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Strengthening Pedagogical Content Knowledge in Designing Laboratory Activity Based on Small-Scale Chemistry Practicum Approach

Fitria Fatichatul Hidayah*
Universitas Muhammadiyah Semarang, INDONESIA

Muhamad Imaduddin
Institut Agama Islam Negeri Kudus, INDONESIA

Eko Yuliyanto
Universitas Muhammadiyah Semarang, INDONESIA

Gunawan
Universitas Diponegoro, INDONESIA

Muhammad Cholid Djunaidi
Universitas Diponegoro, INDONESIA

Siti Qomariyah
Institut Agama Islam Negeri Kudus, INDONESIA

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Abstract: The purpose of this research is to strengthen pedagogical content knowledge (PCK) in designing laboratory activities based on small-scale chemistry approaches. This research is action research involving 60 trainee teachers with stages that include (a) Reflect; (b) Plan; (c) Act; (d) Observe; (e) Reflect (2nd); (f) Plan (2nd). Qualitative data were collected through (a) Questionnaires reflecting on experiences in practicing chemistry learning and responses to the importance of learning, (b) a Portfolio of chemistry practicum design, (c) documentation of the process of carrying out design, implementation, and practicum evaluation activities, (d) field notes, (e) reflection sheet, and (f) Portfolio of follow-up plans. The data is displayed through the R computation system with data pre-processing stages in the teacher's reflection text which includes basic cleaning, case folding, normalization, stemming, and deleting meaningless words. Display data in the form of word clouds, frequency expression diagrams, and tabulations. Descriptive narratives are used to analyze the documentation obtained in the action process. The teacher group demonstrated performance in implementing small-scale practicum activities. Teachers are increasingly skilled in modifying conventional laboratory equipment, minimizing the amount of chemical use, minimizing waste disposal, and increasing efficiency in the duration of practicum implementation. The follow-up plan for this activity includes quality improvement in aspects of (a) skill in using laboratory equipment, (b) understanding of chemical concepts, (c) equipment availability, materials, and work procedures, and (d) implementation of chemistry practicum.

Keywords: *Laboratory activity, pedagogical content knowledge, small-scale chemistry.*

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Introduction

Failures that occur to students are often associated with the performance of their teachers. The teacher is often used as one of the factors that cause the poor quality of student achievement, even though there are other factors such as schools, home situations, internal students, government policies, or other things related to the education system (Amusan, 2016). Teachers need to have the determination and enthusiasm to improve the quality of their learning so that they can improve the success of student learning experiences (Maryati et al., 2019). Qualified teachers need to master content knowledge related to the subjects taught, as well as pedagogic skills which include principles and strategies in classroom management (Ball et al., 2008; Shulman, 2015).

Shulman introduced the idea of pedagogical content knowledge (PCK) in 1987, and studies on this subject have developed rapidly (Abell, 2008; Maryati et al., 2019). PCK is an indicator of the competence of teachers and prospective teachers. The PCK concept serves as a guide for teachers in transforming content through examples, experiences, and experiences (Ball et al., 2008; Shulman, 2015) and is not limited to the teacher's knowledge of teaching certain topics, but also refers to things that are done by the teacher in the classroom and the reasons for doing so (Baxter & Lederman, 1999). This indicates that PCK should be explored at two levels, namely the planned PCK and the implemented PCK. The planned PCK is a combination of content and pedagogic knowledge about the necessary learning strategies so that learning topics can

* **Corresponding author:**
Fitria Fatichatul Hidayah, Universitas Muhammadiyah Semarang, Indonesia. ✉ fitriafatichatul@unimus.ac.id

be understood comprehensively by students. The implemented PCK is related to the type of PCK observed during teaching and learning practice (Maryati et al., 2019).

The 2012 PCK Summit agreed that the PCK model that can be tested as teacher professionalism is "the model of teacher professional knowledge and skills [TPK&S]". This model shows pedagogical content knowledge and skill (PCK&S) as a knowledge base in planning and communicating specific topics in very specific classroom contexts and as a skill when engaging in the act of teaching. TPK&S is derived from the generic teacher professional knowledge (GTPK) and refers to topic-specific professional knowledge (TSPK) (Gess-Newsome, 2015). TSPK shows that the condition of teaching material content is at the topic level, the knowledge that combines subject matter, pedagogy, and context; as well as the knowledge possessed by the teaching profession (Gess-Newsome, 2015; Mavhunga & Rollnick, 2013).

The specific topic of chemistry, in this case, chemistry, shows that practicum activities are an integral part of the curriculum at the school and college levels. Experience in laboratory activities can construct concepts (Lunetta et al., 2007), practice collaboration skills, and increase interest and positive attitudes toward chemistry (Hofstein & Lunetta, 2004). In the implementation of practicum activities, there are still many obstacles related to budgets, room conditions, availability of tools and materials, duration of activity implementation, laboratory management, and the quality of teaching staff is still low in carrying out practicum activities (Bell & Bradley, 2012; Bradley, 2001; Tsaparlis, 2016). Solutions to the constraints on implementing laboratory activities or hands-on activities in chemistry learning have been tried above in various ways such as demonstration learning, using virtual laboratories, and presenting shows through films, videos, and illustrations on whiteboards. However, these laboratory learning solutions cannot replace hands-on activity in the laboratory (Bradley, 1999).

