, several studies have well documented a decline in students' attitudes towards chemistry. For instance, Irwanto, Rohaeti and Prodjosantoso (2018b) suggested that the scientific attitudes of first and second-year students tend to be neutral to positive. In a study conducted by Villafane and Lewis (2016), they found that college students had slightly positive science attitudes in introductory college chemistry. A similar trend was also reported by Cigdemoglu, Arslan and Cam (2017). They reported a decline in college students' chemistry attitudes after teaching and learning although it was not significant. In fact, students' attitudes toward science decreased over elementary and secondary school years (Fulmer, Ma & Liang, 2019; Kapici & Akcay, 2016). In response to this issue, Xu et al. (2013) suggest that educators should not only focus on increasing conceptual understanding but also cultivating positive chemistry attitudes through constructivist-oriented instruction.

Given that SPSs and scientific attitudes play an essential role in supporting students' success and future careers (Calik et al., 2015; Molefe, Stears & Hobden, 2016; Villafane & Lewis, 2016), the researcher then designed a constructive learning model; Research-Oriented Collaborative Inquiry Learning (REORCILEA). As a student-centered learning model, the REORCILEA combines scientific inquiry steps into a cooperative environment reinforced by research-based learning (RBL) principles (Irwanto, 2019; Rohaeti, Prodjosantoso & Irwanto, 2020). Rooted in Vygotsky's sociocultural theory, the REORCILEA offers opportunities for students to discuss, think more deeply, and collaborate together with their mates and teachers in the construction of knowledge (Straits & Wilke, 2007). In inquiry learning, students are required to take examples of everyday life problems, formulate and test hypotheses, and find appropriate solutions (Balim, 2009). In collaborative learning settings, students are stimulated to work together in small group activities during class and share their own plans and ideas with other students. It is intended to provide them with high-level skills and enhance their own and peer learning (Ruys, van Keer & Aelterman, 2010; Tekbiyik, 2015). In RBL settings, students are instructed to design and conduct investigations, collect and analyze data, and apply the knowledge they have learned in more complex situations (Knutson, Smith, Wallert & Provost, 2010; Willcoxson, Manning, Johnston & Gething, 2011).

In general, in the REORCILEA environment, students are encouraged to present their ideas and take an active role as scientists. Students are stimulated to develop conceptual understanding through presenting ideas, asking questions, explaining phenomena, and directing their learning towards more scientific ideas (Garbett, 2011). Briefly, this learning model is designed so that students not only receive knowledge but also promote enthusiasm for critical inquiry and find creative solutions (Guinness, 2012). In addition, through hands-on activities, students are expected to be better at linking theory with practice and improve problem-solving and collaborative skills (Shieh & Chang, 2014). Students should not only follow practical techniques but should be encouraged to participate actively in the classroom in order to construct knowledge and enhance laboratory skills effectively (Johnstone & Al-Shuaili, 2001; Veiga et al., 2019). The researcher believes that laboratory work helps students in developing attitudes, cultivating scientific skills, and solving problems (Feyzioglu, Demirdag, Akyildiz & Altun, 2012; Leman & Burcin, 2010).

1.1. Purpose of the Study

Previous evidence suggested that collaborative inquiry projects in research-oriented learning mode, separately, were able to foster scientific process skills and scientific attitudes (Gibson & Chase, 2002; Gurses et al., 2014). For instance, Turkmen (2009) investigated the effect of a technology-based inquiry approach on 5th graders' attitude towards science in the "sun, earth, and moon" unit. He reported that inquiry-based science teaching was more powerful in promoting science attitudes than traditional teaching methods. Similarly, Gibson and Chase (2002) reported that inquiry-based teaching significantly enhances middle-school students' attitudes towards science. Furthermore, Kongkaew, Scholfield, Supapaan, Mann, Mongkhon and Chanunun (2019) agreed that research-oriented learning is a promising way to engage undergraduate students in learning and enhance their research skills. To the best of our knowledge, improvements in SPSs and scientific attitudes using a mixed teaching approach have rarely been investigated, particularly in college chemistry courses. In fact, it provides powerful effects compared to a single approach (e.g., Ku, Ho, Hau & Lai, 2013; Rohaeti et al., 2020). Thus, there is an urgent need to catalyze the learning process at the tertiary level and foster scientific process skills and scientific attitudes using REORCILEA. It is intended that pre-service chemistry teachers not only gain better knowledge but also have soft skills and positive attitudes. The research questions in this study are:

1. Is there a statistically significant increase in SPS scores before and after the REORCILEA intervention?
2. Is there a statistically significant increase in scientific attitude scores before and after the REORCILEA intervention?

2. Methodology

2.1. Research Design

In the current study, a one-group pretest and posttest design was adapted. This design is a form of quasi-experimental design, where students in a single class without a comparison group are given intervention in the form of implementing the REORCILEA model for four meetings (Creswell, 2012). In this design, the intervention was administered to a single experimental group before the dependent variables (i.e., scientific process skills and scientific attitudes) were measured. It was aimed to determine whether there was an increase in performance before and after the intervention of the independent variable (i.e., REORCILEA model). In essence, the scores obtained by the students at the pretest and posttest were compared after they completed the treatment. The process was carried out within four weeks in the 2018/2019 academic year.

2.2. Participants

A total of 50 pre-service chemistry teachers (6 males and 44 females) from the Faculty of Mathematics and Natural Sciences at a medium-sized public university were recruited as participants in this study. All of those participants were first-year undergraduate students in the Department of Chemistry Education, aged approximately 18 to 19 years. It should be noted that all students had similar college entrance test scores and socioeconomic backgrounds. They came from suburban areas with lower-middle-income families. In Indonesia, pre-service chemistry teachers have to complete a four-year educational program. After they graduate, students are expected to become secondary school chemistry teachers. All students who voluntarily participated in this study took a 4-week General Chemistry course in a semester. They were selected using a convenience sampling technique. In addition, it is important to notice that all samples participated voluntarily and no one objected to participating in this study.

