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Redesigning Laboratories for Pre-service Chemistry Teachers: From Cookbook Experiments to Inquiry-Based Science, Environment, Technology, and Society Approach

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ABSTRACT

Because school laboratory activities obtained by pre-service teachers tend to use cookbook experiments, this study focused on redesigning chemistry laboratory activities at the university level from cookbook experiments to inquiry-based Science, Environment, Technology, and Society (SETS) approach, and analyzing pre-service chemistry teachers‟ performances and their views to the redesigned laboratory activities. Through action research methodology, team teaching was conducted with 20 PCTs by following „Plan-Do-Study-Act‟ (PDSA) Cycle model within „The Course of Laboratory Practice in Basic Chemistry (CLP-BC)‟. Science process skills test (SPST), performance observation sheets (POS), presentation observation sheets (PrOS), self-reflective journals (SRJ), and interviews were used to evaluate the redesigned process. The CLP-BC activities consisted of 16 meetings through two PSDA cycles. The redesigned chemistry laboratory activities included such topics as colligative properties of the solution; chemical equilibrium on solubility; acid-base titration; solubility product; and voltaic cells. The results indicated improvements at the PCTs‟ science process skills, performances in managing laboratory and discussion activities as well as their positive responses at their self-reflective journals.

Keywords: Cookbook experiments, inquiry, laboratory, pre-service chemistry teachers, science-environment-technology-society approach.

INTRODUCTION

The National Science Education Standards have emphasized three essential and interrelated learning objectives for all students studying science: learning about the nature of science and scientists‟ studies; learning doing science (that is, developing the abilities to design and conduct scientific investigations); and understanding scientific concepts and principles. Engaging students in inquiry learning facilitates all of three aspects; so that, the National Research Council (NRC) considers inquiry as an excellent content for science

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learning and learning methods (National Research Council, 1996). Science students at all grades should have an opportunity to use scientific inquiry and develop scientific inquiry abilities to think and act in ways. These activities include asking questions, planning and conducting investigations, using appropriate tools and techniques to collect data, thinking critically and logically about the relationship between evidence and explanation, constructing and analyzing alternative explanations, and communicating scientific arguments (National Research Council, 2012). Thus, science/chemistry teachers have an important role in preparing inquiry-based learning environment for their students.

Chemistry laboratory activities are important for chemistry learning because chemistry is an experimental science (Golinski, 1999). Chemistry laboratory practices enhance conceptual understanding of chemical principles and their applications in daily life because concepts help students to define and explain objects and events in their environments (Arends, 2012). Chemistry teachers should design and carry out chemical experiments by using science-related technology (Hidayah & Imaduddin, 2015). Many schools and universities have not fully implemented inquiry-based chemistry learning in practicum. Indeed, conventional chemistry practices lead to the use of guidelines provided by the lecturer or "the cookbook experiments". The "cookbook experiments" direct students to confirm what they have learned during instruction. Previous studies have shown that traditional/didactic instruction is not very successful in changing students‟ conceptions (Bodner, 1991; Gunstone & White, 1981; Luckie et al., 2013; Nakhleh, 1992; Smith & Metz, 1996; Ural, 2016). The didactic teaching style (i.e., "cookbook experiments") may be quite successful in instilling facts, rules, procedures, and algorithms of a specific science domain. However, it is insufficient to help students filter and build their ideas about science concepts because they are not encouraged to think them at a higher level or metacognition (Rickey, Teichert, & Tien, 2008; Zulfiani & Herlanti, 2018).

Many researchers have criticized the effectiveness of prescription-based practicum activities or "recipe following" or "cookbook" experiments (Brownell, Kloser, Fukami, & Shavelson, 2012; B. Feyzioğlu, 2009; E. Y. Feyzioğlu, 2012; Ural, 2016). The cookbook activities may somewhat show the possibility of "hands-on" activities, but they are rarely related to "minds-on" ones. When performing these tasks, students often forget the purpose of the activities and track steps mechanically without in-depth reflection or real involvement (Millar, 2010). Laboratory inquiry activities offer opportunities for pre-service teachers to examine how to present science learning to students (E. Lee, Brown, Luft, & Roehrig, 2007). The activities may also be used to explore scientific knowledge, challenge explanations, and provide opportunities to discuss any change in understanding (France & Haigh, 2009). Inquiry-based lab activities have the potential to develop students‟ conceptual understanding (Hofstein & Lunetta, 2004; Wardani, Widodo, & Winarno, 2017). Nevertheless, many in-service and pre-service science teaching courses do not equip teachers with skills that are used as facilitators to guide inquiry. Teachers often lack enough information about such new learning models as inquiry-based learning and its implications for teaching and curriculum. So, many teachers have still preferred conventional teaching methods, which purpose to directly transfer knowledge to students (Hofstein & Lunetta, 2004; Li, 2016). Therefore, developing and implementing inquiry-based lesson plans should be included in teacher education programs.

As a part of the teacher preparation program, pre-service teachers can manage laboratory activities through the process of planning a teaching sequence that is similar to their future teaching careers in the schools. When school-level students have great roles in investigating, thinking, planning, practicing, and reflecting, inquiry can be implemented as a teaching approach (Berg, Bergendahl, Lundberg, & Tibell, 2003) for pre-service teachers at the university level. In this study, we attempted to redesign chemistry laboratory activities for pre-service chemistry teachers (PCTs) within the „Course of Laboratory Practice in Basic Chemistry (CLP-BC)‟. The activity began with a laboratory activity using an experiment guide or cookbook, and then it was redesigned into an inquiry-based Science, Environment, Technology, and Society (SETS) activity.

