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

Irwanto Irwanto

Department of Chemistry Education, Universitas Negeri Jakarta (Indonesia)

Irwanto@unj.ac.id

Received January 2022
Accepted March 2022

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 REORCLEA (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 REORCLEA 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 REORCLEA to other college chemistry courses to improve their performance.

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

To cite this article:


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 & Date, 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, Urtay, 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, Guven & 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, Akku 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; Willecoxson, 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, Schofield, 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 & Zakharides, 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](image)

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.

<table>
<thead>
<tr>
<th>Sub-domains</th>
<th>M</th>
<th>SD</th>
<th>t</th>
<th>p</th>
<th>Cohen’s d</th>
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<td>0.415</td>
<td>-7.897</td>
<td>0.000</td>
<td>1.12</td>
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<td>3.520</td>
<td>0.416</td>
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<td>0.455</td>
<td>-6.556</td>
<td>0.000</td>
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<tr>
<td>Pretest</td>
<td>2.800</td>
<td>0.364</td>
<td>-7.399</td>
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<tr>
<td>Pretest</td>
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<td>0.337</td>
<td>-8.785</td>
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<td>-11.345</td>
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<td>0.354</td>
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<tr>
<td>Identifying and Controlling Variables</td>
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<td>Pretest</td>
<td>2.780</td>
<td>0.352</td>
<td>-5.423</td>
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<td>0.77</td>
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<td>0.391</td>
<td>-8.986</td>
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<td>3.380</td>
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<td>Pretest</td>
<td>25.660</td>
<td>1.636</td>
<td>-14.219</td>
<td>0.000</td>
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<td>Posttest</td>
<td>30.450</td>
<td>1.768</td>
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</table>

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; α = 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.

<table>
<thead>
<tr>
<th>Subscales</th>
<th>M</th>
<th>SD</th>
<th>t</th>
<th>p</th>
<th>Cohen’s d</th>
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<td>3.405</td>
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<td>3.555</td>
<td>0.355</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intellectual Honesty</td>
<td></td>
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</tr>
<tr>
<td>Pretest</td>
<td>3.355</td>
<td>0.268</td>
<td>-3.105</td>
<td>0.003</td>
<td>0.44</td>
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<tr>
<td>Posttest</td>
<td>3.530</td>
<td>0.370</td>
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</tr>
<tr>
<td>Suspended Judgment</td>
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</tr>
<tr>
<td>Pretest</td>
<td>3.260</td>
<td>0.323</td>
<td>-2.267</td>
<td>0.028</td>
<td>0.32</td>
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<tr>
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<td>0.316</td>
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</tr>
<tr>
<td>Critical-Mindedness</td>
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<tr>
<td>Pretest</td>
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<td>-2.740</td>
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<tr>
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<td>0.364</td>
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<tr>
<td>Humility</td>
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<tr>
<td>Pretest</td>
<td>3.390</td>
<td>0.351</td>
<td>-3.386</td>
<td>0.001</td>
<td>0.48</td>
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<tr>
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<td>0.354</td>
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<tr>
<td>All Subscales</td>
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<tr>
<td>Pretest</td>
<td>29.665</td>
<td>1.417</td>
<td>-9.278</td>
<td>0.000</td>
<td>1.31</td>
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<tr>
<td>Posttest</td>
<td>31.275</td>
<td>1.938</td>
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</table>

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; α = 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; Gooley & 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.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author received no financial support for the research, authorship, and/or publication of this article.

References


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


Published by OmniaScience (www.omniascience.com)

Journal of Technology and Science Education, 2022 (www.jotse.org)

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