2.3. Instruments

To evaluate SPSs and scientific attitudes, the Scientific Process Skills Observation Checklist (SPSOC) and the Scientific Attitudes Scale (SAS) were respectively designed in this study.

2.3.1. The Scientific Process Skills Observation Checklist (SPSOC)

To collect data, the Scientific Process Skills Observation Checklist (SPSOC) was designed to assess pre-service chemistry teachers' scientific process skills based on their performance during the laboratory work. The SPSOC comprised 18 items. Of all the items, 8 items were used to assess basic scientific process skills, including observing, inferring, measuring, and communicating; and 10 items were for evaluating integrated scientific process skills, including formulating hypotheses, designing an investigation, experimenting, identifying and controlling variables, and interpreting data. All items in the SPSOC were constructed from the relevant literature (e.g., American Association for the Advancement of Science (AAAS), 1967; Aka et al., 2010; Feyzioglu et al. 2012; Karsli & Sahin, 2009; Koksal & Berberoglu, 2014; Livermore, 1964). The SPSOC measured the data using a four-point scale (ranging from "1" for unobserved to "4" for clearly observed). Noted that the possible score of SPSOC ranged from 18 to 72. The highest score reflects that the pre-service chemistry teachers have good scientific process skills during the intervention. The reliability coefficient of Cronbach's alpha of the SPSOC was 0.88. The SPSOC has been considered reliable as it has fulfilled the minimum acceptable limit of 0.70 (Taber, 2018). This means that the SPSOC can be used to measure the scientific process skills of pre-service chemistry teachers.

2.3.2. The Scientific Attitudes Survey (SAS)

The SAS, originally constructed by the researcher, was utilized to gather pre-service teachers' responses related to the attitudes or views during the instruction. This scale comprised 9 sub-domains; rationality, intellectual honesty, open-mindedness, curiosity, suspended judgment, aversion to superstition, critical-mindedness, humility, and objectivity. All subscales in the SAS were adapted from previous works (e.g., Billey & Zakhariades, 1975; Gauld & Hukins, 1980; Onder, Celik & Silay, 2012). The SAS has 36 four-point Likert scale items (18 positives and 18 negatives). Each sub-domain included 4 items (2 negatively worded; 2 positively worded). As a note, a score of "1" indicated strongly disagree and a score of "4" implied strongly agree. All negatively worded items were reverse-scored. The maximum and minimum scores obtained by participants were 144 and 36 points, respectively. The student with a high score reflects a more positive attitude. Prior to being administered both in the pretest and posttest, the survey has been validated by four experts. The value of Cronbach's alpha was 0.84. The SAS was completed for 15 minutes in both pretest and posttest.

2.4. Procedure

After obtaining written permission from the Institutional Review Board (IRB), the researcher met with the lecturer and his students. The researcher then explained the aims and objectives of the research. At the start of the application, the SPSOC and SAS were administered to all students. They were then divided into four- or five-member teams based on their pretest scores. Each meeting had two 50 min laboratory sessions and three 45 min courses per week. The topics in this course included acid-base theories, acid-base reactions, acid-base strengths, pH values, buffers, and titrations. To evaluate their performance, both instruments were re-administered at the end of treatment.

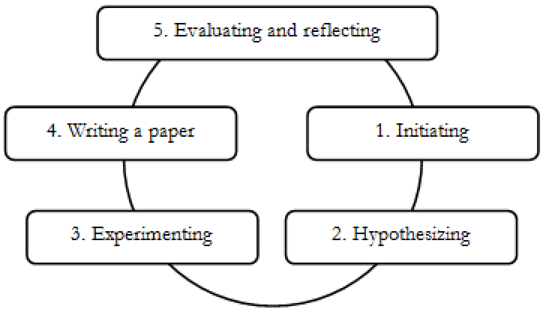

Figure 1. Learning Cycle in the REORCILEA Model

Specifically, the syntax of REORCILEA consisted of five phases. In the *Initiating* phase, the lecturer gave students the freedom to choose problems that they consider relevant to the learning goals. Students discussed the problems in small groups by thinking divergently and critically analyzing the problems from different perspectives to find certain ideas or solutions. In the *Hypothesizing* phase, students explicitly formulated their own hypothesis supported by empirical evidence and then they determined the most appropriate research method to investigate the relationship between variables. In the *Experimenting* phase, students tested their hypotheses using a predetermined systematic procedure in small groups. In the *Writing* phase, students collected, organized, and presented their data; wrote brief and informative papers to present the results of their experiment; and related them to relevant literature either to support or to decline their findings. In the *Evaluating and reflecting* phase, students drew the conclusions by linking the hypothesis to the scientific facts, analyzed the hypothesis in order to determine whether or not to accept the proposed hypotheses, and checked the validity and reliability of research data, as well as to proposed possible further problems.

In order to examine the effectiveness of the REORCILEA, face-to-face meetings were conducted for 150 minutes prior to 100 minutes of laboratory works per week in the half of a semester instructed by a male lecturer. During the intervention, students in small groups discussed problems, asked questions, formulated hypotheses, conducted an experiment, wrote a paper, evaluated their work, and reflected on their own learning. Laboratory works and paper writing were individual tasks that were done outside the face-to-face lectures as structured assignments. At the end of the lecture, both researcher and lecturer evaluated the practicality of the REORCILEA model to improve the effectiveness of the next meeting.

2.5. Data Analysis

Aiming to capture a deeper understanding of the influence of the REORCILEA on students' SPSs and scientific attitudes, a paired-samples *t*-test was executed to compare the pretest and posttest administration results. Descriptive statistics were also employed to describe the characteristics of the data including mean scores, standard deviations, and frequencies. The Kolmogorov-Smirnov and Levene tests were checked to verify the normal and homogeneous distribution of the pretest and posttest scores. After the test assumptions were met ($p > 0.05$), a paired-samples *t*-test was used to investigate a significant increase from pretest to posttest scores. The *t*-test was aimed to investigate whether there was a significant effect of REORCILEA on students' SPSs and scientific attitudes. Then, Cohen's *d* was calculated to explain how much the score increased before and after the intervention. The effect size is defined as the magnitude of the difference between the pretest and posttest scores and is grouped into three categories: 0.20 to 0.30 indicating a weak effect; 0.40 to 0.70, medium effect; and 0.80 to 1.00, large effect (Cohen, 1988). The quantitative data were then analyzed through the SPSS 17. The level of significance was determined at 0.05.

