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# INTRODUCING THE SMALL-SCALE CHEMISTRY APPROACH THROUGH INQUIRY-BASED LABORATORY ACTIVITIES FOR PRE-SERVICE TEACHERS

Fitria Fatichatul Hidayah[1*], Muhamad Imaduddin[2**], Eko Yuliyanto[3***], Gunawan[4****], Muhammad Cholid Djunaidi[5*****]

*[1,3]Department of Chemistry Education, Universitas Muhammadiyah Semarang, Indonesia,*
*[2]Program Study of Natural Science Education, Institut Agama Islam Negeri Kudus, Indonesia*
*[4,5]Department of Chemistry, Diponegoro University, Indonesia*

E-mail: * *fitriafatichatul@unimus.ac.id*, ***imad@iainkudus.ac.id*, ****ekoyuliyanto@unimus.ac.id,*
*****gunawan@live.undip.ac.id*, ******cholidjunaidi@live.undip.ac.id*

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**Abstract:** This study introduces a small-scale chemistry (SSC) approach to inquiry-based practicum activities. SSC was introduced to train PCTs' laboratory skills so that they can be creative when teaching in schools in situations where it is not possible to obtain standard lab facilities. The research method is an action research model that includes four stages in the inquiry training process, namely (1) prescription-based practicum learning; (2) small-scale practical demonstrations; (3) small-scale chemistry practicum mentoring; (4) design and implementation of small-scale practicum designs. This research involved 15 Pre-service Chemistry Teachers (PCTs) who were in the Basic Chemistry practicum course. Data collection used documentation techniques for practical activities with an SSC approach, activity response interviews, and open response questionnaires. Instrument validity used face validity, while reliability was obtained by stability of observations. The results of the documentation and interviews were described as narrative, while the responses to the questionnaire were recapitulated and analyzed to obtain a bar chart. Videos were checked using the adequacy rubric which includes performance and procedures. 15 types of chemistry practicums with the SSC approach have been obtained. PCTs have also been able to choose the types of materials that are not only found specifically in the laboratory, but also materials that are easily found in daily lives to be used in school chemistry practical topics. PCTs also reflected that their understanding of the concept is getting better with practicals that are easy to do and their interest in implementing it further.

**Keywords:** Pre-service chemistry teachers; Small-scale chemistry; Inquiry; Laboratory activities

**Abstrak:** Kajian ini memperkenalkan pendekatan *small-scale chemistry* (SSC) pada kegiatan praktikum berbasis inkuiri. SSC diperkenalkan untuk melatih keterampilan laboratorium PCT sehingga mereka dapat berkreasi saat mengajar di sekolah dalam situasi yang tidak memungkinkan untuk mendapatkan fasilitas laboratorium standar. Metode penelitian adalah model penelitian tindakan yang meliputi empat tahapan dalam proses pelatihan inkuiri, yaitu (1) pembelajaran praktikum berbasis prosedur kerja; (2) demonstrasi praktikum kimia skala kecil; (3) pendampingan praktikum kimia skala kecil; (4) desain dan implementasi desain praktikum skala kecil. Penelitian ini melibatkan 15 calon guru kimia (PCTs) yang sedang mengikuti mata kuliah praktikum Kimia Dasar. Pengumpulan data menggunakan teknik dokumentasi kegiatan praktikum dengan pendekatan SSC, wawancara respon kegiatan, dan angket respon terbuka. Validitas instrumen menggunakan *face validity*, sedangkan reliabilitas diperoleh dengan *stability of observations*. Hasil dokumentasi dan wawancara dideskripsikan secara naratif, sedangkan jawaban kuesioner direkap dan dianalisis sehingga diperoleh diagram batang. Video diperiksa menggunakan rubrik kecukupan yang meliputi kinerja dan prosedur. Telah diperoleh 15 jenis praktikum kimia dengan pendekatan SSC. PCTs juga telah dapat memilih jenis bahan yang tidak hanya ditemukan secara khusus di laboratorium, tetapi juga bahan yang mudah ditemukan dalam kehidupan sehari-hari untuk digunakan dalam topik praktikum kimia sekolah. PCTs juga merefleksikan bahwa pemahaman mereka terhadap konsep semakin baik dengan praktik yang mudah dilakukan dan minat mereka untuk menerapkannya lebih lanjut.

**Kata kunci:** Calon guru kimia; *Small-scale chemistry*; *Inquiry*; Aktivitas laboratorium

## INTRODUCTION

Laboratory activities play an important role in chemistry learning both at school and college levels. This practical learning constructs concepts based on direct experience (Bradley, 1999; Hofstein and Mamlok-Naaman, 2007; Lunetta, Hofstein and Clough, 2007; Imaduddin and Hidayah, 2019), foster interest and good scientific behavior, and train communication and collaboration skills (Hofstein and Lunetta, 2004). However, there are still many obstacles related to the implementation of laboratory activities in educational institutions. The problems include the unavailability of funds for the implementation of laboratory activities, laboratory class conditions, the absence of laboratory staff, implementation barriers related to the process including duration, lack of tools and materials, lack of teachers' lab experiences, and poor laboratory governance (Bell and Bradley, 2012; Tsaparlis, 2016). The laboratory experience of first-year educator candidates is also a concern in terms of how to construct an understanding of chemistry based on laboratory activities (Zuhaida and Imaduddin, 2019).