SETS establishes the relationship between students‟ beliefs and the real world. This process will lead students to recognize possible problems they have. The created learning environment fosters students to collect data to solve their problems, consider alternative solutions, determine the best problem-solving ways and practice them (Yager, 1990; Zhang & Asher, 2017). The relevant literature concludes that the level of chemistry achievement can be improved through STSE-related-teaching approaches. Students, who experienced the STSE learning approach, showed significant increases in developing positive attitudes towards science, creativity skills, scientific literacy, social skills concerning the chemistry subject (Ahmed, 2018; M.-K. Lee & Erdogan, 2007; Yörük, Morgil, & Seçken, 2010; Zahara & Atun, 2018). Within this framework, this study aimed at designing a 16-week program to improve the PCTs‟ science process skills and competencies of planning an inquiry-based experiment by shifting cookbook activities to inquiry-based SETS approach.

Inquiry as a Laboratory Activity for Pre-service Chemistry Teachers

An alternative way to shift a traditional laboratory instruction is an investigation (or inquiry) approach (Domin, 1999). Inquiry-based teaching increases deeper and more meaningful understanding (National Research Council, 2000). Inquiry-based activities, which are inductive (DeBoer, 1991), have unspecified results and require students to make their work steps. As compared to traditional patterns, inquiry activities involve more student participation, and fewer guidelines, as well as giving more responsibility to students for choosing their working ways (Leonard, 1989). This approach makes students effective authorities for laboratory activities (Roth, 1995; Roth & Bowen, 1994) and improves their attitudes towards science learning (Merritt, Schneider, & Darlington, 1993). Inquiry-based laboratory activities are also able to enhance students' abilities of formal operational thinking (Lawson & Snitgen, 1982).

The inquiry-based science activities that allow discussion, collaboration and interaction between preservice teachers are useful in developing their beliefs of inquiry-based science learning and enhancing their abilities to apply scientific inquiry processes. The overall findings have suggested that the inquiry-based activities, as an instruction method, should be preferred for preservice teacher education (Çimer, 2007; Sağlam & Şahin, 2017; Tatar, 2012). Further, they have shown that inquiry-based learning increases students' interest in student-centered investigations and facilitates conceptual understanding. Describing scientific phenomena through everyday language develops students‟ understanding and enables them to explain scientific phenomena by using scientific vocabulary and making connections with their conducted experiments (Bertsch, Kapelari, & Unterbruner, 2014). Engaging inquiry promotes students to actively involve in questions and answers, scientific inquiry, problem-solving, and experimental learning (Hayat & Rustaman, 2017). Thus, students can not only express their ideas and feelings in various ways but also enjoy their learning processes (Zubaidah, Fuad, Mahanal, & Suarsini, 2017).

A prominent figure, Joseph Schwab, played a crucial role in inquiry-based curriculum development in the 1960s and 1970s. Schwab stated that student participation was so essential for practical activities to train science process skills such as asking questions, collecting data, and interpreting results to appreciate questions (Schwab, 1960) (see Schwab‟s scale of inquiry in science teaching for Table 1. (Mugaloglu & Saribas, 2010; Settlage & Southerland, 2007).

Table 1. *Openness Levels of the Inquiry-based Teaching Approach*

Level	Source of the Question	Ways to Gather Data	Interpreting Results
Level 0	Given	Given	Given
Level 1	Given	Given	Open
Level 2	Given	Open	Open
Level 3	Open	Open	Open

The type of inquiry can be distinguished as structured, guided, or open (Colburn, 2000; Hegarty-Hazel, 1986). The teacher has excellent control over questions, methods, and interpretations in Level 0, which is the lowest level of investigation. The teacher directly submits problems, procedures, and material content to students for the investigation process, but does not tell the expected results. Students find relationships between variables or generalize the collected data. This level of investigation is identified as a structured inquiry (Colburn, 2000) and known as cookbook activities. In fact, cookbook activities generally cover more directions at observing and collecting data than structured investigation activities. Structured inquiry assignments are based on the content-related curriculum (Zion & Mendelovici, 2012). In structured inquiry groups, lecturers also discuss possible experimental results and the best way to analyze the obtained data (Faulconer, 2016). Students produce the interpretation of results at level 1, while the teacher controls their asking questions and problem-solving procedures. The teacher only determines questions that need to be answered at level 2, but students are free to use their methods to answer the questions and interpret the results. Levels 1 and 2 are labeled as a guided inquiry. Students control these three components at level 3. This level is interpreted as an open inquiry (Colburn, 2000), which is the most sophisticated level of inquiry-based learning. Educators define this type of inquiry as the knowledge framework that allows students to choose various questions and approaches (Faulconer, 2016; Zion & Mendelovici, 2012). Thus, students are exposed to sustainable decision-making procedures at every stage of the open inquiry.