3. Results

In this section, pre-service chemistry teachers' scientific process skills and their scientific attitude scores before and after treatment were compared. After the assumption test was fulfilled, a paired-samples *t*-test was employed to explore the significant increase between pretest and posttest scores. The comparison of pretest and posttest scores on scientific process skills is summarized in Table 1.

Sub-domains		*M*	*SD*	*t*	*p*	Cohen's *d*
Observing	Pretest	2.960	0.415	-7.897	0.000	1.12
	Posttest	3.520	0.416			
Measuring	Pretest	2.890	0.455	-6.556	0.000	0.93
	Posttest	3.480	0.428			
Inferring	Pretest	2.800	0.364	-7.399	0.000	1.05
	Posttest	3.290	0.321			
Communicating	Pretest	2.780	0.337	-8.785	0.000	1.24
	Posttest	3.360	0.429			
Formulating Hypotheses	Pretest	2.860	0.379	-11.345	0.000	1.60
	Posttest	3.550	0.354			
Identifying and Controlling Variables	Pretest	2.780	0.352	-5.423	0.000	0.77
	Posttest	3.150	0.307			
Designing Investigation	Pretest	2.780	0.322	-7.769	0.000	1.10
	Posttest	3.270	0.307			
Experimenting	Pretest	2.600	0.391	-8.986	0.000	1.27
	Posttest	3.380	0.358			
Interpreting	Pretest	2.820	0.471	-6.187	0.000	0.88
	Posttest	3.450	0.466			
All Subscales	Pretest	25.660	1.636	-14.219	0.000	2.01
	Posttest	30.450	1.768			

Table 1. Differences Between Pretest and Posttest Scores on SPSs

As shown in Table 1, when analyzed by subscale, "Formulating Hypotheses" (*M* = 3.550; *SD* = 0.354) had the highest posttest score compared to the other subscales. Considering Cohen's *d* values from all sub-skills, students in the "Formulating Hypotheses" skill had the highest increase in the mean score (*d* = 1.60), while the lowest was in the "Identifying and Controlling Variables" skill (*d* = 0.77). In general, after application, the SPS posttest scores were at a satisfactory level with a high effect size (*d* = 2.01). Table 1 indicates there was a statistically significant increase between pretest (*M* = 25.660; *SD* = 1.636) and posttest (*M* = 30.450; *SD* = 1.768) scores in scientific process skills [*t*(49) = –14.219; *p* = 0.000; *a* = 0.05]. In other words, a highly significant gap between pretest and posttest scores in scientific process skills during application existed. Thus, it can be concluded that the activities used in the instruction were sufficient to reveal the gap between the pretest and posttest scores.

Furthermore, the comparison between the pretest and posttest scores of both groups regarding scientific attitudes is presented in Table 2. Specifically, when observed from posttest scores, students showed a more positive attitude in terms of "Humility" (*M* = 3.605; *SD* = 0.354) compared to other subscales.

Subscales		***M***	***SD***	***t***	***p***	**Cohen's *d***
Rationality	Pretest	3.255	0.344	-2.646	0.011	0.37
	Posttest	3.405	0.327			
Curiosity	Pretest	3.225	0.300	-4.025	0.000	0.57
	Posttest	3.450	0.331			
Open-Mindedness	Pretest	3.145	0.343	-5.250	0.000	0.74
	Posttest	3.415	0.341			
Aversion to Superstition	Pretest	3.275	0.343	-2.394	0.021	0.34
	Posttest	3.395	0.303			
Objectivity	Pretest	3.380	0.324	-2.752	0.008	0.39
	Posttest	3.555	0.355			
Intellectual Honesty	Pretest	3.355	0.268	-3.105	0.003	0.44
	Posttest	3.530	0.370			
Suspended Judgment	Pretest	3.260	0.323	-2.267	0.028	0.32
	Posttest	3.370	0.316			
Critical-Mindedness	Pretest	3.380	0.291	-2.740	0.009	0.39
	Posttest	3.550	0.364			
Humility	Pretest	3.390	0.351	-3.386	0.001	0.48
	Posttest	3.605	0.354			
All Subscales	Pretest	29.665	1.417	-9.278	0.000	1.31
	Posttest	31.275	1.938			

Table 2. Differences Between Pretest and Posttest Scores on Scientific Attitudes

The mean score of the SAS given at the beginning of the study was 29.665. After the lecture, the attitude posttest score was in the satisfactory category (*M* = 31.275; *SD* = 1.938; *d* = 1.31). Of all the subscales, the highest increase was indicated in "Open-Mindedness" (*d* = 0.74) and the lowest was shown in "Suspended Judgment" (*d* = 0.32). In general, there was an increase from pretest (*M* = 29.665; *SD* = 1.417) to posttest (*M* = 31.275; *SD* = 1,938) in scientific attitudes [*t*(49) = –9.278; *p* = 0.000; *a* = 0.05]. Although the change in attitudes among students tends to be low, the increase is significant. In brief, Table 2 suggests that there is a significant gap between pretest and posttest scores in scientific attitude during treatment. Thus, it can be concluded that the learning activities designed in REORCILEA which were implemented during the instruction were sufficient to explain the increase between pretest and posttest scores in scientific attitudes.

4. Discussion

The current study has successfully evaluated the effect of REORCILEA on Scientific Process Skills (SPSs) and scientific attitudes of pre-service chemistry teachers. Before treatment, the mean pretest scores on SPSs and scientific attitudes were unsatisfactory. After the 4-week instruction, students scored higher in SPSs than before application. In addition, students showed positive attitude changes after engaging in REORCILEA. This indicates that REORCILEA is effective in enlightening students' SPSs and improving their attitudes. The findings of this research are consistent with previous literature (e.g., Karsli & Sahin, 2009; Molefe et al., 2016; Rohaeti et al., 2020).