Various solutions have been sought to provide laboratory experiences to students, such as the implementation of demonstration learning, provision of virtual laboratories, screening of films and videos of laboratory activities, as well as illustrations on whiteboards. Laboratory practicum activities that emphasize hands-on skills will not be replaced easily (Bradley, 1999). By getting around the existing limitations, chemistry practicum does not always have to be expensive. Practicum can include a variety of low-cost and sustainable hands-on activities (Bradley *et al.*, 1998; Sane, 1999). One of the appropriate strategies is a small-scale chemical approach which is implemented in the practicum implementation process.

Small-Scale Chemistry (SSC) is an approach that minimizes the use of laboratory materials and waste in laboratory activities. This approach drastically reduces the use of chemicals up to 1000 times less than conventional laboratory activities (Mamlok-Naaman and Barnea, 2012), reduces the size of standard laboratory equipment, and uses simple plastic equipment (Skinner, 1999; Tesfamariam, Lykknes and Kvittingen, 2017). Through the implementation of this approach, the cost of practicum activities is lower, the duration of the practicum is shorter, the safety of laboratory work is better maintained, and the principles of green chemistry are applied (Singh, Szafran and Pike, 1999; Skinner, 1999; Mohamed, Abdullah & Ismail, 2012; Zakaria, Latip and Tantayanon, 2012; Imaduddin *et al.*, 2020).

SSC is an effective chemistry teaching innovation that requires engineering on conventional procedures to become a much smaller scale practicum. Thus, this process needs to be trained and taught in teacher training programs that are oriented towards hands-on learning activities (Imaduddin *et al.*, 2020). SSC can also improve the quality of chemistry teaching through an environmentally friendly perspective (Abdullah, Mohamed and Ismail, 2007). However, the existing hands-on activities have been criticized for their effectiveness due to prescription-based practice activities or "cookbook" experiments (Feyzioğlu, 2012; Ural, 2016). Teachers usually refer to recipe book guides as the main source of practicum implementation. PCTs must be prepared so that they can modify recipes and guidelines if the tools, materials, and financial support of the agency are not adequate. This SSC can overcome the limitations of supporting facilities, infrastructure, and funds in the implementation of practical chemistry teaching.

Further, prescription-based practicums may involve hands-on experience but rarely involve mind-on activities. When carrying out practical activities with complete guidelines, students often ignore the purpose of the activity and only focus on the stages of the procedure without reflecting deeply (Millar, 2010). Practical activities are expected to develop laboratory skills with an inquiry approach that provides opportunities for PCTs to gain experience that can be implemented in their classrooms in the future (Lee *et al.*, 2007; Imaduddin and Hidayah, 2019). Inquiry-based laboratory activities have the potential to construct conceptual knowledge (Hofstein and Lunetta, 2004; Wardani, Widodo and Winarno, 2017).

Many in-service and pre-service science teaching programs have not provided the skills used as facilitators of inquiry learning. Many teachers ultimately still prefer conventional teaching methods that aim to transfer knowledge directly to students (Hofstein and Lunetta, 2004; Li, 2016). The inquiry-based practicum can also train students' operational skills (Lawson and Snitgen, 1982). Inquiry activities also allow for discussion, collaboration, and interaction between students that can grow their confidence about inquiry-based chemistry learning and increase their ability to apply the stages of scientific inquiry. Inquiry-based learning, as a teaching method, should be prioritized in the education of pre-service teachers (Çimer, 2007; Tatar, 2012; Sağlam and Şahin, 2017). Thus, it is urgent to introduce inquiry to the presentation of practicum activities held with a small-scale chemistry approach. Pre-service chemistry teachers (PCTs) are expected to gain experience in practicum activities with a variety of inquiry activities and have the potential to be implemented in their field of work because they are held with an SSC approach that overcomes the limitations of tools and materials in the laboratory. The purpose of this research is to analyze the process of inquiry-based practicum activities with the SSC approach which is trained on the training program of PCTs. The results will provide an overview of improvement in the preparation of chemistry practicum programs in the education series for PCTs so that in the future they can contribute to the improvement of chemistry learning at the secondary school level.

## METHOD

This study introduces a small-scale chemistry (SSC) approach through inquiry-based laboratory activities. SSC is an approach used in the implementation of chemistry practicum techniques. This approach was implemented in a learning set with a series of inquiry models which were shifted from guided-inquiry-based practicum with a conventional approach to a guided inquiry-based practicum design with an SSC approach.

Action research is designed to bridge the gap between research and practice. Action research should contribute not only to the quality of classroom practice but also to the educational and teaching theory that is accessible to other teachers so that education is more reflective (Cohen, Manion and Morrison, 2007). In this research, the practice of action is shown by the existence of a process of practicing inquiry-based learning which was initially carried out with conventional laboratory techniques to become a technique with an SSC approach which requires PCTs to be more creative in their investigations.

Action research is carried out by modifying the level of inquiry for PCTs based on their level of openness. This action research is a powerful way of improving the quality of local or classroom-scale learning (Cohen, Manion and Morrison, 2007). It reveals an understanding of what is going on so that this research is descriptive (Sagor, 2005). The steps to train PCTs in designing and implementing the small-scale approach in the chemistry practicum design as shown in Figure 1.