This framework is useful for teachers to plan science activities for their students. Because students have more competencies in doing science, teachers will gradually allow them to control all procedures/processes. Scientific experience type of a pre-service teacher influences his or her beliefs about science teaching and learning (Duschl, 1983; Tatar, 2015). They may believe the significance of school students" direct experiences, but do not know how to translate them into class content. Having the opportunity to study new (and strict) content via prior knowledge and engaging social interaction may help pre-service teachers to resolve this problem. Pre-service teachers should make explicit connections amongst the inquiry process, their understanding of how people study science, and their teaching practices (Crawford, 2007; Sağlam & Şahin, 2017).

Based on the inquiry level in Table 1. this study led to design the inquiry-based laboratory activities for the PCTs at level 2 or guided inquiry. Laboratory activities were controlled to adjust their competencies to school-level chemistry studies with several topics. Thus, several problems were deliberately designed to investigate their methods and existing laboratory materials. Besides, the proposed problem challenged the PCTs to review the perspective of the SETS. The results were related to these four aspects, so the chemical content the PCTs had learned was directly associated with their real life.

Science, Environment, Technology, and Society (SETS) Approach in Chemistry Learning

Educational activists from science, technology, society and the environment (STSE) have advocated the contextual literacy of ethics, individual and social responsibility (Aikenhead, 1994; Kumar & Chubin, 2000; Pedretti, 1999; Solomon, 1993). STSE programs and themes aim to interpret science and technology as a socially embedded complex effort and promote the development of critical, scientific, and high-tech citizens, who can understand the STSE issues. The STSE or SETS makes students informed and responsible decision-makers (Pedretti, 2003). This study tried to elicit what the PCTs would be doing through the SETS -based inquiry laboratory activities and whether his or her scientific process skills would increase.

The purpose of the SETS learning is to enable students to understand science better, encourage them to improve their creative and critical thinking skills, and make boring and abstract topics more exciting and enjoyable (Aikenhead, 1994). Previous studies have revealed that the SETS implemented in chemistry learning has possessed a significant impact on learning outcomes (Imaduddin, 2013; Rahmah, Mulyani, & Masyikuri, 2017). Further, they have found a difference amongst critical thinking skills of students, who took the SETS-based guided inquiry, guided inquiry learning, and conventional learning (Jariyah, 2017; Nisak, Wartono, & Suwono, 2017). There is no doubt that learning cannot be actualized in an isolated environment from the world (Nakhleh, 1992). On the other hand, science topics have been taught far from reality or the real world. Through the SETS connections, students aim to build their own understanding of the SETS concept and integrate their life experiences into chemistry and human-made technological world. Students are expected to build and connect these SETS concepts with each other given their continuous interactions (Aikenhead, 1994). The content of the Chemistry course intends to enable students to achieve adequate knowledge for living in a modern technological environment. The SETS relationships should afford students to recognize their environmental and technological conditions, understand their contribution to the community, and predict the possibility of damage that could occur. Therefore, research should be carried out to prepare teachers and develop related equipment allowing students to establish the component connections of the SETS approach (Yörük et al., 2010). The literature has shown how the implementation of the SETS approach in teaching chemistry boosts youngers‟ awareness, despite the fact that some obstacles exist in scientific writing and dissemination of the results. Overall, students‟ scientific literacy levels and their commitments to the sustainable development of the local environment need to be deepened (Simões, Nazaré, & Trigo, 2016). Therefore, given a brief review of the relevant literature, this study focused on redesigning chemistry laboratory activities at the university level from the cookbook experiments to inquiry-based SETS pproach.

Research Questions

The following research questions guided the current study:

1. What is the process of redesigning laboratory activities for PCTs from the cookbook activities to inquiry-based SETS activities?
2. What are PCTs performances and responses to the process of redesigning chemistry laboratory activities from the cookbook activities to inquiry-based SETS activities?

METHODOLOGY

a) Context

The Course of Laboratory Practice (CLP) for pre-service chemistry teachers is a student-centered, and involves several laboratory activities asking for active student engagement. Some chemistry teacher education programs include CLP-related courses, i.e., the „Course of Laboratory Practice in Basic Chemistry (CLP-BC)‟. The CLP-BC, which is commonly taught by teacher-centered approach, contains a guidebook to re-practice laboratory activities in the school context and to deepen their subject-matter knowledge learned in the first year of the teacher education program. Cookbook experimental activities are adapted to the school science curriculum and the topics they will teach in their future teaching careers. Regular activities begin with a pre-test to measure their pre-existing knowledge of the chemical concepts that will be practiced and to prepare tools and materials following the instructional guidelines. The CLP-BC settings consist of a 16-week period of laboratory activities and complete with a post-test. In this context, we redesigned the CLP-BC in which the PCTs experienced a shift from traditional lab activities into SETS-based inquiry activities. That is, they tested and practiced two different types of laboratory activity designs and reflected their experiences of the differences between them.

b) Phases of Research

Since this research characteristically focused on the development and improvement of the CLP-BC, it employed critical theory as a research paradigm. The critical theory concentrates on critics and/or analysis of situations requiring improvement (Kincheloe & McLaren, 2002). Action research, as a research methodology, pursues the critical theory paradigm and deals with problem-solving and project development (Atweh, Kemmis, & Weeks, 1998). This study with the PDSA (Plan, Do, Study, and Act) Cycle model generated a collaborative team study for improving chemistry learning. (Langley et al., 2009). This study comprised of two PDSA cycles: (i) traditional laboratory activities, and (ii) improvement of these activities. Activity details on the PDSA Cycle are shown in Figure 1.