The low quality of practicum learning is related to the teacher's pedagogic skills in representing chemical content in laboratory activities. Many teachers think that laboratory practicum is an activity with high costs and is complicated to prepare. Chemistry practicum does not have to be expensive, but can be carried out with practical strategies that are low-cost and sustainable (Bradley et al., 1998; Musar, 1993; Sane, 1999; Zakaria et al., 2012). One of the right strategies for implementing laboratory activities is a small-scale chemistry approach to organizing chemistry learning.

The Small-Scale Chemistry (SSC) approach minimizes laboratory work activities compared to macro-scale (conventional) laboratory activities. This approach reduces the use of laboratory chemicals (Mamlok-Naaman & Barnea, 2012) by reducing the size of the tool and modifying tools made of plastic (Tesfamariam et al., 2017). The SSC approach practices chemical activity by using materials on a smaller scale and simplifying tools without compromising quality and experimental standards in both education and industry (Singh et al., 1999). Implementation of this approach can save laboratory budgets, streamline practicum learning duration, increase worker safety, and be more environmentally friendly (Bradley et al., 1998; Mohamed et al., 2012; Skinner, 1998; Zakaria et al., 2012). This concept relates to a drastic reduction in the number of laboratory chemicals, the use of small-scale laboratory equipment, and modifying the practicum design so that it is safer and easier to work on. Teachers can implement new practicum activities with this approach while still paying attention to the accuracy of chemical experiments (Abdullah et al., 2009). The skills of chemistry teachers in planning and implementing chemistry practicums with the SSC approach are one of the manifestations of teacher professionalism which is the embodiment of the PCK model (Gess-Newsome, 2015). This professionalism demonstrates basic knowledge in planning and communicating chemical content through the context of chemistry practicum by applying the principles of minimizing tools and materials, work safety, laboratory learning efficiency, and organizing student practicum activities that are more environmentally friendly.

In the context of learning chemistry in Indonesia, the SSC approach is not widely known by high school students and prospective teacher students and is rarely applied by chemistry teachers (Listyarini et al., 2019). This strategy is not widely implemented by teachers because of the limited knowledge, information, and creativity of teachers (Hidayah et al., 2022). This strategy needs to be introduced to teachers through PCK strengthening programs in designing laboratory-based learning activities. This approach is an innovative and effective learning approach (Imaduddin et al., 2020). Research related to the teacher professional development program by the Indonesian government has not been able to increase teacher competence effectively (Rahman et al., 2015; Sumintono & Subekti, 2015). One of the contributing factors is due to a lack of mastery of the subject content (World Bank, 2014). Most teacher training programs tend to only focus on how teachers learn about teaching theory, learning, or certain specific materials (Aydeniz & Kirbulut, 2014). In addition, the failure of the training program can also be due to a large number of participants and the scope of the training curriculum content that is too broad so that the teacher's opportunity to understand the material is reduced (Nealsen, 2003). Research on teacher professional development programs attracts researchers from various parts of the world (Postholm, 2012; Widodo & Riandi, 2013). The purpose of this research is to strengthen PCK in designing laboratory activities based on small-scale chemistry approaches. Teacher PCK is basically dynamic, not static (Baxter & Lederman, 1999) meaning that teacher PCK can be developed at any time (Henze & Van Driel, 2015). This study introduces the SSC approach to improve the quality of laboratory learning through the stages of chemistry teacher training.

Methodology

Research Design

In science education, action research has been widely implemented both at the pre-service and in-service teacher levels for the main purpose of advancing how teachers teach and what students have learned in the classroom learning process. Action research is seen as a practical effort in this case teachers, to analyze their practice and improve it, and can be expanded further about understanding the educational situation and efforts to improve teachers in aspects of their practice (Capobianco & Feldman, 2010). This research is action research involving 60 trainee teachers consisting of 14 male teachers and 46 female teachers. Participants were then grouped randomly with each group consisting of five people during the process of the training program. The characteristics of the participants based on their teaching experience are shown in Table 1.

Tabel 1. The Characteristics of The Participants

Participant characteristics	**Educational Background**			**Duration of Teaching Experience**			**Levels in Teaching Practice**		
	Bachelor	**Master**	**Doctoral**	**0-5 years**	**5-10 years**	**>10 years**	**High School**	**Vocational High School**	**Internship**
Male	12	2	0	3	8	4	11	4	0
Female	39	6	1	23	12	10	29	3	13
	51	8	1	26	20	14	40	7	13

This action research links the reality of teacher practice and reinforcement of teacher teaching techniques with research (Cohen et al., 2007; Fraenkel et al., 2012) to solve laboratory learning problems in chemistry subjects. This research was carried out collaboratively with participating teachers in gathering their in-depth reflections on their teaching experiences. This action research is also known as "practitioner research" whose results can be used by components of other educational institutions such as educators, trainers, counselors, leaders, supervisors, and others (Ary et al., 2010). The action stages in this research use the stages shown in Table 2.