In the first stage, 7 sessions were carried out which included eight practical topics, namely: 1) Solution concentration; 2) Stochiometry 3) Acidimetric Titration; 4) Alkalimetric titration; 5) Properties of Aluminum and its compounds; 6) Boiling point elevation and freezing point depression in solutions; 7) Enthalpy of reaction; 8) Chemical equilibrium. In the second stage, PCTs obtained information related to the small-scale chemistry approach through a practical demonstration session on the pH range. In the third stage, PCTs participated in SSC practicum activities with a guided inquiry approach which was carried out in two sessions.

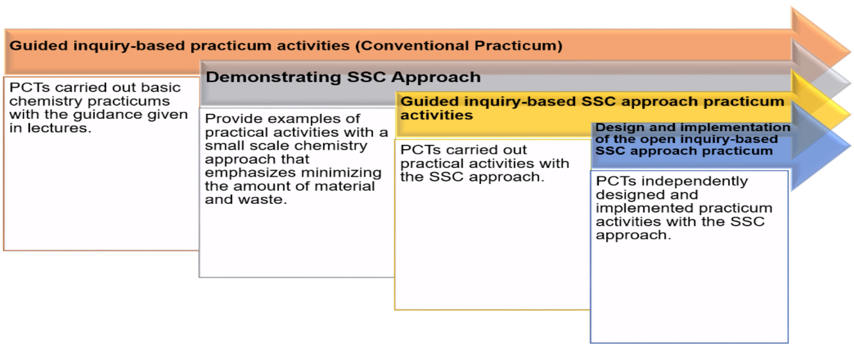



**Figure 1**. Learning stages in introducing inquiry-based Small-Scale Chemistry approac

In the last stage, PCTs are directed to arrange SSC chemistry practicum according to the topic of their choice of chemistry based on the national curriculum in Indonesia. The session for the final stage consisted of four activities which included the design stage, preparation of the right tools and chemicals in the initial trial, revision of the design, follow-up trials, and documentation of practicum activities through video recordings.

This research involved 15 PCTs (13 female and 2 male) who were in the first year of the Basic Chemistry practicum course at the University of Muhammadiyah Semarang, Indonesia. PCTs have minimal experience at their secondary school level. Data collection used documentation techniques for practical activities with an SSC approach, activity response interviews, and open response questionnaires on the process of (1) designing, (2) implementing, (3) analyzing data, (4) inferring results, (5) understanding chemical concepts, and (6) interest in further implementation in classroom learning. Instrument validity used face validity, while reliability was obtained by stability of observations (Cohen, Manion and Morrison, 2007). The results of the documentation and interviews were described as narrative, while the responses to the questionnaire were recapitulated and analyzed using QDA Miner Lite software to obtain a bar chart showing the variation in PCTs responses.

The PCTs' videotape was analyzed for the type of topic of choice. Videos were checked using the adequacy rubric which includes performance and procedures. The performance aspect shows how the chemistry practicum is implemented in aspects that show a small-scale chemistry approach. These aspects include aspects (Pf1) Minimizing material requirements; (Pf2) Reducing the scale of the tools used; (Pf3) Considering the amount of waste; (Pf4) Considering the modification of tools that can be obtained in daily life; (Pf5) Considering safe materials for laboratory activities. The procedural aspect shows the potential of chemistry lab work procedures with the SSC approach to be implemented through the inquiry learning stage. This aspect includes (Pc1) The accuracy of the purpose of the experiment; (Pc2) The accuracy of the work steps prepared; (Pc3) Ease of duplicating; (Pc4) Considering the existence of variables; and (Pc5) The accuracy of determining the type of data for practicum. The types of materials selected by PCTs in their practicum design are then identified in groups of materials obtained specifically in the laboratory and materials that are easily found in daily activities. Chemicals are also grouped based on their function as reactants or as reagents in chemistry lab work procedures. The types of tools and the trend of modifications to the tools used by PCTs were also analyzed and reviewed for potential improvements and the selection of their functions.

## RESULTS AND DISCUSSION

Critical studies related to the inquiry approach showed that inquiry emphasizes scientific processes in the place of appropriate science content (Friedl, 1991) and is wrong in that scientific inquiry is equated with unsupervised student discovery (Hegarty-Hazel, 1990). Lecturers, who teach pedagogical courses in teacher education programs, should consider that inquiry-based learning cannot be an effective method for developing critical thinking dispositions of pre-service teachers (Arsal, 2017). Other research showed the situation in the application of inquiry-based learning that has not been able to improve competence in evaluating and designing scientific investigations appropriately (Arief and Utari, 2015). Restricted guided teaching can be less effective and efficient than other student-centered learning. The guidance provided in the learning process can be in vain if students already have internal knowledge of what will be done (Kirschner, Sweller and Clark, 2006). The inquiry approach will be successful if students are ready and the activities are designed appropriately and according to the stages (Kirschner, Sweller and Clark, 2006; Julien and Lexis, 2015). Therefore, the introduction of the small-scale chemistry approach with inquiry-based practicum activities was not carried out suddenly but was carried out by practicing practicum learning at various levels of openness of inquiry.