According to the results of the *t*-test, the difference between the pretest and posttest scores on SPSs during application was statistically significant. It can be concluded that the activities designed in REORCILEA are sufficient to elevate SPSs among pre-service teachers in the acids and bases unit. According to these findings, it can be asserted that REORCILEA has a great impact on pre-service teachers' SPSs. The current results corroborate previous studies. For example, Saglam and Sahin (2017) and Gehring and Eastman (2008) unveiled that students' SPSs can be nurtured using inquiry-based learning. Based on these reasons, the researcher argues that in the inquiry process, students take responsibility for their own learning. For example, they learn how to develop essential questions and find out the answers while encouraging themselves to engage in intellectual activities like scientists (Gibson & Chase, 2002; Goodey & Talgar, 2016; Jiang & McComas, 2015; Koksal & Berberoglu, 2014; Turkmen, 2009).

The increase in SPSs was also confirmed by Cohen's *d* value in the high category. A reason for this situation may be that during lectures students are directed to be actively involved in managing their own learning. Through small group discussions, students' new ideas emerge and they are encouraged to criticize every possible idea as an alternative solution. In a study, Loes, Culver and Trolian (2018) explained that exposure to collaborative learning allows students to interact more with other colleagues, and ultimately leads to greater openness to diversity of opinions, ideas, and thoughts. In addition, students' superiority in the acquisition of scientific skills is associated with their ability to relate previous information to new situations during the experiment. Supportively, Wilke and Straits (2001) believed that students in inquiry learning not only remember factual information, but also promote higher-order thinking skills, and ultimately lead to the growth of scientific process skills. This study also underlines that pre-service teachers' engagement in scientific inquiry processes motivates them to become physically and mentally active individuals, helps them learn chemistry, and consolidates these processes with scientific knowledge and reasoning (Hsiao, Chen, Hong, Chen, Lu & Chen, 2017; Ozdem-Yilmaz & Cavas, 2016). In other words, the most effective way to enhance scientific skills is through dynamic participation in laboratory experiments and analysis (Lujan & DiCarlo, 2006). Therefore, the researcher suggests to the lecturers to apply inquiry-based science instruction in the General Chemistry course.

During the classroom session in this study, students were also instructed to collect, analyze, and organize data and report their experimental findings in a scientific format, as described by Casem (2006). Wallace and Jefferson (2013) stated that students who are involved in research activities (i.e., finding and selecting appropriate sources and evaluating the relevance of sources) are able to develop their thinking skills. The various advantages of REORCILEA stimulate students to actively generate scientific ideas, carry out a systematic investigation, communicate the results, and construct chemical concepts. This is another possible reason why REORCILEA can effectively promote pre-service teachers' scientific skills. The researcher believes that effective teaching occurs when lecturers motivate and help students overcome learning difficulties using active learning. In another study, Koksal and Berberoglu (2014) also stated that the guided inquiry approach had a positive impact on students' cognitive and affective skills. Guided inquiry improves students' conceptual understanding, inquiry skills, and positive science attitudes. This means that superior posttest scores in SPSs are possible because students interact with equipment, chemicals, and objects to find alternative solutions through investigation and interpretation during the *experimenting* stage. In addition, teamwork support, exchange of ideas, assignment of responsibilities, and collaborative learning environment are seen as major factors in arousing students' generic attitudes and skills (Berg, 2005; Crebert, Bates, Bell, Patrick & Cragnolini, 2004). This argument is a plausible reason why the posttest scores of scientific process skills are quite satisfactory in the current study.

Furthermore, the results of the *t*-test reflected that posttest scores on scientific attitudes enhanced significantly after a 4-week inquiry learning. It can be said that the implementation of REORCILEA during instruction was sufficient to explain the increase in scores from pretest to posttest on scientific attitudes among students. The effectiveness of the REORCILEA model in arousing students' scientific attitudes is also supported by previous studies. For instance, Jiang and McComas (2015) found a significant effect of inquiry learning on attitudes. Recently, Rohaeti et al. (2020) reported that pre-service teachers who were instructed with REORCILEA had a positive attitude, stronger interest in learning, and enjoyed chemistry lectures more than students who were instructed using conventional teaching methods. In the current study, attitude improvement is possible because during lectures students are directly involved in planning, implementing, and evaluating laboratory activities that they previously designed. Chen and Chen (2021) agreed that practical works train scientific methods and increase scientific attitudes among students. In accordance with the principles of collaborative inquiry, the REORCILEA focuses on student-oriented learning. When the learning environment provides students with opportunities to discuss their findings with peers, this has a beneficial effect on students' attitudes towards chemistry (Schwedler & Kaldewey, 2020). In addition, studies (e.g., Hodson, 2005; Pernaa & Aksela, 2009) revealed that practical work provides students with meaningful experiences in solving complex problems, promoting laboratory skills, and elevating scientific attitudes. Thus, the researcher argues that collaborative inquiry succeeded in developing progressively positive attitudes among students in the current study.

The researcher argues that attitudes involve individual cognitive, behavioral, and affective that are organized through previous experiences and then shape a person's view of a particular subject. In a study, Vossen, Henze, Rippe, van Driel and de Vries (2018) also underlined that attitudes include students' knowledge of science (cognition), students' feelings about science (affection), and the way students display certain behaviors towards science. This means that when students engage in and enjoy lecture activities, their attitudes tend to be more positive. The researcher also believes that students who have positive science attitudes are often found in classrooms that involve students actively in learning, support student progress, and use innovative learning strategies (Myers & Fouts, 1992). If pre-service teachers exhibit a positive science attitude, they are more likely to be successful in achieving academic achievements and pursuing their future career paths (Aydeniz & Kaya, 2012; Lindner, Wigenbach, Harlin, Li, Lee, Jackson et al., 2004) and will be attracted to the life of science (Feist, 2012). This assumption is reinforced by van Brederode et al. (2020) who mentioned that a way to promote student attitudes during laboratory work is to involve them in designing experimental procedures with their colleagues. When students have schoolmates who are more interested in chemistry and have positive chemistry attitudes, it is possible for students to arouse their attitudes and performance during laboratory activities (Ardura, Zamora & Perez-Bitrian, 2020).