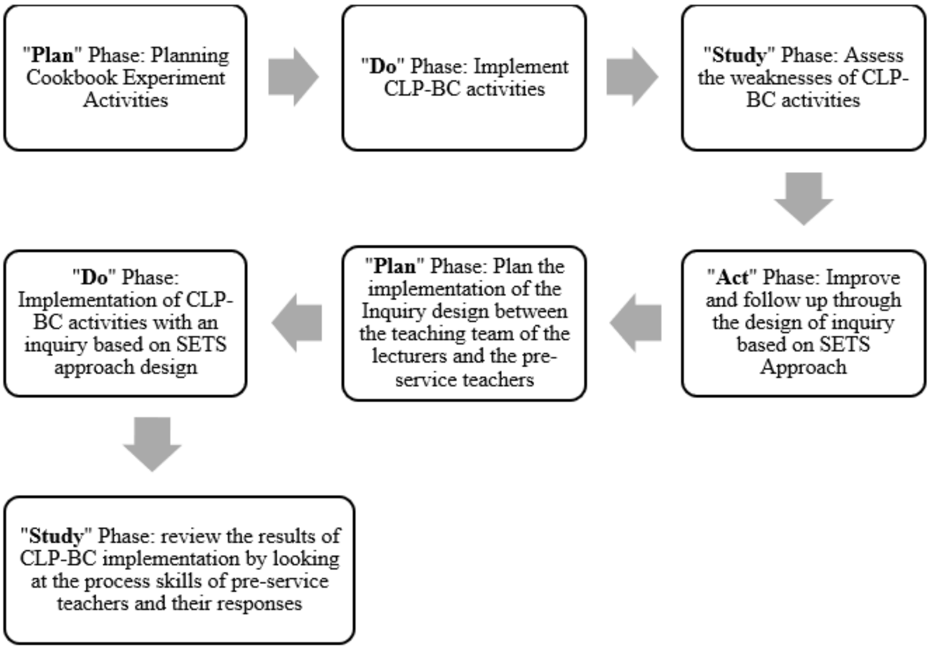

Figure 1. The PDSA cycle for Redesigning Chemistry Laboratory Activities

c) Research Participants

The CLP-BC comprises of two parts, namely CLP-BC I and CLP-BC II. 20 participants were drawn from the first-year pre-service chemistry teachers, who had previously taken the CLP-BC I. These PCTs came from various regions in Indonesia and had a qualification variety of high school education. The CLP-BC I was presented within a traditional laboratory using a guidebook with practical objectives, theoretical basis, practicum tools and materials, and observation sheets, and evaluation of activities. They were divided into pairs for laboratory activities and completed the CLP-BC I at a 16-week semester.

d) Instruments and Data Analysis

The instruments consisted of paper and pencil tests, namely a science process skills test (SPST) integrating science process skills with chemistry topics and SETS aspects. The SPST incorporated „observing, questioning, hypothesizing, predicting, investigating, interpreting, communicating" indicators (Harlen & Jelly, 1997). Because test validity uses the trustworthiness criteria (Guba & Lincoln, 1989), this study ensured them through credibility (member checking), transferability (thick description), dependability (emergence), and confirmability (audit trail data). The SPST, which composed of seven questions with a maximum score of 100 points, covered the characteristics of the Basic Chemistry Practicum (i.e., level and material). Quantitative data were analyzed descriptively. Also, the achievement criteria before and after the treatment were analyzed by calculating normalized gain. The criteria for this N-gain consisted of low $(0{,}0 \leq \langle g \rangle < 3{,}0)$, medium $(0{,}3 \leq \langle g \rangle < 0{,}7)$, and high $(0{,}7 \leq \langle g \rangle < 1{,}0)$ level (Hake, 1998).

Other instruments, namely self-reflective journals (SRJ), performance observation sheets (POS), and presentation observation sheets (PrOS), were adopted from previous studies (Hidayah, 2014). The 24-item SRJ was a 4-point scale (maximum score=96) reflecting the PCTs" views of science process skills and SETS aspects during the course. Analysis was made through the average item scores of self-reflection categories: low $(1{,}0 \leq \bar{x} \leq 2{,}0)$, medium $(2{,}00 < \bar{x} \leq 3{,}0)$, and high $(3{,}00 < \bar{x} \leq 4{,}00)$. The POS comprised of Yes-No Checklist and 30 lists spread over five aspects (i.e., practical preparation, the performance of making solutions, the performance of practicum processes, affective aspects, and performance of final stage). The analysis was done roughly by looking at the changes in average scores of the laboratory activities. In addition, unstructured interviews were conducted to see students' responses to the redesigned process. Presentation observation sheets (PrOS) were scored throughout „interesting aspect of the presented material, participation in learning, activeness in discussions, students' discussion abilities to convey their results, students' skills in asking questions, and exposure to the SETS-integrated material". The CLP-BC program and instruments are summarized in Table 2.