Practical activities can be presented with various levels of the investigation process which can be divided into structured (structured/level 0), guided (guided/level 1 & 2), or open (open/level 3) (Hegarty-Hazel, 1990; Colburn, 2000). At the initial stage, the lecturer controls the course of practicum activities by providing a chemistry practicum guide that includes topics to be worked on by containing the objectives of the practicum, the theoretical basis used, how it works, the need for observational data, and guiding questions for discussion. This leads to recipe book-based or inquiry-based practicum activities at level 0. Such a process is carried out so that PCTs understand the stages in the investigation process and this is the initial stage to practice investigative activities for PCTs. In the next stage, a simulation of chemistry practicum activities with a small-scale approach is shown as a form of guidance in modifying the workings of the practicum at the next stage. This activity initiates a guided inquiry approach or inquiry at level 1. Next, students are guided to do practical activities with the target of modifying the method with the SSC approach. Lecturers provide practical activity objectives with an SSC approach, and PCTs can modify the procedures. This activity trains the inquiry method at level 2. In the final stage, PCTs are challenged independently to arrange practicum activities with inquiry questions, work procedures, and interpretation of observations. The procedure is designed as the SSC approach has been introduced. The practicum design is practiced and documented to be presented in the confirmation session by lecturers and PCTs. At this level (level 3), students control the three components which include problems or questions, obtaining answers (methods), as well as interpreting results (Colburn, 2000). Thus, PCTs are exposed to an ongoing decision-making procedure at every stage. The results of the implementation of the practicum design are then analyzed by grouping them into types of topics in class according to the school curriculum, performance conditions, and work procedures. The results are as shown in Table 1.

**Table 1.** Adequacy of performance and procedures for practicum activities designed by PCTs

| No | Types of Chemistry Practicum | Performance | | | | | Procedural | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pf1 | Pf2 | Pf3 | Pf4 | Pf5 | Pc1 | Pc2 | Pc3 | Pc4 | Pc5 |
| | | | | | | **10th Grade** | | | | | |
| 1 | Identification of sulfur dioxide gas | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2 | Reaction in stoichiometry | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 3 | Testing on electrolyte solutions | - | - | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 4 | Redox Reaction | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 5 | Corrosion | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | | | | | **11th Grade** | | | | | |
| 6 | pH indicator ranges (Acidimetric Titration) | ✓ | ✓ | ✓ | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ |
| 7 | pH indicator ranges (Alkalimetric Titration) | ✓ | ✓ | ✓ | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ |
| 8 | Oil-in-Water Emulsions | - | - | - | ✓ | ✓ | ✓ | ✓ | ✓ | - | ✓ |
| 9 | Effect of Surface Area on Reaction Rate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | ✓ | ✓ | - |
| 10 | Tyndal Effect on Colloids | - | - | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | | | | | **12th Grade** | | | | | |
| 11 | Decrease in freezing point of the solution | - | - | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | Osmosis Phenomenon | - | - | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 13 | Electrolysis in chemical solutions | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 14 | Testing the protein content of foodstuffs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | ✓ | ✓ | - |
| 15 | Some properties of Alkane and Aromatic compound | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

**Performance:**
Pf1 = Minimizing material requirements;
Pf2 = Reducing the scale of the tools used;
Pf3 = Considering the amount of waste;
Pf4 = Considering the modification of tools that can be obtained in daily life;
Pf5 = Considering safe materials for laboratory activities.
**Procedural:**
Pc1 = The accuracy of the purpose of the experiment;
Pc2 = The accuracy of the work steps prepared;
Pc3 = Ease of duplicating;
Pc4 = Considering the existence of variables;
Pc5 = The accuracy of determining the type of data for practicum.

The type of practicum chosen by PCTs already exists on topics that are following the Indonesian school chemistry curriculum. Some results still show that PCTs' performance conditions are not quite right in the design process and implementation of the SSC practicum, namely in terms of minimizing material requirements, reducing the size of the tools used, and considering the amount of wasted waste. The results of several practicum designs that can be improved with the SSC approach are (1) Testing on electrolyte solutions; (2) Oil-in-water emulsions; (3) Tyndal effect on colloids; (4) Decrease in freezing point of solution; and (5) Osmosis phenomenon. The tendency of PCTs that have not taken into account the size of materials, tools, and waste can be improved further with the same practical objectives. Some errors in considering the size of the tools and materials used in practical activities are shown in Figure 2. The consumption of materials for testing can be further reduced and the use of tools can be modified and replaced with smaller sizes.

In addition to the initial performance of the PCTs practicum design, some preliminary designs of the procedure also still indicate the need for improvement in the accuracy of the experimental objectives. For example, in determining the range of pH indicators leading to the use of indicators in acidimetric and alkalimetric titrations, early designs of PCTs showed a lack of accuracy. Moreover, other PCTs have not considered the need to provide variables in the investigation process as happened in the initial design of the “Oil-in-Water emulsions” practicum. Others, PCT pays less attention to neatness and accuracy at the practical work stage, as well as accuracy in determining the type of data in the “Effect of surface area on reaction rate” and “Testing the protein content of foodstuffs” practices. The initial design of the PCTs was then improved according to the directions in the presentation session on the implementation of the SSC approach practicum independently.