5. Conclusions

In conclusion, the REORCILEA is considered an effective platform to promote students' SPSs and scientific attitudes. It can be seen from the significant increase in scores from pretest to posttest after instruction. The researcher considers that the efficacy of a learning model is seen from the increase in student performance after instruction. This means that a learning model is claimed to be effective if it is able to provide a learning environment that develops pre-service teachers' active engagement in the teaching and learning process (Gurses et al., 2007), constructs knowledge through experimentation (Hofstein, Shore & Kipnis, 2004), and fosters achievement after instruction (Jiang & McComas, 2015; Koksal & Berberoglu, 2014). Based on the evidence, it is believed that the REORCILEA had positive effects on students' SPSs and scientific attitudes. In sum, the REORCILEA was declared highly promising in improving scientific skills and scientific attitudes among students. Thus, the researcher concludes that the REORCILEA is an active-effective learning model that has a significant impact on the performance of pre-service chemistry teachers.

The collaborative and inquiry learning activities in the REORCILEA are designed to facilitate students exchanging ideas and finding solutions using the scientific method. In classroom settings, students identify issues and problems, formulate and test hypotheses, design and perform the experiment, write the article, and evaluate and reflect on the learning process. The researcher believes that student involvement can cultivate their learning outcomes. Fung and Lui (2016) agreed that students achieve greater cognitive growth when they engage in collaborative learning activities. In addition, group work is also found to be effective in building conceptual knowledge. In a team-based learning environment, Tosun and Taskesenligil (2013) informed that undergraduate students' scientific processing skills have improved significantly compared to lecture-based learning. The researcher concludes that the improvement of students' skills in this study has a direct impact on the affective aspect. When students' attitudes toward chemistry tend to be more positive, their academic performance enhances. This is because there is a positive and significant relationship between attitudes toward chemistry and achievement (Brown et al., 2015; Xu et al., 2013).

6. Recommendations

In twenty-first century learning, in higher education, scientific process skills and scientific attitudes are seen as two major goals in science learning at the tertiary level (Jiang & McComas, 2015; Karsli & Sahin, 2009; Molefe et al., 2016). According to previous evidence, scientific process skills and chemistry attitudes, separately, can be improved using the inquiry learning model (Gehring & Eastman, 2008; Jiang & McComas, 2015; Saglam & Sahin, 2017). Inquiry-based science learning is an innovative learning model that encourages students to actively ask questions, formulate hypotheses, draw conclusions, and reconstruct knowledge based on their own experiences through practice (Balim, 2009; Wilke & Straits, 2001). In a collaborative inquiry setting, Kobayashi (2009) also reported that inference errors were reduced as each student also monitored the activities of other group members. Thus, in order to develop student performance, the researcher suggests that chemistry learning needs to be designed to provide opportunities for pre-service teachers through inquiry-based tasks. This is because effective teaching occurs when students are encouraged to become active learners to achieve their intellectual potential in the learning process.

The effectiveness of the REORCILEA model for enlightening pre-service teachers' skills and their attitudes in the General Chemistry course was discussed. However, the current study has some methodological limitations. First, this study utilized a single group without a comparison group; so that future studies are suggested to compare between experimental group and comparison group with regard to SPSs and scientific attitudes. Second, to gain a deeper understanding of the influence of the REORCILEA model on scientific skills and attitudes towards STEM-related subjects, further research needs to employ qualitative data.

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References

Ajzen, I. (2001). Nature and operation of attitudes. *Annual Review of Psychology,* 52, 27-58. https://doi.org/10.1146/annurev.psych.52.1.27

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

Akkuzu, N., & Uyulgan, M.A. (2016). An epistemological inquiry into organic chemistry education: Exploration of undergraduate students' conceptual understanding of functional groups. *Chemistry Education Research and Practice,* 17(1), 36-57. https://doi.org/10.1039/c5rp00128e

American Association for the Advancement of Science (AAAS) (1967). *Science – A process approach.* AAAS.

Ardura, D., Zamora, A., & Perez-Bitrian, A. (2020). The role of motivation on secondary school students' causal attributions to choose or abandon chemistry. *Chemistry Education Research and Practice,* 22(1), 43-61. https://doi.org/10.1039/d0rp00168f

Aydeniz, M., & Kaya, E. (2012). Factors impacting Turkish students' attitudes towards science and their academic performance in science. *Journal of Turkish Science Education,* 9(2), 25-48.

Balim, A.G. (2009). The effects of discovery learning on students' success and inquiry learning skills. *Eurasian Journal of Educational Research*, 35, 1-20.

Berg, C.A.R. (2005). Factors related to observed attitude change toward learning chemistry among university students. *Chemistry Education Research and Practice,* 6(1), 1-18. https://doi.org/10.1039/b4rp90001d

Billey, V.Y., & Zakhariades, G.A. (1975). The development and application of a scale for measuring scientific attitudes. *Science Education,* 59(2), 155-165. https://doi.org/10.1002/sce.3730590203

Boesdorfer, S.B., & Livermore, R.A. (2018). Secondary school chemistry teacher's current use of laboratory activities and the impact of expense on their laboratory choices. *Chemistry Education Research and Practice,* 19(1), 135-148. https://doi.org/10.1039/c7rp00159b

Brown, S.J., White, S., Sharma, B., Wakeling, L., Naiker, M., Chandra, S. et al. (2015). Attitude to the study of chemistry and its relationship with achievement in an introductory undergraduate course. *Journal of the Scholarship of Teaching and Learning,* 15(2), 33-41. https://doi.org/10.14434/josotl.v15i2.13283

Calik, M., Ultay, N., Kolomuc, A., & Aytar, A. (2015). A cross-age study of science student teachers' chemistry attitudes. *Chemistry Education Research and Practice,* 16(2), 228-236. https://doi.org/10.1039/c4rp00133h