Table 2. The CLP-BC program and instruments

Research Phases	Week	Focus	Instruments
"Plan" Phase	1	Pre-test and preparation of the cookbook experiments	SPST
"Do" Phase	2-7	The Cookbook Experiments	POS
"Study" Phase	8	Focus Group Discussion (FGD) for designing SETS-based inquiry approach between the lecturers and PCTs	
"Act" and "Plan" Phase	9	Consultation on the design of inquiry practices and assistance in preparing practical tools and materials	
"Do" Phase	10-14	The SETS-based inquiry activities	POS
	15	Presentation of the results of the inquiry activities in practicum	PrOS
"Study" Phase	16	Post-test and evaluation	SPST, SRJ

RESULTS AND DISCUSSION

Design of the CLP-BC Program for Pre-service Chemistry Teachers

A strong movement towards inquiry learning, especially BSCS for biology and PSSC for physics (DeBoer, 1991), was developed in the 1960s. The inquiry-based projects in the 1960s revealed many explanations for their failure. Kohlberg and Gilligan believed that inquiry activities assumed formal operational thinking rather than trying to develop it (Kohlberg & Gilligan, 1971). Linn argued that the inquiry approach in the 1960s required students to simultaneously attend the concept of new subject matter, unknown laboratory equipment, and new problem-solving tasks (Linn, 1980). Other critical studies showed that inquiry emphasized scientific processes in place of proper science content (Friedl, 1991) and wrongly equated scientific inquiry with the discovery of unsupervised students (Hegarty-Hazel, 1990). Lecturers, who teach pedagogical courses in teacher education programs, should consider that inquiry-based learning could not be an effective method to develop pre-service teachers‟ critical thinking dispositions (Arsal, 2017). The implementation of inquiry-based learning also showed its inability to improve their competencies of scientifically evaluating and designing scientific investigations (Arief & Utari, 2015). Teaching with minimal guidance is less effective and efficient as compared with the teaching approach that emphasizes student-centered learning. The provision of guidance is increasingly not seen as a benefit when students already have prior knowledge providing "internal" guidance (Kirschner, Sweller, & Clark, 2006). Inquiry learning is only successful in promoting student learning if students are ready or activities are designed correctly (Julien & Lexis, 2015; Kirschner et al., 2006). Therefore, the current study did not carry out suddenly the redesigning process. The first-year PCTs firstly experienced traditional laboratory activities to prepare and train their skills before the inquiry laboratory activities.

As can be seen from Table 3, the five laboratory activities were prepared for mastering the PCTs‟ science content about the chemistry curriculum at the school level. Based on the second (Plan) phase at the 9th week (see Table 2.), the SETS-based inquiry approach contained five themes. In each theme, a problem, which was raised regarding the SETS aspects, asked a group of the PCTs to conduct a further investigation through their laboratory activities.

Table 3. *The chemistry topic in the CLP-BC cookbook model*

No	Topics	Purposes of laboratory activities
1	Colligative properties of the solution	1) Students can observe and know the difference in the boiling point of solvent with the electrolyte solution and non-electrolyte solution 2) Students can observe and know the difference in freezing point of solvent with the electrolyte solution and non-electrolyte solution
2	Chemical equilibrium	1) Students can observe and know reactions that can take place in two directions 2) Students can observe and know the occurrence of a shift in the equilibrium position of acetic acid with the addition of sodium acetate 3) Students can observe and know the occurrence of a shift in the equilibrium position of acetic acid with the addition of ammonium chloride, NH_4Cl
3	Acid-base titration	Students can observe and know the pH change of the solution from acid and base reactions
4	Solubility and Solubility Product	1) Students can determine the solubility of $Ca(OH)_2$ in water and NaOH solution 2) Students can observe and know the effect of NaOH on the solubility of $Ca\ (OH)_2$ and the results of the solubility of $Ca(OH)_2$
5	Voltaic Cells	1) Students can observe and know the electrical energy produced by spontaneous redox reactions 2) Students can observe and know the electrical energy produced from spontaneous redox reactions using potato medium

Each group solved five problems, and the designs were not allowed to be the same as the other groups. Variations were made by changing several laboratory variables, i.e., the type of material, tools, stages, or the overall work method (see Table 3 for the five problems proposed for the PCTs). The five problems were prepared by taking into account the topics in the previous laboratory activities and linking them to the SETS aspect. The PCTs were required to design practical activities and relate them to answer the questions posed on the problem. The communication between groups of the PCTs was important to avoid the same practical design on the variable aspect.

As observed in Table 4, ten groups of the PCTs could design each of the five activities differently. Thus, the inquiry-based SETS approach included fifty variations of practical activities related to problem-solving. The variation was driven by the intensity of communication between groups in one class. The group of the PCTs designed activities and scheduled problem-solving activities in practicum. The problem-solving duration lasted five working weeks, preceded by a design guidance process before the laboratory activity. This mentoring process took much time for pre-service teachers and lecturers of the CLP-BC courses.