The design and implementation of the SSC practicum from other PCTs showed satisfactory results both in terms of performance and in the presentation of practical procedures. PCTs have paid attention to material sampling at an optimal scale with a small size, the use of a tool whose function is modified so that it can be used in small-scale practicums, as well as considering waste disposal. An example of the use of materials on a small scale is in the "Identification of sulfur dioxide gas" practicum which only requires one drop of $KMnO_4$ and $K_2Cr_2O_7$ solutions. Furthermore, this system is used to identify the formation of $SO_2$ gas in the reaction of adding $Na_2SO_4$ and $H_2SO_4$. The formation of $SO_2$ gas was evidenced by a change in the purple color from $KMnO_4$ to fading and a color change from $K_2Cr_2O_7$ which was initially orange to greenish (Jeffery et al., 1989; Worley et al., 2019). This is as shown in Figure 3.

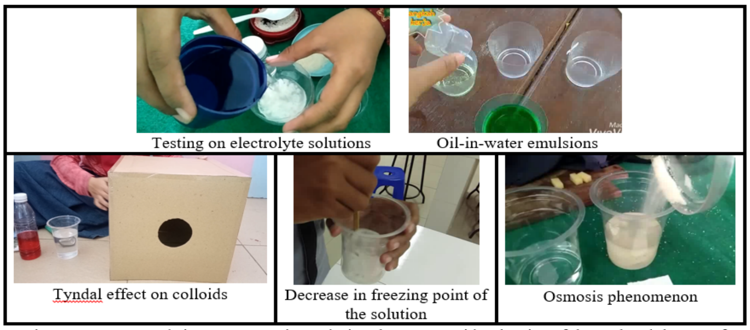
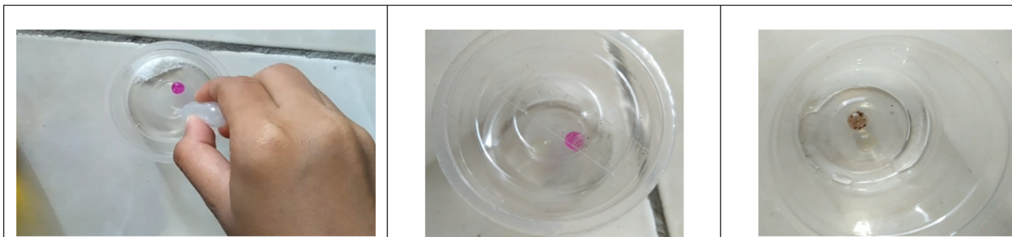



**Figure 2.** Some trends in PCTs’ practicum design that not consider the size of the tool and the use of materials.



(A) Placement of reactants on the system | (B) The reaction vessel is closed so that the $SO_2$ gas that is formed does not leave the system. | (C) The color changes that occur in the drops of $KMnO_4$ and $K_2Cr_2O_7$ solutions

$$2KMnO_4 + 5Na_2SO_3 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 5Na_2SO_4 + 3H_2O$$

$$K_2Cr_2O_7 + 3Na_2SO_3 + 4H_2SO_4 \rightarrow 3Na_2SO_4 + Cr_2(SO_4)_3 + K_2SO_4 + 4H_2O$$

**Figure 3.** One of the practical designs of PCTs showing the characteristics of chemical changes in the reaction system of $KMnO_4$, $K_2Cr_2O_7$, $Na_2SO_3$, and $H_2SO_4$

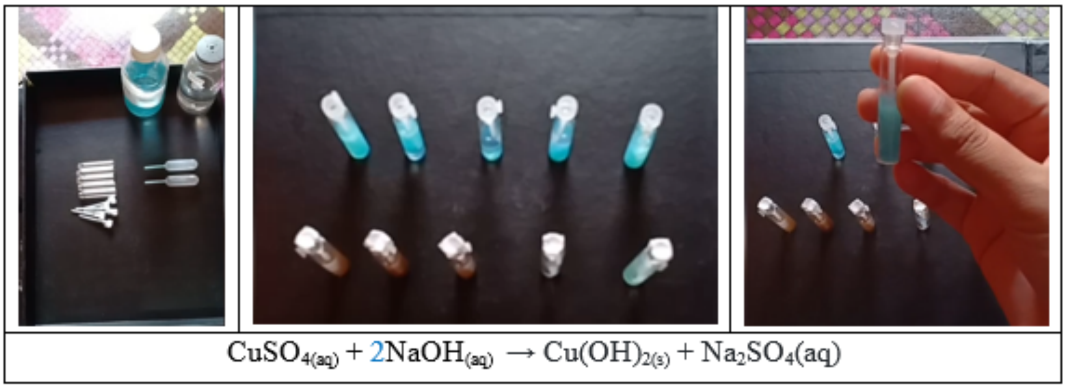



**Figure 4.** Experimental design related to Gay Lussac's Law of Comparison of Volumes using $CuSO_4$(aq) and NaOH(aq) reactants

PCTs have also been able to modify the tools that exist in everyday life for chemistry practicum activities with the SSC approach. An example is the use of a small size oil perfume bottle used for reactants in the "Reaction in stoichiometry" practicum on Gay Lussac's law. The container in the form of a small perfume bottle can show how different the reaction products are in terms of the height of the precipitate that is the product of the reaction. This shows the phenomenon of the reaction between CuSO4 and $H_2O$ which produces $Cu(OH)_2$ precipitate (Jeffery *et al.*, 1989). The shape and size of the perfume bottle make it possible to easily observe the difference in height of the resulting precipitate as shown in Figure 4.

