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RESEARCH-ORIENTED COLLABORATIVE INQUIRY LEARNING MODEL: IMPROVING STUDENTS' SCIENTIFIC ATTITUDES IN GENERAL CHEMISTRY

Eli Rohaeti,
Anti Kolonial Prodjosantoso,
Irwanto

Abstract. *Promoting students' attitudes, a part of affective domains is a major goal in higher education. Unfortunately, only a few studies were available related to the improvement of pre-service chemistry teachers' attitudes as this domain was rarely explored using a mixed teaching approach. In this quasi-experimental research, we investigated the effect of the Research-Oriented Collaborative Inquiry Learning (REORCILEA) in improving students' scientific attitudes. A total of sixty-four (6 males, 58 females) first-year pre-service chemistry teachers at the Department of Chemistry Education of a public university in Indonesia attended the General Chemistry course. In order to collect the data, the Scientific Attitudes Scale and Interview Protocol were administered. The data were then analyzed using t-test and thematic analysis. The results of the t-test revealed that students in the experimental group obtained significantly greater scores than the ones of the control group regarding their scientific attitudes. After analyzing the interview data qualitatively, students who were exposed to non-traditional teaching approach had stronger learning interests and enjoyed the chemistry lectures. In conclusion, REORCILEA model could be considered more effective in improving students' scientific attitudes compared to conventional teaching methods.*

Keywords: *collaborative inquiry learning, general chemistry, pre-service chemistry teachers, research-oriented learning, scientific attitudes.*

Eli Rohaeti,
Anti Kolonial Prodjosantoso,
Irwanto
Yogyakarta State University, Indonesia

Introduction

General Chemistry is a course served in the early semester that aims to equip students with a basic introduction to chemistry in college. Unfortunately, this compulsory course is often considered difficult by most first-year students (Cooper, Grove, Underwood, & Klymkowsky, 2010; Tai, Sadler, & Loehr, 2005). Previous research showed that many students found difficulties in understanding some concepts in chemistry and they were not familiar with laboratory equipment used in General Chemistry, and their scientific skills were also regarded low (Cengiz & Karataş, 2015; Mulford & Robinson, 2002; Taylor, Rogers, & Veal, 2009). We assume that this problem might lead to a decrease in students' scientific attitudes that ultimately affects their academic performance. A number of studies confirmed a positive and significant relationship between attitudes and achievement in General Chemistry lectures (Brown et al., 2015a; Brandriet, Xu, Bretz, & Lewis, 2011). Therefore, it was considered necessary to apply mixed teaching approaches to promote students' attitudes and motivation in learning General Chemistry.

In order to address this problem, REORCILEA model was designed to provide powerful effects than a single teaching approach. Previous studies have successfully integrated different teaching approaches to improve students' critical thinking, conceptual understanding, and interest in science (Ku, Ho, Hau, & Lai, 2013; Raes, Schellens, & de Wever, 2013; Sun, Looi, & Xie, 2016). To our knowledge, the improvement of pre-service chemistry teachers' attitudes through mixed teaching approaches was rarely explored. In fact, promoting students' attitudes, a part of affective constructs, in introductory university chemistry courses is a major goal in higher education.

Research-Oriented Collaborative Inquiry Learning (REORCILEA)

REORCILEA is a student-centred learning model, which integrates the principles of scientific inquiry into a collaborative environment supported by research-oriented learning elements. Rooted in Vygotsky's sociocultural theory to bridge research and teaching, this learning model encourages students to leap from their current level of development to a higher level

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of development (Clarà, 2016). Within collaborative inquiry learning situations, students work together in small groups to undertake inquiry steps similar to what scientists always do with minimum guidance of the lecturer. This method allows students to directly involve themselves in the communication process and to self-regulated learning activities in order to gain greater knowledge (Bell, Urhahne, Schanze, & Ploetzner, 2009; Gijlers, Saab, van Joolingen, de Jong, & van Hout-Wolters, 2009). In research-oriented learning settings, students are engaged in research practices that will enhance their research competences (Böttcher & Thiel, 2017; Healey, 2005). Advance laboratory support will also encourage students to develop positive attitudes, promote their scientific skills, and solve various problems (Arabacioglu & Unver, 2016; Feyzioğlu, Demirdağ, Akyıldız, & Altun, 2012).