Casem, M.L. (2006). Student perspectives on curricular change: Lessons from an undergraduate lower-division biology core. *CBE - Life Science Education,* 5(1), 65-75. https://doi.org/10.1187%2fcbe.05-06-0084

Chen, B., & Chen, L. (2021). Examining the sources of high school chemistry teachers' practical knowledge of teaching with practical work: from the teachers' perspective. *Chemistry Education Research and Practice,* 22(2), 476-485. https://doi.org/10.1039/D0RP00246A

Cigdemoglu, C., Arslan, H.O., & Cam, A. (2017). Argumentation to foster pre-service science teachers' knowledge, competency, and attitude on the domains of chemical literacy of acids and bases. *Chemistry Education Research and Practice,* 18(2), 288-303. https://doi.org/10.1039/c6rp00167j

Cohen, J. (1988). *Statistical power analysis* (2nd ed.). Erlbaum.

Crebert, G., Bates, M., Bell, B., Patrick, C.J., & Cragnolini, V. (2004). Developing generic skills at university, during work placement and in employment: Graduates' perceptions. *Higher Education Research & Development,* 23(2), 147-165. https://doi.org/10.1080/0729436042000206636

Creswell, J.W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston, MA: Pearson Education.

Demirdogen, B., & Uzuntiryaki-Kondakci, E. (2016). Closing the gap between beliefs and practice: Change of pre-service chemistry teachers' orientations during a PCK-based NOS course. *Chemistry Education Research and Practice,* 17(4), 818-841 https://doi.org/10.1039/c6rp00062b

Feist, G.J. (2012). Predicting interest in and attitudes toward science from personality and need for cognition. *Personality and Individual Differences*, 52(7), 771-775. https://doi.org/10.1016/j.paid.2012.01.005

Feyzioglu, B., Demirdag, B., Akyildiz, 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. https://doi.org/10.1037/t69196-000

Fulmer, G.W., Ma, H., & Liang, L.L. (2019). Middle school student attitudes toward science, and their relationships with instructional practices: A survey of Chinese students' preferred versus actual instruction. *Asia-Pacific Science Education,* 5, 9. https://doi.org/10.1186/s41029-019-0037-8

Fung, D., & Lui, W.M. (2016). Individual to collaborative: Guided group work and the role of teachers in junior secondary science classrooms. *International Journal of Science Education,* 38(7), 1057-1076. https://doi.org/10.1080/09500693.2016.1177777

Garbett, D. (2011). Constructivism deconstructed in science teacher education. *Australian Journal of Teacher Education,* 36(6), 36-49. https://doi.org/10.14221/ajte.2011v36n6.5

Gauld, C.F., & Hukins, A.A. (1980). Studies in science education scientific attitudes: A review. *Studies in Science Education,* 7(1), 129-161. https://doi.org/10.1080/03057268008559877

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(1), 54-63. https://doi.org/10.1187%2fcbe.07-10-0091

George-Williams, S.R., Karis, D., Ziebell, A.L., Kitson, R.R.A., Coppo, P., Schmid, S. et al. (2019). Investigating student and staff perceptions of students' experiences in teaching laboratories through the lens of meaningful learning. *Chemistry Education Research and Practice,* 20(1), 187-196. https://doi.org/10.1039/c8rp00188j

Gibson, H.L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. *Science Education,* 86(5), 693-705. https://doi.org/10.1002/sce.10039

Goodey, N.M., & Talgar, C.P. (2016). Guided inquiry in a biochemistry laboratory course improves experimental design ability. *Chemistry Education Research and Practice,* 17(4), 1127-1144. https://doi.org/10.1039/c6rp00142d

Guinness, P. (2012). Research-based learning: Teaching development through fieldschools. *Journal of Geography in Higher Education*, 37(3), 329-339. https://doi.org/10.1080/03098265.2012.696188

Gurses, A., Acikyildiz, M., Dogar, C., & Sozbilir, M. (2007). An investigation into the effectiveness of problem-based learning in a physical chemistry laboratory course. *Research in Science & Technological Education,* 25(1), 99-113. https://doi.org/10.1080/02635140601053641

Gurses, A., Cuya, S., Gunes, K., & Dogar, C. (2014). Determination of the relation between undergraduate students' awareness levels regarding their scientific process skills and application potentials. *American Journal of Educational Research*, 2(5), 250-256. https://doi.org/10.12691/education-2-5-3

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. https://doi.org/10.12973/iji.2017.1028a

Hodson, D. (2005). Teaching and learning chemistry in the laboratory: A critical look at the research. *Educación Quimica,* 16(1), 30-38. https://doi.org/10.22201/fq.18708404e.2005.1.66134

Hofstein, A., & Mamlok-Naaman, R. (2011). High-school students' attitudes toward and interest in learning chemistry. *Educación Quimica*, 22(2), 90-102. https://doi.org/10.1016/s0187-893x(18)30121-6

Hofstein, A., Shore, R., & Kipnis, M. (2004). Providing high school chemistry students with opportunities to develop learning skills in an inquiry-type laboratory: A case study. *International Journal of Science Education,* 26(1), 47-62. https://doi.org/10.1080/0950069032000070342

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 & Technology Education,* 13(7), 3393-3416. https://doi.org/10.12973/eurasia.2017.00735a

Irwanto, Rohaeti, E., & Prodjosantoso, A.K. (2018a). Undergraduate students' science process skills in terms of some variables: A perspective from Indonesia. *Journal of Baltic Science Education,* 17(5), 751-764. https://doi.org/10.33225/jbse/18.17.751

Irwanto, Rohaeti, E., & Prodjosantoso, A.K. (2018b). 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 (2019). *Developing a REORCILEA (Research-oriented collaborative inquiry learning) model to improve critical thinking skills, science process skills, and scientific attitudes of preservice chemistry teachers.* Unpublished doctoral dissertation. Yogyakarta State University, Yogyakarta, Indonesia.