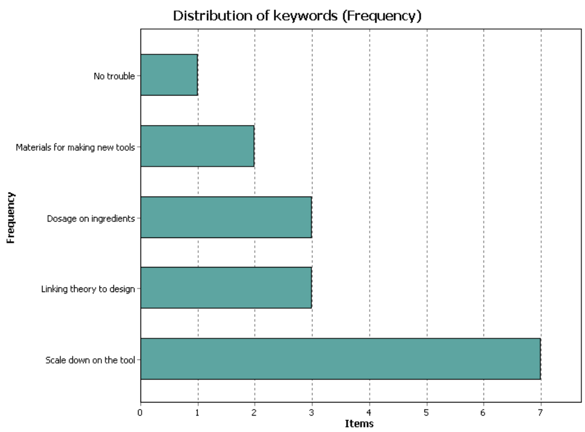
In Indonesia, it seems, the SSC approach in chemistry learning is still not widely applied by teachers and taught to high school students and college students (Listyarini *et al.*, 2019). In this activity, the practicum is carried out not only with the SSC approach, but also applies the principle of the inquiry approach. PCTs can ultimately determine their own practicum design. This inquiry-based laboratory activity can improve operational thinking skills (Lawson and Snitgen, 1982; Zulfiani and Herlanti, 2018). The inquiry approach, in this research, involves more PCTs' participation, and less guidance, and gives PCTs more responsibility for choosing how they work (Imaduddin and Hidayah, 2019; Leonard, 1989). This approach makes students, in this case, PCTs, become effective authoritarians for laboratory activities (Luckie et al., 2013; Roth, 1995; Roth and Bowen, 1994). PCTs are free to determine the type of equipment and material needed in their design. Some trends in the selection of materials for lab work by PCTs indicate that materials are not only obtained specifically for activities in the laboratory, but PCTs consider materials found in everyday life. The trend of selecting materials for experimental activities is shown in Table 2.

Inquiry-based teaching promotes deeper and more meaningful understanding (National Research Council, 2000). The process of practicing practicum activities with various levels of inquiry obtained PCTs' responses at several stages which included the process of design, implementation, analyzing the results, and inferring the results. The responses are shown in Figure 5. The condition of PCTs shows that there is a majority of difficulty in determining the smaller-scale tools that can be used in practicum at the design stage, difficulties in operating small tools at the implementation stage, the uncertainty of data accuracy at the analysis stage. However, at the stage of concluding the results, PCTs showed their confidence by giving statements regarding the ease of inferring the results of the experiments they had designed themselves.

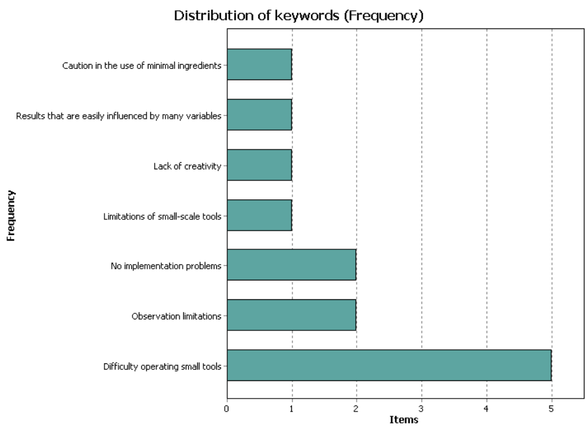
**Table 2.** Trends in the selection of materials

| No | Substances | Types of Chemistry Practicum |
|---|---|---|
| **A** | **Chemicals in the laboratory** | |
| | | **Reactant** |
| 1 | $Na_2SO_3$, $K_2Cr_2O_7$, $H_2SO_4$ | Identification of Sulfur Dioxide Gas |
| | $KMnO_4$ | [1] Identification of Sulfur Dioxide Gas<br>[2] Some properties of Alkane and Aromatic compound |
| 2 | N-Hexane, Benzene | Some properties of Alkane and Aromatic compound |
| 3 | $CuSO_4$ | [1] Reaction in Stoichiometry<br>[2] Redox Reaction |
| 4 | NaOH | [1] Reaction in Stoichiometry<br>[2] Corrosion<br>[3] pH indicator ranges and titration |
| 5 | $CH_3COOH$ | pH indicator ranges |
| 6 | HCl, $NH_4OH$ | Corrosion |
| 7 | $ZnSO_4$, a piece of Zn, a piece of Cu, a piece of Al | Redox Reaction |
| 8 | KI | Electrolysis in chemical solutions |
| | | **Reagent** |
| 1 | Biuret | Testing the protein content of foodstuffs |
| 2 | Phenolptalein | [1] pH indicator ranges and titration<br>[2] Electrolysis in chemical solutions |
| 3 | Methyl red | pH indicator ranges |
| 4 | Methyl orange | pH indicator ranges |
| 5 | Amilum | Electrolysis in chemical solutions |
| **B** | **Materials in the daily life** | |
| | | **Reactant** |
| 1 | Egg shell | Effect of Surface Area on Reaction Rate |
| 2 | Cooking oil | Oil-in-Water Emulsions |
| 3 | Liquid detergent | Oil-in-Water Emulsions |
| 4 | Dish soap | Oil-in-Water Emulsions |