Separately, a number of previous studies reported that collaborative inquiry in a research-oriented learning environment was able to promote scientific attitudes (Toma & Greca, 2018; Vishnumolakala, Southam, Treagust, Mocerino, & Qureshi, 2017; Yaşar & Anagün, 2009). For example, Vishnumolakala et al. (2017) investigated students' attitudes using process-oriented guided-inquiry learning. They show that students' attitudes are higher after instruction. In addition, the inquiry process provides meaningful affective experiences for students who are new to chemistry. Then, students' intention for research usage is positively correlated with their perceptions and attitudes towards research (Griffioen, 2019). Accordingly, when students are involved in research-oriented learning, students feel challenged and find awareness about the importance of research to improve practical skills (Natland, Weissinger, Graaf, & Carnochan, 2016). In addition, research activities stimulate students to solve various problems in the real world (Al-Maktoumi, Al-Ismaily, & Kacimov, 2016). Thus, the research skills acquired during an investigation can help students improve their scientific attitudes.

At present, linking research and learning in higher education is increasingly seen as an effective vehicle for improving the quality of learning (Pan, Cotton, & Murray, 2014; Zamorski, 2002). If the lecturer is able to integrate theoretical and practical needs through the application of the REORCILEA model, the scientific attitudes of the pre-service chemistry teacher will develop progressively. Thus, the REORCILEA model is claimed as a solution to activate the lecture process while promoting students' affective domain.

Scientific Attitudes

Scientific attitudes refer to the relatively stable tendency of students to perceive an object based on personal beliefs, such as good-bad, pleasant-unpleasant, and like-dislike (Ajzen, 2001). Brown et al. (2015b) asserted that attitudes related to an individual's tendency to respond to certain stimuli in the context of chemistry, which responses include cognitive, affective, and behavioural elements. In addition, Osborne, Simon, and Collins (2003) explained that attitudes include beliefs, feelings, and values on certain objects as the result of learning science and applying science in real life. Specifically, Cheung (2009) stated that in this context, attitudes are related to chemistry, such as chemists, chemistry subjects, chemistry topics, and research on chemistry.

Previous research has been conducted on scientific attitudes. Villafañe and Lewis (2016) reported that students had slightly positive attitudes toward science in General Chemistry lectures. Although students' attitudes were quite positive, attitude remained a priority that should be further developed. Based on the findings of research done by Cigdemoglu, Arslan, and Cam (2017), there was a decrease in students' attitudes after being given specific instructions. In fact, Çalık, Ültay, Kolomuç, and Aytar (2015) found a tendency among students to have weaker attitudes toward chemistry as their year of study increases. Given that the affective domain can change from time to time as a result of environmental influences, attitudes need to be evaluated and improved on an ongoing basis.

Scientific attitudes are a key element to the success of chemistry learning. Earlier studies show that attitude has a positive influence on other variables, such as problem-solving skills (Demirel, Derman, & Karagedik, 2015), self-efficacy (Hacieminoglu, 2016; Kurbanoglu & Akin, 2010; Senler, 2016), and learning achievement (Brandriet et al., 2011; Brown et al., 2015a; Cheung, 2009; Salta & Tzougraki, 2004; Usak et al., 2009; Yüksel & Geban, 2014). Numerous other quantitative studies have also investigated the influence of attitudes toward chemistry at various levels of education (Brown et al., 2014; Brown et al., 2015a; Cheung, 2009, 2011; Hofstein & Mamlok-Naaman, 2011; Kubiatko, Balatova, Fancovicova, & Prokop, 2017; Kurbanoglu & Akin, 2010). In general, the results of their research indicated that educators began promoting student attitudes in chemistry learning at an earlier age. Riegle-Crumb et al. (2015) emphasized that the failure of learning activities in developing scientific attitudes would lead to poor scientific orientation manifested in daily activities.