Table 2. Stages of Implementation of Action Research

Phase	**Activity objectives**	**Data explored**	**Instrument**
Reflect	Identify focus areas based on the problem	[1] Mapping chemical topics that are important to carry out laboratory activities or hands-on activities. [2] Mapping on the experience of practicing laboratory activities on a particular chemistry topic	A questionnaire containing reflections on experiences in practicing hands-on activity or laboratories in chemistry learning & Questionnaire on the importance of hands-on activity-based learning or practicum in chemistry learning.
Plan	Take action and/or collect information and data to observe or capture experiences or monitor practices.	The teacher's preference is in choosing the type of practicum that can be modified with a small-scale chemistry approach.	Group portfolio on chemistry practicum design.
Act	Implement plans or change practices and collect data.	The process of design activities, implementation of practicum activity designs, and evaluation of practicum designs	Documentation of the process of implementing design, implementation, and practicum evaluation activities, group practicum design portfolios, field notes on design, and practice evaluation discussions.
Observe	Synthesize and analyze implementation experience	The teacher's response about the stages of planning and implementation	Reflection sheet on the design and implementation of a small-scale chemistry practicum
Reflect	Researchers reflect and interpret information. Action will be taken and new focus areas identified.	Identification of difficulties in the implementation of the design.	Reflection sheet
Plan	A new action plan is developed to solve the problem.	Types of follow-up in professional practice as a teacher or prospective teacher	Portfolio of follow-up plans in teaching practice.

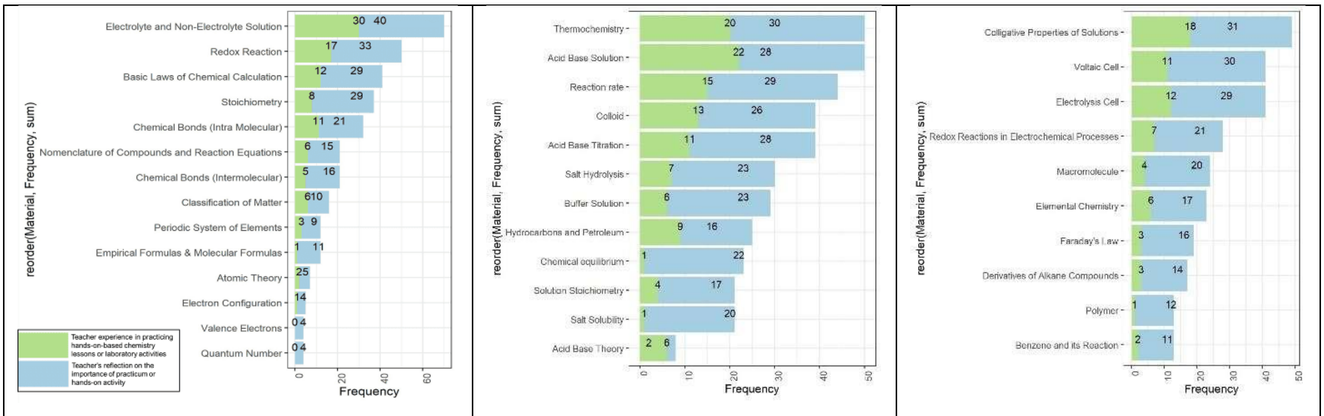
Qualitative data analysis is displayed through the R computation system with data pre-processing stages in the teacher's reflection text which includes basic cleaning, case folding, normalization, stemming, and deleting meaningless words (Qomariyah et al., 2019). The display of the initial reflection stage is in the form of experience teaching laboratory activities and their level of importance. Display data resulting from the qualitative reflection in the form of word clouds and expression frequency diagrams. This display is used in the second observation and reflection stages. Display of data at the planning stage through tabulations of groups of teacher practicum preferences and responses to follow-up practicum implementation with the SSC approach. A descriptive narrative is used to analyze the documentation at the action stage.

In this action research, the data collectors may be biased because they are very aware of the purpose of this research. Researchers are careful in each process by not ignoring the results, phenomena, or whatever they want to obtain. Researchers are careful in collecting data so as not to distort research results. In addition, this research is also weak in external validity, so it cannot be used for generalization (Fraenkel et al., 2012). This research describes the types of attitudes that occur in groups of teachers through training in the creation and implementation of the SSC practicum approach. Certain changes need to be replicated if the results are to be generalized to other individuals, settings, and situations (Atweh et al., 1998). The researcher's strategy for determining the validity and reliability of the data in this research used triangulation by collecting data from participant activity documentation, portfolios, and participant response questionnaires about training. Thus, the synchronization of the data obtained leads to credible results (Cohen et al., 2007) indicating the PCK conditions of the participants that were observed to develop during the process in the program.

Findings / Results

Phase I (Reflect): The Experience in Implementation of Practical or Hands-on Activity-Based Teaching and Level of Importance of Practicum

The teacher reflects on laboratory teaching practices that he has experienced and practiced professionally. Figure 1 shows that of the 60 teachers participating in the training, no more than half have experience in teaching practicum or hands-on activities on certain chemistry topics. The teachers also showed differences in understanding of the importance of practicum or hands-on activity on each chemistry topic. Based on the distribution of chemistry topics in the Indonesian curriculum, the chemistry topics most often practiced in classroom learning include the topic of electrolyte and non-electrolyte solutions at level X, the topic of acid and base solutions at level XI, and the colligative properties of solutions at level XII.