Table 4. *The Problems for the CLP-BC with the inquiry-based SETS approach*

No	Topics	Problems for the inquiry-based SETSactivities
1	Colligative properties of the solution	Suppose you work in a company that produces methyl alcohol, ethyl alcohol, and isopropyl alcohol. Production employees suddenly forget to label the barrel containing alcohol. The shipping department wants to know what type of alcohol will be sent so they can put it in the appropriate truck. Your group is asked to **identify alcohol in the barrel**. The only available chemical known is tertiary butyl alcohol. All alcohol in the plant dissolves tertiary butyl alcohol.
2	Chemical equilibrium on the solubility	A homeowner is interested in buying water purifiers that are often offered in several advertisements on TV, the internet, and other media. Before buying the tool, the homeowner takes the initiative to test whether he really needs water purification or not. Therefore, he requests the services of a consumer advocate to check it. As a team works in consumer advocates, you are asked to check the hardness of the water owned by the homeowner. **How do you check the water hardness level**, including hard water or soft water? Also, advise homeowners about what should do!
3	Acid-base titration	Vinegar and olive oil are the main ingredients in most salad dressings. Acetic acid is available in vinegar. Vinegar is an aqueous solution that contains acetic acid as a solute. You are a member of the chemical analysis team. Your team is asked to analyze the quality of supplied vinegar in a company because the company has received complaints about the unsuitability of their dressings for the served salad. Indeed, the condition of olive oil is not a problem. Your team is asked **to determine the concentration (molarity and percent mass) of acetic acid** in vinegar samples that the company has distributed to restaurants.
4	Solubility Product	Water in the pool generally contains a number of dissolved calcium ions. The swimming pool is purified with the addition of several chlorination agents. Calcium hypochlorite is commonly used. Besides, calcium ions emerge from plaster lining the pond. Plaster is a hydrate of calcium sulfate. A swimming pool company has recently contacted your group to address complaints from several customers. Customers have complained about plaster in the pool that began to disappear after one year. The company wants to **know how many plasters that might be dissolved** before the pool water becomes a saturated solution of calcium sulfate. At first, the swimming pool includes soft water (non-hard water) which does not contain calcium ions.
5	Voltaic Cells	Suppose your group is stranded somewhere in the sea and you have to turn on the global positioning system (GPS). You do not have a replacement battery, but you have a bag full of coins. **How much voltage** can you make from this coin to make a battery?

Learning with the SETS approach overcomes misconceptions by considering the role of science in society (Yörük et al., 2010). The main objective of the SETS-related chemistry is to present chemistry and technology as a methodology, which allows pre-service teachers to compare benefits and losses in the presented problem-solving process. The presented problems are part of the SETS components to find out the benefits and applications in life to solve social problems through chemistry and technology. Using this approach will increase scientific literacy and student interest (Yörük et al., 2010). The problems with the inquiry-based SETS activities show chemistry-related professions as well as chemical positions, i.e., individual parts as citizens, communities, service users, or consumers. Allowing students to recognize the interaction(s) between SETS components will make abstract concepts more concrete.

In some cases, students may find inquiry laboratories time-consuming, and other laboratory works funny (Chatterjee, Williamson, McCann, & Peck, 2009; Luckie et al., 2012). For example; the PCTs stated the following quotation:

> "*The first pleasant experience where we made the practical prescription, not from the lecturer or teacher.*" [PCT 1]

Practical work can reveal the disparity between theory and practical experiments by constructing an understanding of the role played by experiments, while practical work is too costly and time-consuming (Castro & Morales, 2017; Ma & Nickerson, 2006). Other PCTs also showed enthusiasm through a statement suggesting that inquiry activities could construct their understanding of the chemistry concepts.

> "*Such a meaningful experience because it trains independence in working in the laboratory. With independence, the things that are wrong and right can be seen up to the roots, although it is somewhat confusing*." [PCT 2]

The settings of inquiry activities in the redesigning process are presented in Figure 2. The PCTs might not carry out them in practicum before the stages were completed. Before practical activities, problems were given to them to solve through practical activities. They designed practical activities, identified equipment and material needs, and prepared the tools and materials themselves. Practical activities were carried out after the approval of the lecturer.