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Research Purposes and Research Questions

Teaching methods have been recognized as factors that influence students' scientific attitudes (Raved & Assaraf, 2010). Literature showed that a well-managed classroom environment is a strong determinant of students' attitudes (Osborne et al., 2003). If students have a positive attitude, they are predicted to be more successful in achieving their goals and careers (Aydeniz & Kaya, 2012; Kubiatko, Balatova, Fancovicova, & Prokop, 2017) and they tend to be more interested in science (Feist, 2012). Thus, this research was specifically intended to analyze the effect of the REORCILEA in improving the scientific attitudes of pre-service chemistry teachers. Regarding this aim, three research questions were addressed as follows:

1. Is there any significant difference in scientific attitude scores between experimental and control group students?
2. How do the scores between the two groups change after being given intervention?
3. How do the experimental group students perceive the instructions?

Research Methodology

Research Design

A non-equivalent control group pre-test and post-test design was utilized in this research. In this research design, subjects were not randomly assigned to groups; instead, randomly-formed groups were assigned as experimental and control groups (Fraenkel & Wallen, 2006). The experimental group students were exposed to the teaching and learning using REORCILEA, while the ones in the control group were taught using a conventional teaching method by the same lecturer. The researchers observed how the teacher taught during the treatment. In this research, REORCILEA is the independent variable, while students' scientific attitudes are the dependent variable.

Research Sample

This research involved 64 first-year pre-service chemistry teachers (aged 18-20 years) who were randomly selected from two intact classes during the first semester of the 2018/2019 academic year. Students in the experimental (n = 33; 3 males and 30 females) and control (n = 31; 3 males and 28 females) groups attended the General Chemistry course, a compulsory course served in the first year at a public university in Indonesia. This course included three 50 min courses and two 50 min laboratory sessions per week for 10 sessions over 8 weeks. Both groups were taught the same topics; reaction rates, acids-bases, and colligative properties. All students had equal educational and socio-economic backgrounds ranging from low- to middle-income families. As ethical procedures, a written consent form was distributed to participants and they signed the consent form after obtaining permission from the Head of the Department of Chemistry Education. All students participated voluntarily in this research. Thus, they could withdraw at any time. In the beginning, the researchers also informed that their attitude scores would not affect their performance. In order to ensure confidentiality, the names of participants were made anonymous (Fraenkel & Wallen, 2006).

Data Collection Instruments

Scientific Attitudes Scale (SAS). The SAS was developed by the researchers to collect valid responses related to the attitudes or opinions of participants during the instruction process. The SAS consisted of 9 sub-scales; rationality, open-mindedness, curiosity, aversion to superstition, intellectual honesty, critical-mindedness, objectivity, suspended judgment, and humility. All sub-scales were adapted from relevant literature (e.g., Billeh & Zakhariades, 1975; Gauld & Hukins, 1980; Haney, 1964; Kozlow & Nay, 1976). The assessment components were described into 36 statements (18 positives and 18 negatives) using a 4-point Likert scale. Chang (1994) reported that greater reliability was found on a 4-point scale. In addition, a 4-point scale was chosen to avoid a neutral midpoint which has the potential to create a central tendency bias; for instance, respondents are indifferent and feel ambivalent (Baka, Figgou, & Triga, 2012; Greenleaf, 1992). A score "1" showed strong disagreement, while a score of "4" expressed

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strong agreement. Every negative statement was given the opposite score. The minimum and maximum scores obtained by students were 36 and 144 points respectively. Before being used in the pre- and post-tests, the SAS had been validated by 4 experts, which results showed that the coefficient of Cronbach's alpha reliability was .84.