Grade X	Grade XI	Grade XII

Figure 1. The Teacher's Reflection (N=60) on the Experience of Practicing Teaching in the Classroom, as well as the Importance of Practical or Hands-On Activities on Chemistry Topics

Phase II (Plan): Preferences on SSC-Based Practicum Design

In this phase, the teacher group is introduced to an approach that can be used to address the problems of chemical laboratory activities, namely the SSC approach. The teacher group designs practicum activities according to their interests and preferences. From the teacher's design, it can be seen how the teacher's preferences in choosing practicum activities for their students. From this activity, seven topics were designed by 12 groups of teachers. Teachers reflect on the types of practice they do in classroom practice. With an understanding of the SSC approach obtained in this training activity, the teacher tries to redesign the existing practicum by paying attention to aspects of the tools, material sizes, and practicum stages. Details of the teacher's design are shown in Table 3.

Table 3. Preferences on Practicum Design by Participants

No	Chemistry topic	The Purposes of Laboratory Activity	Evaluation of procedure design
1	Thermochemistry	[1] Determine the enthalpy change for a reaction [2] Use a simple calorimeter to determine the enthalpy change	[1] Measurements on materials have not paid attention to the small-scale chemistry approach. The dose of one tablespoon should be reduced again. [2] The setting of the objectives of laboratory activities and work procedures is not accurate. [3] The size of the designed volume needs to be checked again for its applicability with the size of the tool used (digital thermometer)
2	Acid and Base Solutions (Qualitative and Quantitative Testing)	[1] Identify the buffer solution based on the pH range of color change. [2] Determination of vitamin C levels in chili by iodometry	[1] The teacher group has tried to reduce volume and mass, but has not designed a work procedure that is concise in time, [2] The need for accuracy in sample preparation, as well as considering the suitability of the tool.
3	Reaction rate	Identify factors affecting reaction rate (temperature, surface area, and stirring)	[1] The teacher group has paid attention to the use of materials that are more environmentally friendly, for example replacing magnesium tape with egg shells, and HCl with vinegar and has tried to reduce the volume to a drop scale. [2] Utilization of existing materials can still be minimized. The use of cups and also one vitamin C tablet per cup provided needs to be reviewed.
4	Carbon Compound	Identify carbohydrates and reduce sugars	The teacher group has noticed a reduction in the volume scale from ml to drops. The tool is appropriate for qualitative testing.
5	Equilibrium in reaction	Determine the effect of the concentration factor on the reaction equilibrium	The teacher group has been able to determine the volume on a small scale, but it is not yet appropriate to determine the apparatus or container for observing the reaction.
6	Electrochemistry	Coating metals that are easily oxidized with those that are difficult to oxidize.	[1] Incompatibility of work procedures with the expected goals in the practicum activity design. [2] The measurement of the material can still be reduced in volume size.
7	Polar characteristics of a compound	Analyzing the polarity of gasoline, water, and alcohol	The teacher group has not considered the amount of waste and the volume of consumables in laboratory activities.

Table 3 shows that in the early stages of practicum design, the teacher group had not paid full attention to the components of the type and modification of the use of tools, the use of materials that had minimal risk of danger and were environmentally friendly, the stages of efficient work in practicum, and efforts to minimize waste disposal in practicum work.

Phase III (Act): Design and Implementation of Laboratory Activities

Participants design practicum activities with available tools and materials. Work procedures at this stage are set with time targets in the preparation of practicum designs. A group representative was asked to observe and identify the availability of tools and materials in the tool and material basket. Group representatives may only remember without recording the availability of tools and materials. The duration of the observation and activity considering the availability of tools and materials is 15 minutes. After that, group representatives returned to their groups to discuss and design three types of practicum that might be done with the availability of tools and materials. The duration of this design activity is limited to 15 minutes. The thing to remember at this stage is that each group must ensure that all the tools and materials taken to the group table will be used for practicum activities. The next stage is to carry out the practicum according to the group design with a limited implementation time and reporting of the results of the practice for 30 minutes. The final stage that is carried out is the activity of presenting the results in each group, as well as evaluating the design of practicum activities from each group. The core stages of this phase are shown in Figure 3.

		
The Stage of Identifying Availability of Tools and Materials	Discussion about the Design of Chemistry Practicum Activities with a SSC Approach	Implementation Stage of the Practicum Design

Figure 3. Stages of Designing and Testing Laboratory Activities Based on Small-Scale Chemistry