Jiang, F., & McComas, W.F. (2015). The effects of inquiry teaching on student science achievement and attitudes: Evidence from propensity score analysis of PISA data. *International Journal of Science Education,* 37(3), 554-576. https://doi.org/10.1080/09500693.2014.1000426

Jirout, J., & Zimmerman, C. (2015). Development of science process skills in the early childhood years. In Cabe-Trundle, K., & Saçkes, M. (Eds.), *Research in Early Childhood Science Education* (143-165). Springer. https://doi.org/10.1007/978-94-017-9505-0_7

Johnstone A.H., & Al-Shuaili, A. (2001). Learning in the laboratory: Some thoughts from literature. *University Chemical Education,* 5(2), 42-51.

Juhji, J., & Nuangchalerm, P. (2020). Interaction between science process skills and scientific attitudes of students towards technological pedagogical content knowledge. *Journal for the Education of Gifted Young Scientists,* 8(1), 1-16. https://doi.org/10.17478/jegys.600979

Kapici, H.O., & Akcay, H. (2016). Middle school students' attitudes toward science, scientists, science teachers and classes. *Asia-Pasific Forum on Science Learning and Teaching,* 17(1), 10.

Karsli, F., & Sahin, C. (2009). Developing worksheet based on science process skills: Factors affecting solubility. *Asia-Pacific Forum on Science Learning and Teaching*, 10(1), 1-13.

Ketelhut, D.J. (2007). The impact of student self-efficacy on scientific inquiry skills: An exploratory investigation in River city, a multi-user virtual environment. *Journal of Science Education and Technology,* 16, 99-111. https://doi.org/10.1007/s10956-006-9038-y

Knox, K.J., Gillis, E.A.L., & Dake, G.R. (2019). A positive student experience of collaborative project work in upper-year undergraduate chemistry. *Chemistry Education Research and Practice,* 20(2), 340-357. https://doi.org/10.1039/c8rp00251g

Knutson, K., Smith, J., Wallert, M.A., & Provost, J.J. (2010). Bringing the excitement and motivation of research to students; Using inquiry and research-based learning in a year-long biochemistry laboratory. *Biochemistry and Molecular Biology Education*, 38(5), 317-323. https://doi.org/10.1002/bmb.20400

Kobayashi, H. (2009). Collaborative discovery learning with hypothesis evaluation schema and acquisition of scientific literacy. *The Japanese Journal of Educational Psychology,* 57(2), 131-142. https://doi.org/10.5926/jjep.57.131

Koksal, E.A., & Berberoglu, G. (2014). The Effect of guided-inquiry instruction on 6th grade Turkish students' achievement, science process skills, and attitudes toward science. *International Journal of Science Education,* 36(1), 66-78. https://doi.org/10.1080/09500693.2012.721942

Kongkaew, C., Scholfield, C.N., Supapaan, T., Mann, C., Mongkhon, P., & Chanunun, S. (2019). Impact of research-based learning on student knowledge and assessment in Pharmacoepidemiology: A one group pretest-posttest experimental study. *Thai Journal of Pharmaceutical Sciences,* 43(4), 236-241.

Koray, O., Koksal, M.S., Ozdemir, M., & Presley, A.İ. (2007). The effect of creative and critical thinking based laboratory applications on academic achievement and science process skills. *Elementary Education Online,* 6(3), 377-389.

Ku, K.Y.L., Ho, I.T., Hau, K.T., & Lai, E.C.M. (2013). Integrating direct and inquiry-based instruction in the teaching of critical thinking: An intervention study. *Instructional Science,* 42(2), 251-269. https://doi.org/10.1007/s11251-013-9279-0

Leman, T., & Burcin, A.S. (2010). Investigation the effectiveness of laboratory works related to "acids and bases" on learning achievements and attitudes toward laboratory. *Procedia Social Behavioural Science,* 2, 2631-2636. https://doi.org/10.1016/j.sbspro.2010.03.385

Lindner, J.R., Wigenbach, G.W., Harlin, J., Li, Y., Lee, I.H., Jackson, R. et al. (2004). Students' beliefs about science and sources of influence affecting science career choice. *NACTA Journal,* 48(2), 2-7.

Livermore, A.H. (1964). The process approach of the AAAS commission on science education. *Journal of Research in Science Teaching,* 2(4), 271-282. https://doi.org/10.1002/tea.3660020403

Loes, C.N., Culver, K.C., & Trolian, T.L. (2018). How collaborative learning enhances students' openness to diversity. *The Journal of Higher Education,* 89(6), 935-960. https://doi.org/10.1080/00221546.2018.1442638

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. https://doi.org/10.1152/advan.00061.2005

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. https://doi.org/10.15700/saje.V36n3a1279

Myers, R.E., & Fouts, J.T. (1992). A cluster analysis of high school science classroom environments and attitude toward science. *Journal of Research in Science Teaching*, 29(9), 929-937. https://doi.org/10.1002/tea.3660290904

Onder, F., Celik, P., & Silay, I. (2012). Psychometric evaluation on the Turkish adaptation of the scientific attitude inventory. *Journal of Baltic Science Education,* 11(1), 7-15. https://doi.org/10.33225/jbse/12.11.07

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. https://doi.org/10.33225/jbse/16.15.506

Pernaa, J., & Aksela, M. (2009). Chemistry teachers' and students' perceptions of practical work through different ICT learning environments. *Problems of Education in the 21st Century,* 16, 80-88.

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. https://doi.org/10.33225/jbse/17.16.266

Rajecki, D.W. (1990). *Attitudes* (2nd ed.). Sinauer Associates.