Semi-Structured Interview Protocol (SIP). The SIP was employed to obtain a deeper understanding, detailed descriptions and further insights about participants' ideas regarding chemistry teaching. The interviews were conducted individually in the form of face-to-face interviews by the third author (Patton, 2002) after obtaining opinions from two chemistry education experts. Each interview session lasted from 20 to 25 min. Interviews were conducted on the same day after students completed the SAS. Some questions included: "*Is there any positive change in your attitudes toward chemistry before and after the intervention?*" and "*Does the use of REORCILEA activities improve your scientific attitudes?*".

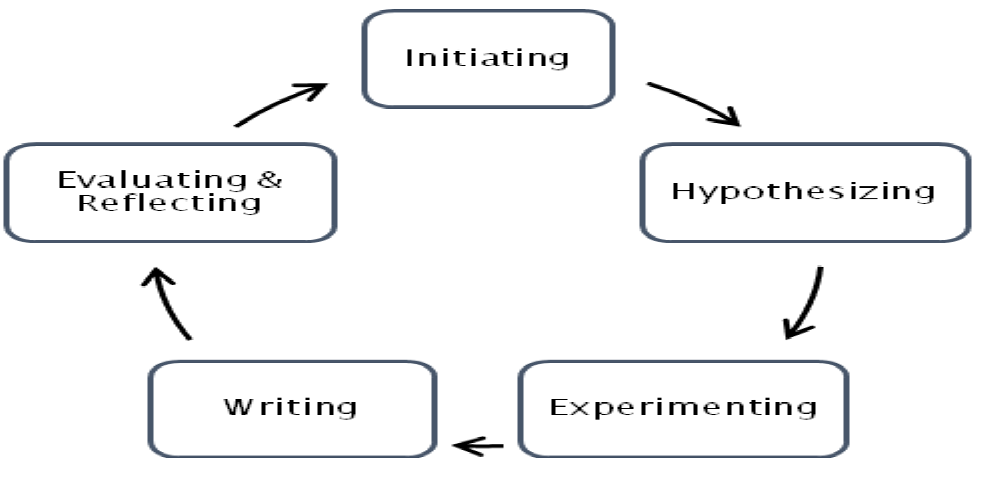
Procedures

Prior to the application of different treatments, a pre-test had been given. After the intervention, the post-test was then administered, and interviews were carried out. The SAS was used as a pre- and post-tests in both groups, while the SIP was only given to nine (PT1 to PT9) experimental group students selected based on the mean post-test score after instructions were given. Three students who obtained scores were low, medium, and high and were selected using a purposive sampling technique (Cohen, Manion, & Morrison, 2007).

The Treatment for the Experimental Group

The REORCILEA model, developed by Irwanto (2019), allowed students to follow a series of learning activities; (1) Initiating, (2) Hypothesizing, (3) Experimenting, (4) Writing, and (5) Evaluating and Reflecting. In the ***Initiating*** stage, students were faced with unstructured problems and stimulated to solve daily life problems. In the ***Hypothesizing*** stage, students asked various questions, claims, and possible solutions based on the empirical evidence that they found. In the ***Experimenting*** stage, students worked in small groups to test their hypotheses in the laboratory like true scientists. In the ***Writing*** stage, students collected, organized and presented the data they had obtained in the form of tables, graphs, and charts presented in a written report. In the ***Evaluating and Reflecting*** stage, students were involved to evaluate and reflect on their performance during the learning activities, and to set further learning goals. These five activities form a cycle as shown in Figure 1.

Figure 1
Learning cycle in REORCILEA (adapted from Irwanto, 2019)



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The Treatment for the Control Group

In teacher-centred learning, students listened to lectures on a topic. During the treatment, they were instructed to read textbooks and take notes. After the explanation of the concept, students were asked to complete the questions and the lecturer provided the answers on PowerPoint slides. In the laboratory, students worked in groups to do instruction in the recipe book and answered the questions provided at the end of the worksheet. Finally, students collected their individual written lab reports.