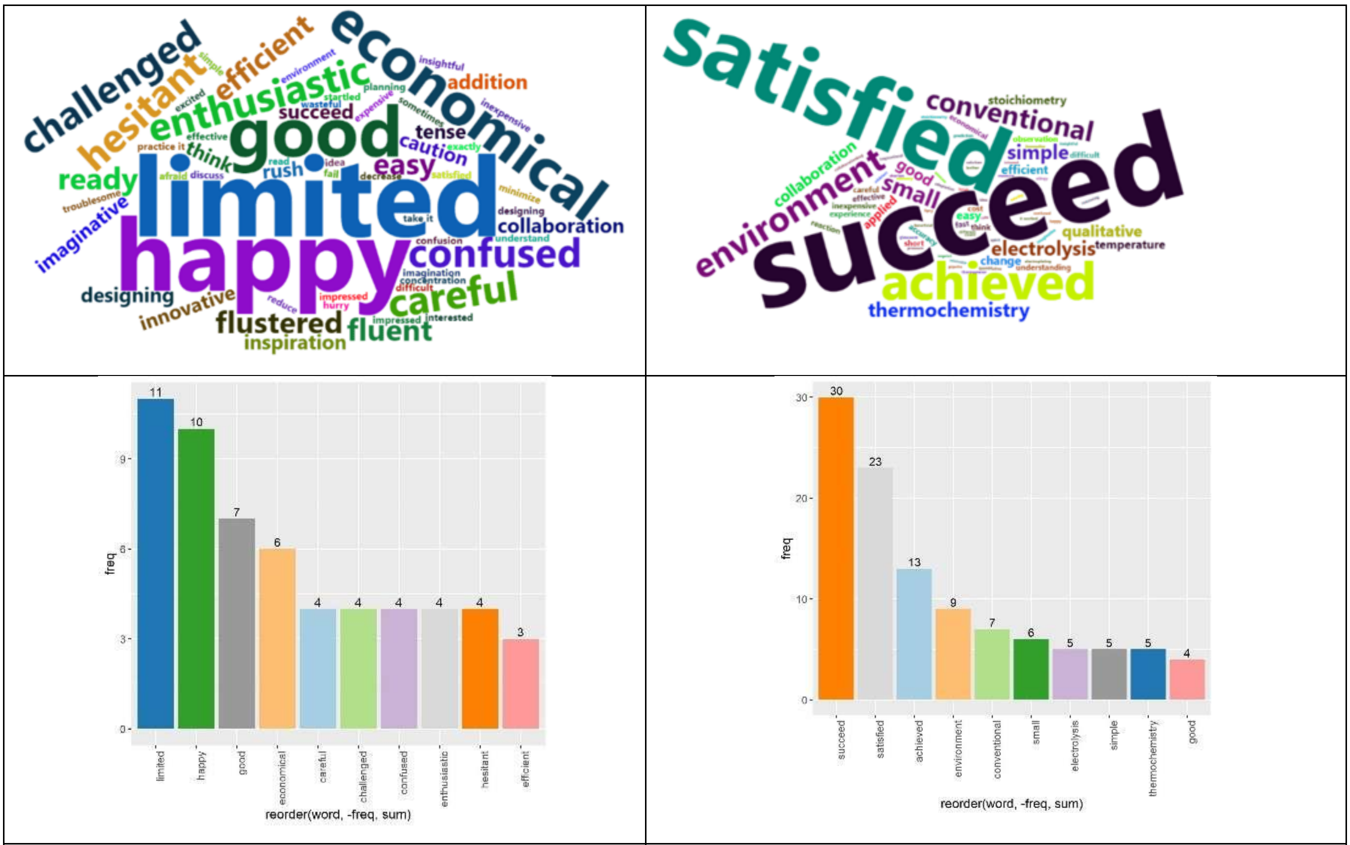
Phase IV (Observe): Analysis of Expressions and Findings During the Process of Planning and Implementation

This stage analyzes the experiences of participants in implementing the SSC approach in practical activities. Based on the availability of tools and materials, three alternative types of practicum can be done covering the topics of electrochemistry, thermochemistry, and stoichiometry. This is shown in Figure 4. The topic of electrochemistry is related to the separation of Cu from $CuSO_4$ solution. In this practicum, conventional volume modification of $CuSO_4$ was demonstrated, which is usually a few ml, in SSC-based activity using only 2-3 drops of solution. This is also shown in the measurement of temperature in measuring the heat absorbed in the dilution and neutralization reactions. The use of a 2 ml perfume bottle and the use of only about 5-10 drops of the solution is applied in a practical design by measuring with a digital mini-thermometer. The use of this 2 ml perfume sample bottle container is also used in stoichiometry practicum, observations on differences in precipitate height are used to identify the coefficients of the reaction.

		
Separation of Cu from $CuSO_4$	Thermochemistry: Dissolution and Neutralization	Stochiometry: Coefficients in Reaction Equations

Figure 4. Alternative Proper Design Results With Availability of Tools and Materials

Based on the experience of designing and simulating group practicum activities, teacher expressions were collected through an open questionnaire that asked about feelings and experiences during the process of SSC practicum training. The results of the analysis of the participants' expressions are shown in word cloud analysis as shown in Figure 5.



Expression and Experience at the Planning Stage	Expression and Experience at the Implementation Stage

Figure 5. Word Cloud Analysis on the Reflections of Chemistry Educators

Phase V (Reflect): Evaluation of the Practicum Design Based on the SSC Approach

At this stage, the practicum design in the previous phase is evaluated to see the potential for improvement or the potential for its implementation in classroom learning. Details of the reflection results on the practicum design prepared by the group are shown in Table 4.

Table 4. Identification of Group Design Results

Topics	Sub-topics	Potential Improvement and Implementation
Thermochemistry	Calorimeter	It is necessary to pay attention again to the suitability of the size of the material used which shows the utilization of NaOH and HCl on a drip scale
	Identify exothermic and endothermic reactions	The size of the reactants needs to be set so that temperature measurements can be carried out with the digital mini-thermometer used
Electrochemistry	Separation of Cu from $CuSO_4$ solution	The design has been implemented. Modifications to variables such as time and solution concentration can be made for further implementation.
Stoichiometry	Formation of $Cu(OH)_2$ precipitate	The use of containers or places for observing the formation of precipitates can be modified further not using test tube containers or petri dish mats, but using mica-coated paper.
	Determine which species is the limiting reagent	Practicum can be carried out by adding a tool in the form of a ruler to measure the height of the precipitate formed
	Law of conservation of mass	Practicum can be carried out by reducing the size of the reaction compartment, considering the existence of a closed system, and minimizing practicum waste.