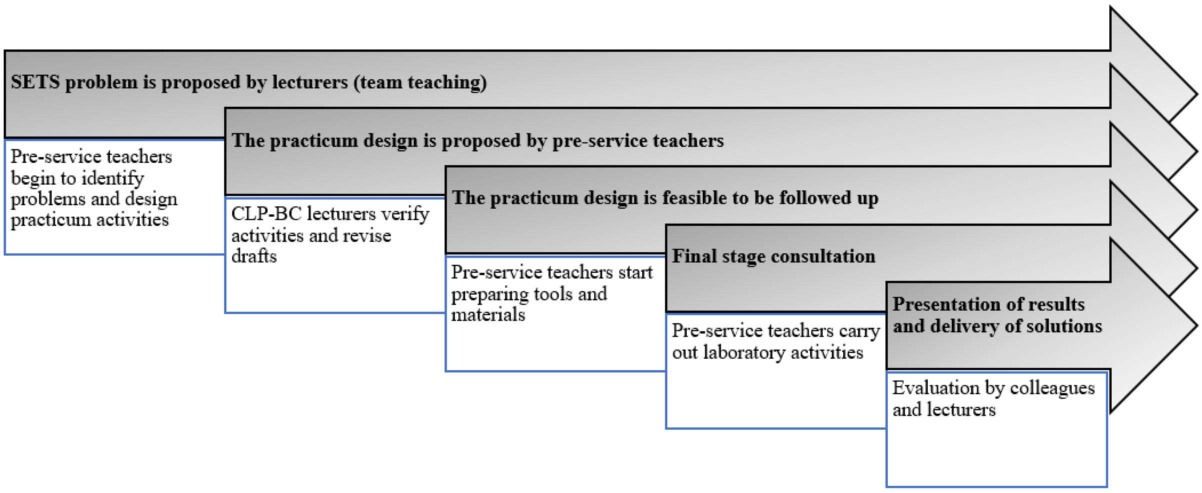

Figure 2. The Settings of the Inquiry Activities in Redesigning Process

Inquiry encouraged the PCTs to find the limits of their understanding of subject-matter knowledge, enabled them to build knowledge different from their pre-existing knowledge and helped them understand the possibility of practical work in teaching. To develop their competencies, the PCTs might also gain an understanding of various aspects of pedagogical knowledge (Nivalainen, Asikainen, & Hirvonen, 2013). Through mentoring from the lecturers, the PCTs would understand the chemical concepts perceived as weak or still needed improvement, and their stages of understanding. This understanding could be transferred to problem-solving strategies of such topics as the colligative nature of the solution, chemical equilibrium on solubility, acid-base titration, solubility products, and voltaic cells.

Pre-service Chemistry Teachers' Performances and Responses

During the design process of the cookbook experiments into the inquiry-based SETS approach, how the PCTs managed laboratory activities could be directly observed. Observations were conducted within the aspects of preparing practical activities, making a practical solution, running the practice, affective issues in the laboratory, and their performances at the end of practical activities. All of them were observed by Yes-No Checklist in the POS. As seen from Table 5, the number of "Yes" response was made in integers. As compared the number of "Yes" response with the maximal number of "Yes" response for each aspect, the number of the items was 37.

Table 5. *The PCTs' performances of laboratory activities*

No.	Aspects	The average scores (Cookbook Experiment)	The average scores of each inquiry-based SETS activities				
			I	II	III	IV	V
1	Practical preparation	4/6	6/6	6/6	6/6	6/6	6/6
2	Performance of making solutions	6/7	6/7	6/7	6/7	6/7	6/7
3	Performance of practical processes	10/14	10/14	10/14	10/14	10/14	10/14
4	Affective issues	5/6	6/6	6/6	6/6	6/6	6/6
5	Performance of the final stage	4/4	4/4	4/4	4/4	4/4	4/4
	Total	**29**/37	**32**/37	**32**/37	**32**/37	**32**/37	**32**/37

As can be seen from Table 5, there were changes in the PCTs" performances of the implementation of inquiry activities. The PCTs complemented all performance aspects. Inquiry learning seems to have provided them to experience the processes of preparing equipment and chemical materials, operating special tools for practical activities, and making reagents. They motivated them to learn the whole processes in preparing practical laboratory activities. For instance; the PCT 3 stated that he had to buy directly one of the chemical materials that they did not find in the laboratory.

> "*I was initially confused because I did not find oxalic acid to standardize NaOH solution in the laboratory. However, consulting with laboratory staff and lecturers, I just found out that the ingredients can be purchased at Indrasari stores, one of the chemical stores in Semarang city. I just visited the chemical store for the first time because I needed materials for the experiment I was going to do. Valuable experience because I will know where to buy chemicals when I become a teacher.*" [PCT 3]

Also, when carrying out practical activities, the PCTs did not have much doubt because they really understood what they were doing. It was different from the use of the cookbook format. The PCTs flipped their notes because they hesitated how to carry out practical work steps. An excerpt is in the following:

"Designing practical laboratory activities myself, I became more aware of what to do. There is no need to open a work step record because everything has been memorized". [PCT 4]

Based on the five inquiry activities, the results were presented through discussion activities. Two groups independently presented each topic. Given their performances of the discussion session, the sharp differences occurred about such aspects as including media presentation, participation in learning, activeness in the discussion, the PCTs" abilities to convey the results of the discussion, questioning skills, and exposure related to SETS aspects (see Table 6).

Table 6. *The results of the Presentation Observation Sheet for Discussion Session*

No	Topics	The average scores in each aspect						Total
		A	B	C	D	E	F	
1	Colligative properties of the solution	3	3	3	3	3	3	18
2	Chemical equilibrium on solubility	4	4	4	4	4	4	24
3	Acid-base titration	4	4	3	4	3	3	21
4	Solubility Product	3	4	4	3	4	3	21
5	Voltaic Cells	3	3	3	3	4	4	20

Note: A: Interesting aspects of the presented material, B: Participation in learning, C: Activeness in discussions, D: Students 'discussion abilities to convey the results, E: Students' skills in asking questions, F: Exposure to the SETS-integrated material.

As observed in Table 6, discussing how to check for water hardness (fourth topic) was the best scores for all aspects. The concept of Ca^{2+} solubility seems to have become attractive because of limestone soil conditions in some areas, Demak and Purwodadi Regency, Central Java Province. In the last decade, several authors have emphasized the importance of carrying out environmental projects based on scientific research, real problems and laboratory activities (Gayford, 2002; Kolstoe, 2002; Moseley, 2000). One of the strategies for implementing these issues may be the SETS approach (Zhang & Asher, 2017). Overall, a proper assessment of the project, a deepened students' scientific literacy, and their commitment(s) to the sustainable development of the local environment appear to be indicators of the achievement (Simões et al., 2016). The PCTs from Purwodadi told how she was interested in carrying out the practical laboratory activities to check the water hardness.