Data Analysis

Kolmogorov-Smirnov test and Levene's test were performed to examine the assumption of normality and homogeneity. Subsequent to conducting assumption tests (see Table 1), pre- and post-test scores on scientific attitudes showed normal and homogeneous distribution ($p > .05$). Thus, pre-test and post-test data could be directly analyzed using the *t*-test. Independent samples *t*-test was carried out to understand whether there were statistically significant differences in the mean scores between the two sample groups. Paired samples *t*-test was executed to explore the effect of learning methods on student performance in a single class. Furthermore, the increase in students' scores before and after treatment was calculated using the effect size formula (*d*) (Cohen, 1988). Cohen's *d* values described the strength of the difference between pre- and post-test scores that were classified into three categories: .20 to .30 showed weak; .40 to .70, moderate; and .80 to 1.00, strong effects (Cohen, 1988). For statistical analysis, SPSS 17.0 was performed.

Table 1. The normality and homogeneity test for the pre- and post-tests scores

Groups	Pre-test		Post-test	
	Normality	Homogeneity	Normality	Homogeneity
Experimental	.886	.616	.878	.652
Control	.997		.811	

Note: $p > .05$ = Data were normally/homogeneously distributed

A qualitative analysis technique in the form of thematic analysis (Braun & Clarke, 2006) was utilized to analyze the obtained data. The results of the interviews were transcribed verbatim in Microsoft Word. The interview transcripts were then organized into narrations that have been interpreted by the researchers. In order to avoid biases, participant validation was done by evaluating the transcripts and interview analysis to interviewees (Cohen, Manion, & Morrison, 2007). Every statement was kept anonymous to fulfil research ethics.

Research Results

Quantitative Findings

In order to address the first research question on whether the scientific attitudes scores between the experimental and control group students differed significantly, the researchers carried out an independent samples *t*-test. The *t*-test results compared to the pre-SAS scores between the experimental and control groups are summarized in Table 2. At the beginning of the lecture, students in the control group obtained greater mean scores than the ones in the experimental group in five scientific sub-attitudes (i.e., rationality, curiosity, open-mindedness, intellectual honesty, and critical-mindedness). Whereas, in the other four dimensions (i.e., aversion to superstition, objectivity, suspended judgment, and humility), the experimental group showed slightly superior results. In general, there was no statistically significant difference in the overall pre-test scores between the experimental and control groups ($t(62) = –.360$; $p = .720$). Moreover, the differences in scores across sub-skills were not found statistically significant ($p > .05$). It indicates that all participants had equal attitudes at the beginning of the lecture.

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Table 2
The differences in pre-test attitudes scores between the two groups

Sub-Scales	Groups	*n*	*M*	*SD*	*t*	*p*
Rationality	Experimental	33	3.167	.352	-.223	.825
	Control	31	3.186	.323		
Curiosity	Experimental	33	3.318	.387	-1.084	.282
	Control	31	3.427	.419		
Open-Mindedness	Experimental	33	3.280	.379	-1.102	.275
	Control	31	3.379	.335		
Aversion to Superstition	Experimental	33	3.432	.326	.870	.388
	Control	31	3.355	.381		
Objectivity	Experimental	33	3.409	.399	.090	.929
	Control	31	3.401	.361		
Intellectual Honesty	Experimental	33	3.462	.442	-1.858	.068
	Control	31	3.637	.302		
Suspended Judgment	Experimental	33	3.227	.366	.487	.628
	Control	31	3.186	.316		
Critical-Mindedness	Experimental	33	3.386	.386	-.008	.994
	Control	31	3.387	.347		
Humility	Experimental	33	3.485	.428	.639	.525
	Control	31	3.419	.389		
All Sub-Scales	Experimental	33	30.167	2.174	-.360	.720
	Control	31	30.376	2.481		

At the end of the lecture, students in the experimental group dominated the post-test scores in all sub-attitudes, except in the 'rationality' ($t(62) = -.178$; $p = .859$) which score was slightly lower than the control group (see Table 3). Furthermore, a significant difference was found in four sub-attitudes; objectivity, intellectual honesty, suspended judgment, and critical-mindedness. However, there were no statistically significant differences in the other five sub-attitudes between the two groups. Overall, the post-test scores between the control and experimental groups were significantly different ($t = 2.558$; $p = .013$). These results showed that the REORCILEA model has been found effective in developing the scientific attitudes of pre-service chemistry teachers.