The results of the evaluation of the practicum design of the participants indicated that the participants were able to design practicum activities using a small-scale chemistry approach and the resulting designs could be implemented in classroom learning, even though some aspects still have the potential to be improved. The shift in the form of tools in conventional laboratories needs to be shifted to understanding the function of tools in the practicum process. In addition, an understanding of the various alternative chemicals that can be used in practical activities also needs to be enriched through training activities or direct teaching practice. The difficulties in designing and implementing the SSC practicum are shown through word cloud analysis in Figure 6.

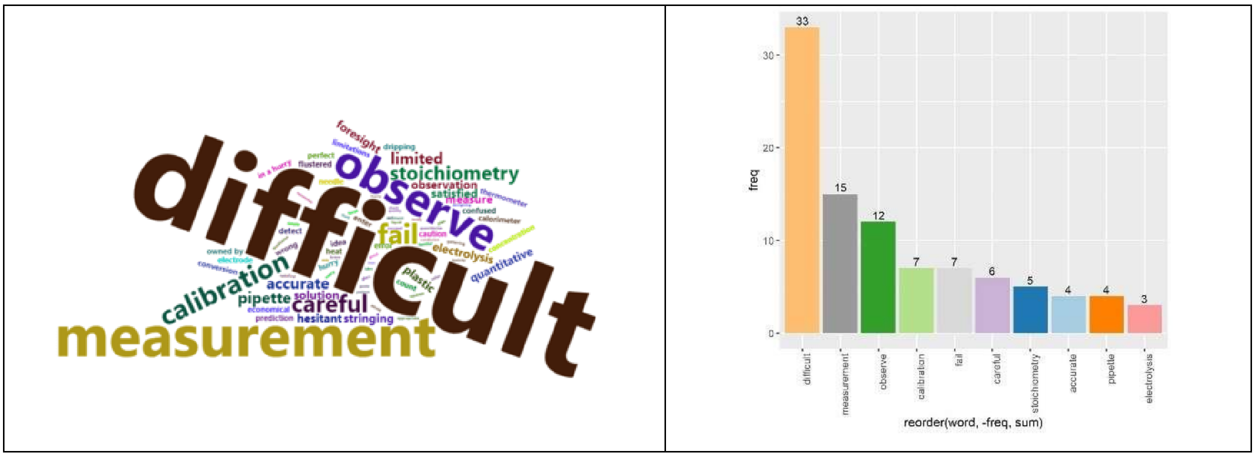


Figure 6. The Frequencies of Words Related to Constraints at the Design and Implementation Stages of Practice With a Small-Scale Chemistry Approach

Tahap VI (Plan): Planning for Program Follow-Up

This stage is a new action plan developed to solve the problem. After the reflection stage on the teacher's PCK, concrete follow-up is needed to implement the SSC approach in their classroom practice. Therefore, it is necessary to formulate a plan through a focus group discussion. The results of this activity formulate follow-up planning aspects which include (1) Skills in using tools, (2) Understanding of chemical concepts, (3) Availability of tools, materials, and work procedures, and (4) Implementation of chemistry practicum. Details of the form of planning or follow-up of the participants are shown in Table 5.

Table 5. Follow-Up Plan Formulated Through Focus Group Discussion

Aspects	**Follow-up Activity**	**Involved Parties**
Skills in the Use of Tools	Practice utilizing tools that have the potential to be used for practicum activities with the SSC approach Conducting practicum trials with the SSC approach compared to conventional practicum Train observation, measurement, and calibration in the practicum process with the SSC approach	Chemistry Teacher & Laboratory Assistant (optional)
Understanding of Chemical Concepts in Laboratory Activities	Exploring scientific references and practical references for implementing practicums with the SSC approach Collaboration with colleagues in modifying practicum with the SSC approach Deepening of chemical concepts for practicum learning through the MGMP working group	Chemistry Teacher and Regional Chemistry Teacher Group
Availability of Tools, Materials, and Work Procedures	Coordination with policymakers at the school level in procuring tools and materials according to the needs of the SSC approach practicum Modifying tools from objects that can be found around them that have the potential to be used in practicums Modify existing practicum work procedures by paying attention to the type and size of tools and materials, as well as minimizing waste.	Principal, Chemistry Teacher, and Laboratory Assistant
Practicum Implementation	Identification of conventional practicum that can be modified with the SSC approach under the national curriculum Inventory of measurement conversion potential and quantitative practicum procedures Trial the duration of practicum implementation with the SSC approach and conventional practicum Test students' understanding of concepts through practicum activities with the SSC approach	Chemistry Teacher, Laboratory Assistant (optional), and Students

Table 5 shows how further research stages still need to be carried out to see how the implementation conditions are at the class level of each participant.

Discussion

Phase I (Reflect): The Experience in Implementation of Practical or Hands-On Activity-Based Teaching and Level of Importance of Practicum

While teachers' PCK can be developed through teaching experience, it can also be developed through intensive training in collaboration with content and pedagogy experts (Loughran et al., 2004; Williams & Lockley, 2012). In this training, the program begins with the stages of reflecting on the teacher's experience on chemical topics, as well as identifying the importance of practical learning on topics that have been taught by the teachers.