"I brought water from my house to check it myself in a chemical laboratory. I am curious about the results. It is nice to learn that I can be used to understand what is around me". [PCT 5]

As shown in Table 7, the PCTs" science process skills also showed an increase at a medium level (N-gain = 0.48). These skills contained observing, questioning, hypothesizing, predicting, investigating, interpreting, and communicating (Harlen & Jelly, 1997). Inquiry-based SETS activities developed the PCTs" science process skills. Thirteen of the PCTs obtained N-gain value at the medium level.

Table 7. Achievement criteria before and after learning based on SPST

No	Phase	Minimum	Maximum	Average	SD	Overall N-gain	N-gain (n= 20)		
							Low	Medium	High
1	Pre-test	10	87.5	56.3	19.7	0.48 (medium level)	7 PCTs	13 PCTs	-
2	Post-test	56	95	77.1	9.8				

As can be seen from Table 8, their self-reflective journals showed medium (13 students) and high (7 students) categories. The results of self-reflection also revealed their self-opinion of science process skills, and how inquiry activities affected their future teaching careers. The PCTs showed positive results in their self-reflective journals. Several statements of the SETS approach were also found in interviews.

Table 8. The results of the PCTs" self-reflective journals

Components	Results
Average (n = 20)	67.3
Standard Deviation	11.1
Minimum Score (Total Score = 96)	53
Maximum Score (Total Score = 96)	93
Low Category of Reflection	-
Medium Category of Reflection	13 PCTs
High Category of Reflection	7 PCTs

When the PCTs designed their experiments, they proposed explanations for the phenomena they observed. They discussed their understanding of its contents and faced various misconceptions that they or their colleagues had submitted. From the perspective of teacher knowledge, pre-service teachers are aware of the fact that almost everyone has problems with their understanding, even in simple chemistry. Thus, they should pay attention to this misunderstanding when teaching later in school. Even if the role of a teacher is urgent in conceptual change, the interaction between peers is also an effective method of expressing and remedying misunderstandings (Nivalainen et al., 2013). Inquiry activities trained and improved their questioning and predicting skills. This stage seems to have occurred knowledge construction, as stated by PCT 6.

> *"At first, I was worried because it was not as usual. I then asked another friend, who was not in a group about the procedure she designed. From a casual conversation, I got many questions and ideas about designing lab work to solve problems".* [PCT 6]

Based on observations, several PCTs were almost frustrated because of the challenge of designing a practical laboratory activity based on the SETS problems. Students, who learn in the inquiry environment at an early stage, become impatient, but in the end, they understand what they are going through it and improve their learning. Finally, such a fosters them to begin enjoying it (Duran, McArthur, & Van Hook, 2004). In the CLP-BC, some PCTs showed their frustration and impatience levels through dependency in carrying out activities in the trial design process, preparation of tools and materials, and reporting results. Their final reflections showed a positive response to the redesigning process. The inquiry-based SETS approach needed to be further developed in other practical activities as stated by the PCT 7.

> *"This practical activity shows that chemistry turns out to have a close relationship with the environment, technology, and society. I have just realized how chemistry is used to check the condition of the pool, the condition of the vinegar packaging, making the battery simple. Hopefully, another practicum can also be like this".* [PCT 7]

Similar findings from inquiry learning experiences have shown that pre-service teachers finally get a thorough appreciation of the benefits of teaching and learning science through inquiry (Duran et al., 2004; Varma, Volkmann, & Hanuscin, 2009). Inquiry activities are effective in improving their science process skills (Özdemir & Işik, 2015; Sağlam & Şahin, 2017). The SETS approach also attracts attention and contributes to the improvement of science process skills (Zahara & Atun, 2018).

CONCLUSIONS

We have discussed the redesigned laboratory activities for the PCTs. The activity, which was initially the cookbook experiments, was redesigned concerning a inquiry-based SETS activity. The redesigned chemical topics for laboratory activities included: (1) colligative properties of solution, (2) chemical equilibrium on solubility, (3) acid-base titration, (4) solubility product, and (5) voltaic cells. The results showed that there were differences between the cookbook design and inquiry experiments in terms of learning stages, time allocation, skill and motivation conditions in laboratory activities, as well as outcomes of laboratory activities.

Based on various findings during the redesigning process, there were enhancements of the PCTs‟ performances in regulating laboratory activities. Their performances of the discussion activities about the results of independent practical laboratory activities also developed and showed good results at their science process skills, as well as their positive responses to the self-reflective journals.

The initial stage of the implementation of the inquiry activities may become reasonable and be achieved with intensive mentoring activities in that they may have frustration and constraints at the early stage of inquiry-based learning. The duration for inquiry activities can be accomplished through a peer tutoring system, and some delegated tutors from bright/hard-working students. Peer tutors may assist the processes of designing and preparing practical activities. Blended classes through online activities are also possible to overcome space and time constraints.

Furthermore, developing a higher-level inquiry or open inquiry for the PCTs is necessary. Seeing the results obtained at the guided inquiry has the potential to prepare the PCTs to attain the inquiry level. Also, the PCTs should be able to teach the inquiry-based SETS approach. A further design ought to include microteaching activities if pre-service teachers follow the developmental design of this activity and obtain complete knowledge related to pedagogical competencies.

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