Table 3
The differences in post-test attitudes scores between the two groups

Sub-Scales	Groups	*n*	*M*	*SD*	*t*	*p*
Rationality	Experimental	33	3.258	.426	-.178	.859
	Control	31	3.274	.305		
Curiosity	Experimental	33	3.432	.416	1.625	.109
	Control	31	3.274	.356		
Open-Mindedness	Experimental	33	3.386	.424	1.068	.290
	Control	31	3.274	.415		
Aversion to Superstition	Experimental	33	3.515	.359	1.912	.060
	Control	31	3.355	.308		

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Sub-Scales	Groups	*n*	*M*	*SD*	*t*	*p*
Objectivity	Experimental	33	3.553	.368	2.004	.049
	Control	31	3.355	.422		
Intellectual Honesty	Experimental	33	3.659	.369	2.657	.010
	Control	31	3.403	.401		
Suspended Judgment	Experimental	33	3.432	.376	3.303	.002
	Control	31	3.137	.334		
Critical-Mindedness	Experimental	33	3.538	.381	3.748	.001
	Control	31	3.186	.371		
Humility	Experimental	33	3.530	.389	1.810	.075
	Control	31	3.355	.386		
All Sub-Scales	Experimental	33	31.303	2.635	2.558	.013
	Control	31	29.613	2.648		

In order to respond to the second research question on whether there was a significant difference between the student's mean pre-test and post-test scores, a paired-samples *t*-test was executed. In addition, the effects of the REORCILEA are also described in the form of Cohen's *d* values presented in Table 4. Although the post-SAS scores of the experimental group students in the five sub-attitudes (i.e., rationality, curiosity, open-mindedness, aversion to superstition, and humility) were not significantly different, the scores have increased from pre-test to post-test. In general, there was a significant change in the mean pre-test and post-test scores from 30.167 to 31.303 (increased by 1.136; $t = 3.048$; $p = .005$) for the experimental group and 30.376 to 29.613 (decreased by .763; $t = –2.142$; $p = .040$) for the control group. According to the results of the paired *t*-test, students in the experimental group showed significantly improved scientific attitudes scores compared to the control group after the treatment. In addition, a moderate effect ($d = .53$) in the experimental group showed that students had consistently more positive attitudes and enjoyed the chemistry learning using REORCILEA.

Table 4
Changes in experimental group students' attitudes scores

Sub-Scales	Paired Differences		*t*	*df*	*p*	Cohen's d
	M	*SD*				
Rationality	.091	.369	1.416	32	.166	.25
Curiosity	.114	.438	1.491	32	.146	.26
Open-Mindedness	.106	.647	.942	32	.353	.16
Aversion to Superstition	.083	.413	1.159	32	.255	.20
Objectivity	.144	.415	1.994	32	.055	.35
Intellectual Honesty	.197	.467	2.425	32	.021	.42
Suspended Judgment	.205	.412	2.852	32	.008	.50
Critical-Mindedness	.152	.424	2.055	32	.048	.36
Humility	.045	.521	.501	32	.620	.09
All Sub-Scales	1.136	2.142	3.048	32	.005	.53

Qualitative Analysis

In order to answer the last research question, a thematic analysis was employed. After treatment, the opinions of the experimental group students about the effectiveness of the REORCILEA were collected to support quantita-

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tive data. These followings are students' responses regarding their perceptions before and after attending lectures that indicate positive attitudes towards chemistry.