Practicum activities are related to the identification of certain types of solutions whether they are classified as electrolytes or non-electrolytes through observing whether there are gas bubbles in the solution and the lights on the simple electrolyte test equipment (Pandia et al., 2021; Purnamasari et al., 2018; Supriatni, 2022). Practicum related to acid-base solutions includes identification of acid-base solutions using litmus paper indicators, natural indicators, and universal indicators (Bria et al., 2021; Karo, 2017; Riyanti, 2021; Sari & Nilmarito, 2019). As for the practicum on colligative properties of solutions, teachers tend to carry out practicum activities related to applied chemistry, namely the process of making ice cream with the technique of adding salt to ice cubes used as a coolant to show a decrease in the freezing point with additional ingredients or electrolytes (Hubbi et al., 2017). In addition, the process of making salted eggs using salt is used as a practical activity that shows the concept of solution osmosis (Rukmiasih et al., 2015).

The results of the reflection show that the condition of pedagogic knowledge is related to how knowledge about teaching is related to classroom learning practices. Pedagogical knowledge refers to general knowledge about teaching, as well as theories about learning that teachers acquire during teacher training or after teaching for a certain period. This is shown in the classroom teaching or learning model that is implemented in the classroom. In addition, reflection also shows how the condition of the participant's knowledge of the content. Content knowledge is knowledge of the subject matter from an academic perspective that relates to knowledge that should be taught in the classroom. Content knowledge refers to the breadth and depth of knowledge, regardless of whether it will be taught in class or not (Alimuddin et al., 2020). The content knowledge that is explored is related to the level of importance of the content to be taught in the form of a practicum or not. This is already a combination of content knowledge and pedagogic knowledge, which refers to PCK (Maryati et al., 2019). PCK leads to the necessary learning strategies so that certain learning topics can be understood comprehensively by students. Most teachers do not have a variety of experiences in implementing laboratory activity-based learning (Hidayah et al., 2022).

The lack of experience is due to many factors including one of the targets for completing teaching content in the semester, so teachers choose not to carry out practicums that are considered to require complicated preparation and require a long duration. The epistemological view of chemistry teachers on the implementation of practicum activities in the laboratory needs to be taken seriously. A proper understanding of the nature of science, scientific processes, and relationships between various fields in science is one of the representations of the teacher's PCK (Lee et al., 2007). Formal training in pre-service and in-service programs needs to be carried out by taking into account the results of reflection. The teacher's view of the nature of science (chemistry) will influence the institution in making policies related to laboratories, including the provision of tools and materials (Hidayah et al., 2021).

Phase II (Plan): Preferences on SSC-Based Practicum Design

Laboratory work experience is one of the things that influence the teacher's skills in designing lab work according to the characteristics of chemical content, as well as the adequacy of tools and materials. At this stage, the teacher is also introduced to several modifications of practicum tools that can be used in conducting laboratory learning. Some examples of tools that are modified from objects in everyday life are shown in Figure 2. It shows several containers that can be used as storage areas, as well as places for chemical reactions to take place on a small scale.

		
Storage box for medicine or other small jewelry. Weight [50 gr]; Grid size [2.5 x 3 x 2 cm]; Product size [12.5 x 6.5 x 2 cm]	Capsule blister packs used for capsule contents. - 24 holes per sheet dimensions 13.9cm x 9.8cm - 12 holes per sheet dimensions 9.9cm x 7cm - 10 holes per sheet dimension 9cm x 7cm	Glass Material Mini Perfume Sample Bottle 1 ml/2 ml/3ml

Figure 2. Several Tools Modified for SSC-Based Laboratory Learning Activities

Several research activities focus on developing procedures that use SSC-based tools. The tools are modified to replace conventional laboratory equipment so that practicum can be carried out more easily, more safely, and work procedures that are acceptable to teachers and students (R. Worley, 2018). Other studies also manipulate practical work so that students can visualize dissolution processes, ion movements, and precipitation on a small scale. The characteristic of this laboratory work is to minimize the use of chemicals so that not too much waste is produced (B. Worley et al., 2019). In this research, teachers were trained in their creativity to modify conventional practicum work procedures so that they could be practiced with the SSC approach.

Phase III (Act): Design and Implementation of Laboratory Activities

The act phase aims to provide participants with the provision to be able to carry out practicum activities efficiently and on a small-scale basis. Modification of practicum implementation with portable tools and materials and with a short duration is simulated without prescription-based work procedures. Thus, the actual implementation in the teacher's class can be changed according to the characteristics of students, is it more appropriate to provide work procedures or can they be free to be creative with procedures? The results of observations of group activities show that through a short time target, all group members play an active role in the discussion and division of practicum work.

The experience of laboratory activities encourages collaboration on complex tasks, an appropriate division of tasks, taking roles under certain conditions, and providing responses to work, ideas, and opinions (National Research Council, 2006). The experience of laboratory learning activities can improve the quality of students' conceptual understanding (Bradley, 1999; Lunetta et al., 2007) and has the potential to instill positive attitudes and interests toward the subject and to develop students' communication and collaboration skills (Hofstein & Lunetta, 2004).