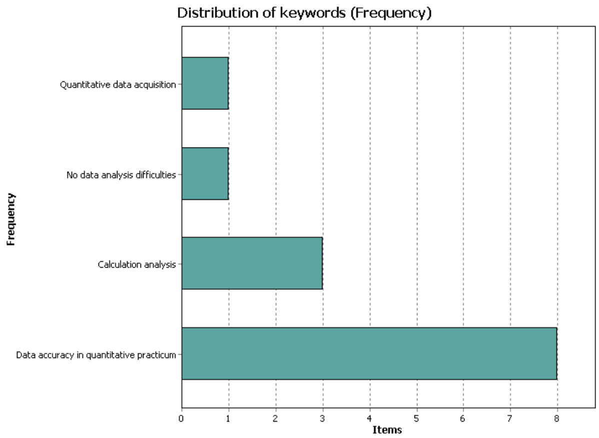
| | | |
|---|---|---|
| 5 | Water | [1] Oil-in-Water Emulsions<br>[2] Tyndal Effect on Colloids<br>[3] Osmosis Phenomenon |
| 6 | Milk | Tyndal Effect on Colloids |
| 7 | Coffee | Tyndal Effect on Colloids |
| 8 | Salt | Tyndal Effect on Colloids<br>Osmosis Phenomenon<br>Decrease in freezing point of solution |
| 9 | Ice | Decrease in freezing point of solution |
| 10 | Sugar | Osmosis Phenomenon |
| 11 | Potato | Osmosis Phenomenon |
| 12 | Food material | Testing the protein content of foodstuffs |
| | **Reagent** | |
| 13 | Betadine (Povidone-iodine) | Testing the protein content of foodstuffs |



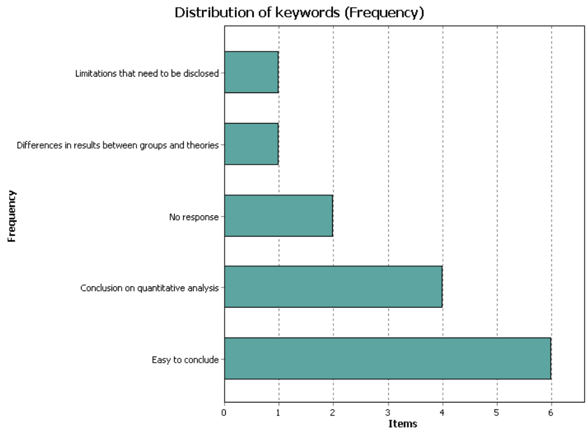

Responses about difficulties in the process of designing laboratory activities




Responses about difficulties in the process of laboratory activity implementation

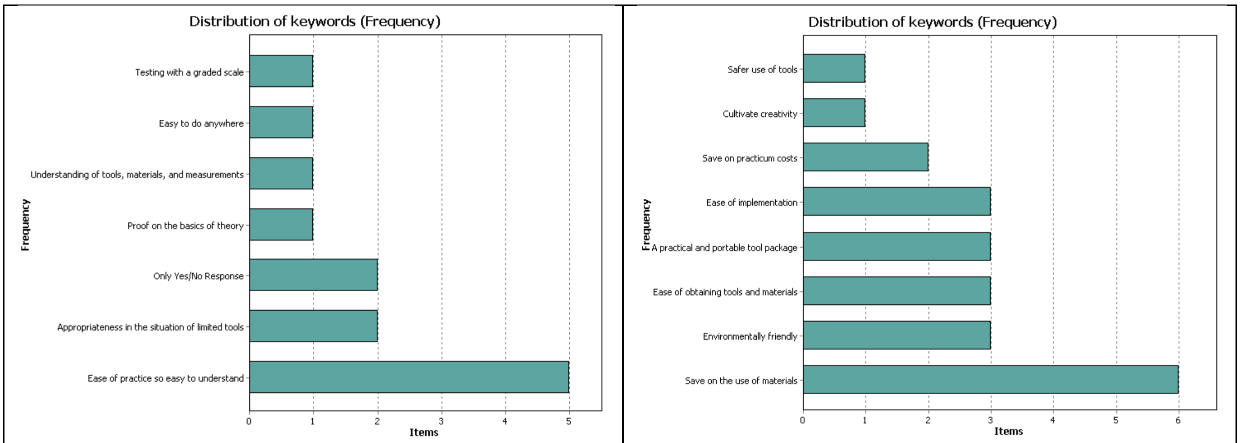



Responses about difficulties in the SSC practicum analysis




Responses about difficulties in concluding practical results

**Figure 5.** The responses of PCTs in the SSC practicum process with an inquiry approach




Responses about increasing understanding of concepts | Responses about interest in further implementation

**Figure 6.** PCTs' responses related to reflection of understanding and interest in further implementation using the SSC approach

Inquiry-based teaching promotes deeper and more meaningful understanding (National Research Council, 2000). The process of practicing practicum activities with various levels of inquiry obtained PCTs' responses at several stages which included the process of design, implementation, analyzing the results, and inferring the results. The responses are shown in Figure 5.