> "I grow more positive perception. Before attending the lecture, I did not understand most of the concepts of General Chemistry. After the lecturer, I understand them better." [PT2]

> "Before the lecturer, I only learned a few topics and did some simple exercises. After the lecturer, I have broader comprehension since I learned from more complex problems that could be solved using higher reasoning." [PT4]

> "After the lecturer, I have more positive attitudes toward chemistry. For instance, at school, an indicator was used in the acid-base titration learning (i.e. PP indicator that showed pinkish colour change). However, after the lecturer, I saw changes in other colours using different indicators. [PT9]"

> Further questions investigate students' perception of the laboratory activities in improving their scientific attitudes. Students' positive attitudes are reflected in these following responses.

> "Indeed, some phenomena related to chemistry intrigued our curiosity to do more investigation that improved our process skills." [PT3]

> "Yes, laboratory activities gave me valuable experience that improved my critical-mindedness about how chemical phenomena occur." [PT5]

> "Problem-solving activities in the laboratory improved my critical-mindedness, accuracy, and scientific skills." [PT7]

Even a student (PT8) who obtained relatively low score stated that "*I have more positive attitudes because laboratory activities were more interesting and challenging than the traditional lecture. For instance, we were required to be more precise, cautious, and accurate. Therefore, we become more responsive and persistent.*" In short, students' responses imply that the REORCILEA has been able to develop their scientific attitudes.

There is other evidence that supports the positive effects of the REORCILEA. After the intervention, most students showed that their scientific attitudes tended to increase. This fact is associated with students' involvement in lab activities. Two students stated:

> "I think laboratory activities are fun and make me understand theory in a better way than traditional lecturer because we can actually prove a theory. [PT1]"

> "I can understand a concept better through experiments than through textbooks because I can prove the theory, explore it and obtain broader knowledge." [PT6]"

In summary, the treatment given to the experimental group has been able to promote students' scientific attitudes to a satisfactory level.

Discussion

The present research was conducted to explore the effect of the research-oriented collaborative inquiry learning (REORCILEA) on the scientific attitudes of first-year pre-service chemistry teachers in General Chemistry course compared to the use of traditional teaching instruction. Based on the results of the independent samples *t*-test, there were statistically significant differences in the scientific attitudes of experimental and control group students, in which experimental group students showed better attitudes. At the end of the intervention, students who were taught using REORCILEA showed a more positive scientific attitude score than those in the comparison group. The efficacy of this research is associated with the active involvement of students during the lecture (Hofstein & Lunetta, 1982). Based on the constructivism, students discuss and collaborate with peers to design, investigate, and communicate data in order to construct their own knowledge. This belief is supported by Berg (2005) who also agreed that student-centred learning where students are

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engaged in collaborative work and contextual ideas exchange can promote positive attitudes among students in college chemistry courses.

The findings of the current research are supported by other empirical evidence in science education. Numerous studies reported that collaborative inquiry and research-oriented learning are more effective methods than traditional instruction (e.g., Brown, 2000; Gibson & Chase, 2002; Jiang & McComas, 2015; Koksal & Berberoglu, 2014; Vossen, Henze, Rippe, van Driel, & de Vries, 2018). This finding makes sense as collaborative inquiry instruction encourages students to exchange and share their ideas with peers, respond and reflect on their arguments. In addition, a research-oriented learning environment supports students to promote critical attitude and curiosity that are important elements of scientific attitudes that allow students to gain new knowledge (Dippelhofer-Stiem, 1989).

The results of paired samples *t*-test confirmed that the experimental group students had their scores increased. Cohen's *d* values in all subscales indicate that the treatment given to the experimental group is more effective than traditional teaching given to the control group in developing students' scientific attitudes. Student-oriented learning is believed to be more effective as it allows students to focus on their learning (Devlin & Samarawickrema, 2010). Collaborative works allow students to solve problems with their peers while they construct knowledge and improve their performance during the activities which then lead students to have positive attitudes. Similarly, Maio and Haddock (2010) claim that hands-on experiences from the surrounding environment develops students' attitudes due to a positive association between the chemistry laboratory environment and students' attitudes (Wong & Fraser, 1996).