Phase IV (Observe): Analysis of Expressions and Findings During the Process of Planning and Implementation

The results of the analysis at the practicum design stage show "limited" feelings and experiences. This expression relates to the limited knowledge of the types of tools that can be modified, the limited adequacy of materials that can be replaced and reacted, the limited ideas related to practicum, and the limited time to determine the type of practicum chosen by the group. Limitations in the variety of tools and materials related to practical experience and also an exploration of ideas are one of the findings in the implementation of the SSC approach (Imaduddin et al., 2020). Even so, the expression "happy" was also shown as an expression that a lot emerged from the participants' self-reflection. Other positive expressions also emerged as the expressions that emerged the most from the participants' reflections in the planning process which included "good", "economical", "challenged", "enthusiastic", and "efficient". This emerging expression is as useful as the SSC approach shown by previous research. The SSC approach shows efficiency in the use of budget and time, increases safety at work, involves students directly, and presents easy experiments and fun (Mayo et al., 2011; Poppe et al., 2010; B. Worley et al., 2019; Zakaria et al., 2012). The negative expressions that appear are related to caution, confusion, and doubt. This arose because this was the participants' first experience in modifying practicum by emphasizing small-scale aspects and reducing practicum waste.

Phase V (Reflect): Evaluation of the Practicum Design Based on the SSC Approach

The phrase "difficult" appears in the reflection of obstacles in the design and implementation stages. This difficulty arises in aspects that are also revealed in the reflection sheet, namely "measurement", "observation", and "calibration". Barriers to measurement include measurement of mass, temperature, and height. The obstacles to observation are related to the small size that must be observed down to the drop scale. While calibration relates to how the process for calibrating a pipette is to obtain the appropriate drop size. This is also in line with previous research which shows the obstacles to implementing the SSC approach are how to operate small tools, difficulties in cleaning tools, and the level of accuracy in measuring volume and mass (Abdullah et al., 2009; Imaduddin et al., 2020; Mohamed et al., 2013)

In the aspect of negative expression, the expression "failed" appears which indicates the participants' dissatisfaction with the results of the design and implementation. This is because not all designs are prepared as expected and easy to implement. Participants also revealed that the designed practice requires "care" and also "accuracy". The effectiveness of the barriers related to chemical content was revealed in the topic "stoichiometry" and continued with the topic "electrochemistry" in 10 phrases that often appear. Thus, thermochemistry became the easiest topic for the participants compared to stoichiometry and electrochemistry. The SSC approach can foster an understanding of chemical concepts, although challenges arise in operating small-scale tools, collecting quantitative data, and managing classroom discipline (Tesfamariam et al., 2017). Various challenges that arise can train laboratory work skills with more care and patience (Abdullah et al., 2007). Based on the results at this reflection stage, participants were asked to try to formulate a follow-up plan in implementing the SSC approach to their real class learning.

Tahap VI (Plan): Planning for Follow-Up Program

The participants' pedagogic content knowledge is followed up through follow-up activities in their respective school units. Further research is needed to explore the profile of the implementation of the SSC practicum in the teacher's institution, as well as see how students respond both to their process skills, mastery of concepts, and affective conditions related to awareness of the importance of laboratory activities or environmental awareness related to waste disposal.

Conclusion

Strengthening PCK in designing laboratory activities based on the SSC approach using action research stages which include (a) Reflect; (b) Plans; (c) Acts; (d) Observe; (e) Reflect (2nd); (f) Plan (2nd). Although the teachers' initial reflections indicated that no more than half of the teacher participants had experience in a teaching practicum in classroom learning, the group of teachers in this training was able to demonstrate performance in implementing small-scale practicum activities. The observation results show how the condition of the teacher group feels successful and has achieved the goals of their practicum design. The results of the final reflection show that practicum pedagogic skills and practicum content knowledge are better than the initial conditions. This is shown by the teacher's skills in modifying the use of conventional laboratory equipment, minimizing the size of the chemicals used, minimizing waste disposal, and efficiency in the duration of the practicum implementation. The participants have also been able to formulate a follow-up plan for this training activity which includes aspects of (a) skills in using tools, (b) understanding of chemical concepts, (c) availability of tools, materials, and work procedures, (d) implementation of chemistry practicum. The formulated follow-up shows the potential for implementing the SSC approach that has been trained to be practiced in the classroom by teachers.

Recommendations

The focus of this research is on a series of processes that must be experienced by teachers so that their PCK becomes stronger. This research is limited to disclosing qualitative results from a series of processes undertaken by teachers in this PCK strengthening program. Research designs specifically related to the percentage of waste reduction, the efficiency of the duration of practicum implementation, as well as aspects of the percentage reduction in practicum costs when compared to conventional practicum were not carried out in this study. Further research to reveal how the specifications for each variable can be carried out in other sessions. Teacher group discussion activities are needed in discussing the potential for the creation and implementation of practicums with the SSC approach in order to obtain a variety of environmentally friendly chemistry practicum learning activities.

Limitations

This research is limited to action research which discusses the PCK conditions of the participants in designing laboratory activities with the SSC approach. The results obtained indicate that there is a strengthening of pedagogic content knowledge in designing practicum activities that pay attention to modifications to the size of tools with a smaller scale, modifications to the size and type of materials used, minimization of waste disposal, and time efficiency in carrying out practicums.

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Authorship Contribution Statement

Hidayah: Writing, conceptualization, and securing funding. Imaduddin: Writing and analysis. Yuliyanto: Design and technical or material support. Gunawan: Editing and reviewing. Djunaidi: Editing and reviewing. Qomariyah: Statistical analysis.

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