The condition of PCTs shows that there is a majority of difficulty in determining the smaller-scale tools that can be used in practicum at the design stage, difficulties in operating small tools at the implementation stage, the uncertainty of data accuracy at the analysis stage. However, at the stage of concluding the results, PCTs showed their confidence by giving statements regarding the ease of inferring the results of the experiments they had designed themselves.

The various advantages of implementing a practicum with the SSC approach include: saving costs and time, increasing safety, easy to use and environmentally friendly, instilling ethics of resource conservation, increasing students' understanding of scientific concepts, maintaining student interest in the subject, involving students directly, providing an individual learning experience, and providing easy and fun experiments (Bradley, 1999; Kelkar, Dhavale dan Pol, 2001; Vermaak dan Bradley, 2003; Tallmadge *et al.*, 2004; Abdullah, Mohamed dan Ismail, 2009; Poppe, Markic dan Eilks, 2010; Mattson dan Anderson, 2011; Mayo, Pike dan Forbes, David, 2011; Zakaria, Latip dan Tantayanon, 2012). The SSC approach can overcome various challenges faced by teachers when preparing practicum plans including conditions of lack of equipment and chemicals, lack of laboratory assistants, lack of laboratory space, lack of time, and lack of teacher confidence (Bradley *et al.*, 1998). Many researchs showed how the overall teacher and student reactions to the SSC approach are very positive. Teachers become aware of opportunities to use new approaches to conducting practicums with minimum resources to support student learning. Students who have experimental experience with the SSC approach can develop better scientific reasoning skills by engaging in small group discussions and reflections during micro-scale practical activities (Mafumiko, 2008). Other findings also show that the SSC approach can improve the understanding of chemical concepts, although there is no significant difference in attitudes and motivation (Abdullah, Mohamed dan Ismail, 2009). In this study, PCTs responded to the reflection on increasing their understanding of the concept and their interest in further implementation. The SSC approach can improve students' understanding of chemical concepts despite the challenges of operating small-scale equipment, collecting quantitative data, and maintaining classroom discipline (Tesfamariam, Lykknes dan Kvittingen, 2017). PCTs found it easy to practice laboratory activities with the SSC approach so that they felt it easier to understand the chemical concepts being studied (Figure 6.). PCTs also showed interest in further implementation by emphasizing the importance of using minimal materials so that it can save costs and the amount of waste to the environment.

The overall results of this research indicate that there is a great opportunity in the development of practicum using the SSC perspective by training it to PCTs through an inquiry approach that varies according to the learning conditions, as well as the potential of facilities and infrastructure for laboratory activities owned. The introduction of this SSC approach also has the potential to overcome problems in future educators' misunderstandings related to chemistry which can be separated between hands-on and minds-on activities. The trend of avoided chemistry practicum has the potential to be corrected in the future through the process of introducing the SSC approach to PCTs. In addition, experience in the inquiry approach has the potential to construct knowledge of chemical concepts, as well as implementation in future PCTs' classes.

## CONCLUSION

Chemical laboratory activities with a small-scale chemistry approach were introduced to PCTs with inquiry-based activities. The introduction has been carried out with the stages of conventional practicum learning based on structured inquiry (level 0) to lead to open inquiry (level 3). Eight conventional chemistry practicum topics (macro-scale) are carried out on a prescription basis. Small-scale chemistry practicum activities were introduced with demonstrations and continued with practical guidance. In the end, PCTs were required to be able to design small-scale chemistry practicum activities with chemistry topics according to the Indonesian school curriculum. 15 types of chemistry labs set with the SSC approach have been obtained. The initial design produced by PCTs indicates the need for improvement in implementation performance in four practicums which include (1) Testing on electrolyte solutions; (2) Oil-in-water emulsions; (3) Tyndal effect on colloids; (4) Decrease in freezing point of solution; and (5) Osmosis phenomenon. Performance improvement is carried out by improving the scale of the tools used, minimizing the amount of material needed, and considering the amount of waste disposal. In the procedural aspect, it was found that five practicums still needed improvement, namely (1) Acidimetric titration, (2) Alkalimetric titrations, (3) Oil-in-Water emulsions, (4) Effect of surface area on reaction rate, and (5) Testing the protein content of foodstuffs. However, all of them can be improved in terms of performance and procedures. Other results show that PCTs have also been able to choose the types of materials that are not only found specifically in the laboratory, but also materials that are easily found in their daily lives to be used in school chemistry practical topics.

PCTs showed difficulties in determining tools that can be used for small-scale chemistry labs at the design stage, difficulties in using small-sized tools at the practical implementation stage, and determining data accuracy at the analysis stage. Nevertheless, PCTs showed good inference ability on the results of implementing small-scale chemistry practicum designs with an inquiry approach. PCTs also reflected that their understanding of the concept is getting better with practicals that are easy to do and their interest in implementing it further. The implication of this research is the need for advanced designs for chemistry topic practicums, as well as measuring PCTs process skills in implementing SSC practicum activities with an inquiry approach. Thus, improvements to the quality of practicum can be carried out continuously by paying attention to the growth of process skills that will be obtained by PCTs.

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