On the other side, control group students showed rather negative attitudes after they were taught using traditional teacher-centred approach. This might occur due to the large class which made the students less active in the learning process. Researchers believe that teacher-centred teaching is less effective due to the lack of student-student interactions and teacher-student relations. Consequently, the traditional lecture environment does not provide opportunities for students to share, criticize, or revise their arguments while they investigate certain problems (Walker, Sampson, Southerland, & Enderle, 2016). Whereas, Brown et al. (2015b) argued that attitudes that include cognitive, affective, and individual behavioural perspectives that are organized through previous experiences form ones' views about a certain particular subject. It means that attitudes are related to students' experiences, whether or not students perceive laboratory activities interesting and how much such activities help them in completing the course (Baseya & Francis, 2011). When students do not enjoy the lecture, they tend to have negative attitudes which ultimately affect their academic performance. Thus, it can be claimed that the learning environment is a determining factor that affected students' attitudes in both groups in this research.

The results of the interviews provided more evidence that indicates the changes in the perceptions of the experimental group students after instruction. Students perceived that the REORCILEA is more effective than traditional teaching in developing their attitudes. This positive perception might be formed as they worked in small groups which allowed them to directly engage in the planning, implementation, and evaluation of laboratory activities. Supportively, Walker, Sampson, and Zimmerman (2011) reported that students who were trained to design and investigate, analyze, interpret, and communicate the data they obtained tend to have more positive attitudes towards science. In another research, Tsybulsky, Dodick, and Camhi (2017) also found that science learning in authentic college research labs had a positive effect on students' attitudes towards science.

Conclusions and Suggestions

In summary, this research reports that the REORCILEA model is considered better in promoting students' scientific attitudes compared to traditional college instruction. Specifically, the results show that experimental group students develop their scientific attitudes at the end of the course. This indicates that the REORCILEA is a viable constructivist-teaching model in improving students' attitudes in the context of undergraduate general chemistry. In this design, REORCILEA provides opportunities for pre-service chemistry teachers to integrate chemical content into the investigation process. More broadly, the use of the REORCILEA gives a positive contribution in preparing pre-service teachers to succeed in college and in the workplace. Referring to these benefits, REORCILEA should be included in the higher education curriculum to solve daily life problems in order to foster students' affectiveness. More importantly, this research can be utilized as a guide for chemical educa-

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tors to design and develop more effective instructions in general chemistry courses. These results can also be implemented in introductory chemistry courses to make chemical knowledge more meaningful. Moreover, current research provides new insights on effective teaching strategies for higher education institutions and instructors regarding how to significantly promote the scientific attitudes of pre-service chemistry teachers using a combined approach.

Related to the limitations, this research was conducted for the first time in which the number of participants was small. It is suggested that future research involves larger sample sizes to make the finding more generalizable. In order to obtain a more significant effect, the implementation of the learning model can be prolonged. This research only focused on students' attitudes. Hence, future research is encouraged to examine the effect of the REORCILEA on the cognitive and psychomotor domains to obtain more comprehensive findings. In addition, future research is recommended to compare the effectiveness of the REORCILEA model to other non-traditional teaching methods. Regarding the fact that this research is the first research conducted to investigate the effect of the REORCILEA on students' scientific attitudes in General Chemistry course, the findings of this research add up to the body of knowledge in this field and open up new directions for future research.

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Eli Rohaeti Dr., Associate Professor, Department of Chemistry Education, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Colombo Street No.1 Yogyakarta, Indonesia.
E-mail: eli_rohaeti@uny.ac.id

Anti Kolonial Prodjosantoso Professor, Department of Chemistry Education, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Colombo Street No.1 Yogyakarta, Indonesia.
E-mail: prodjosantoso@uny.ac.id

Irwanto *(Corresponding author)* Dr., Researcher, Department of Chemistry Education, Graduate School of Yogyakarta State University, Colombo Street No.1 Yogyakarta, Yogyakarta 55281, Indonesia.
E-mail: dr_irwanto@yahoo.com
ORCID: https://orcid.org/0000-0001-5842-5931