Rohaeti, E., Prodjosantoso, A.K., & Irwanto (2020). Research-oriented collaborative inquiry learning model: Improving students' scientific attitudes in general chemistry. *Journal of Baltic Science Education,* 19(1), 108-120. https://doi.org/10.33225/jbse/20.19.108

Runquist, O., & Kerr, S. (2005). Are we serious about preparing chemists for the 21st century workplace or are we just teaching chemistry? *Journal of Chemical Education,* 82(2), 231-233. https://doi.org/10.1021/ed082p231

Ruys, I., van Keer, H., & Aelterman, A. (2010). Collaborative learning in pre-service teacher education: An exploratory study on related conceptions, self-efficacy and implementation. *Educational Studies,* 36(5), 537-553. https://doi.org/10.1080/03055691003729021

Saglam, M.K., & Sahin, M. (2017). Inquiry-based professional development practices for science teachers. *Journal of Turkish Science Education,* 14(4), 66-76. https://doi.org/10.12973/tused.10213a

Schwedler, S., & Kaldewey, M. (2020). Linking the submicroscopic and symbolic level in physical chemistry: how voluntary simulation-based learning activities foster first-year university students' conceptual understanding. *Chemistry Education Research and Practice,* 21(4), 1132-1147. https://doi.org/10.1039/c9rp00211a

Setiawan, A., & Sugiyanto, S. (2020). Science process skills analysis of science teacher on professional teacher program in Indonesia. *Jurnal Pendidikan IPA Indonesia,* 9(2), 241-247. https://doi.org/10.15294/jpii.v9i2.23817

Shaibu, A.A., & Mari, J.S. (2003). The effect of process-skill instruction on secondary school students' formal reasoning ability in Nigeria. *Science Education International,* 14(4), 51-54.

Shieh, R.S., & Chang, W. (2014). Fostering student's creative and problem solving skills through a hands-on activity. *Journal of Baltic Science Education,* 13(5), 650-661. https://doi.org/10.33225/jbse/14.13.650

Simpson, R.D., & Oliver, J.S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education,* 74(1), 1-18. https://doi.org/10.1002/sce.3730740102

Smith, K.C., & Sepulveda, A. (2018). Students' perceptions of common practices, including some academically dishonest practices, in the undergraduate general chemistry classroom laboratory. *Chemistry Education Research and Practice,* 19(1), 1142-1150. https://doi.org/10.1039/c8rp00058a

Straits, W., & Wilke, R. (2007). How constructivist are we? Representation of transmission and participatory models of instruction in the Journal of College Science Teaching. *Journal of College Science Teaching*, 36(7), 58-61.

Taber, K.S. (2018). The use of cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education,* 48(6), 1273-1296. https://doi.org/10.1007/s11165-016-9602-2

Tekbiyik, A. (2015). The use of jigsaw collaborative learning method in teaching socio-scientific issues: The case of nuclear energy. *Journal of Baltic Science Education,* 14(2), 237-253. https://doi.org/10.33225/jbse/15.14.237

Tosun, C. (2019). Scientific process skills test development within the topic "matter and its nature" and the predictive effect of different variables on 7th and 8th grade students' scientific process skill levels. *Chemistry Education Research and Practice,* 20(1), 160-174. https://doi.org/10.1039/c8rp00071a

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. https://doi.org/10.1039/c2rp20060k

Turkmen, H. (2009). An effect of technology based inquiry approach on the of "earth, sun, & moon" subject. *Asia-Pacific Forum on Science Learning and Teaching,* 10(1), Article 5.

van Brederode, M.E., Zoon, S.A., & Meeter, M. (2020). Examining the effect of lab instructions on students' critical thinking during a chemical inquiry practical. *Chemistry Education Research and Practice,* 21(4), 1173-1182. https://doi.org/10.1039/d0rp00020e

Veiga, N., Luzardo, F., Irving, K., Rodriguez-Ayan, M.N., & Torres, J. (2019). Online pre-laboratory tools for first-year undergraduate chemistry course in Uruguay: Student preferences and implications on student performance. *Chemistry Education Research and Practice,* 20(1), 229-245. https://doi.org/10.1039/c8rp00204e

Vilia, P.N., Candeias, A.A., Neto, A.S., Franco, M.D.G.S., & Melo, M. (2017). Academic achievement in physics-chemistry: The predictive effect of attitudes and reasoning abilities. *Frontiers in Psychology,* 8. https://doi.org/10.3389/fpsyg.2017.01064

Villafane, S.M., & Lewis, J.E. (2016). Exploring a measure of science attitude for different groups of students enrolled in introductory college chemistry. *Chemistry Education Research and Practice,* 17(4), 731-742. https://doi.org/10.1039/c5rp00185d

Vossen, T.E., Henze, I., Rippe, R.C., van Driel, J.H., & de Vries, M.J. (2018). Attitudes of secondary school students towards doing research and design activities. *International Journal of Science Education,* 40(13), 1629-165. https://doi.org/10.1080/09500693.2018.1494395

Wallace, E.D., & Jefferson, R.N. (2013). Developing critical thinking skills for information seeking success. *New Review of Academic Librarianship,* 19(3), 246-255. https://doi.org/10.1080/13614533.2013.802702

Wheeler, L.B., Maeng, J.L., & Whitworth, B.L. (2015). Teaching assistants' perceptions of a training to support an inquiry-based general chemistry laboratory course. *Chemistry Education Research and Practice,* 16(4), 824-842. https://doi.org/10.1039/c5rp00104h

Wiebe, E., Unfried, A., & Faber, M. (2018). The relationship of STEM attitudes and career interest. *Eurasia Journal of Mathematics, Science and Technology Education,* 14(10), 1-17. https://doi.org/10.29333/ejmste/92286

Wilke, R.R., & Straits, W.J. (2001). The effects of discovery learning in a lower-division biology course. *Advances in Physiology Education,* 25(2), 62-69. https://doi.org/10.1152/advances.2001.25.2.62

Willcoxson, L., Manning, M.L., Johnston, N., & Gething, K. (2011). Enhancing the research-teaching nexus: Building teaching-based research from research-based teaching. *International Journal of Teaching and Learning in Higher Education*, 23(1), 1-10.

Xu, X., Villafane, S.M., & Lewis, J.E. (2013). College students' attitudes toward chemistry, conceptual knowledge and achievement: Structural equation model analysis. *Chemistry Education Research and Practice,* 14(2), 188-200. https://doi.org/10.1039/c3rp20170h

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