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The effectiveness of green chemistry practicum training based on experimental inquiry to improve teachers' science process skills

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Abstract- This study was designed to investigate the effects of green chemistry practicum training based on inquiry experiments on chemistry teaching to improve teachers' science process skills. Nine green chemistry experiments were selected, while 18 chemistry teachers aged 26-42 and six chemistry students voluntarily participated in the research. The training was held for three days, consisting of two sessions. The first session was about green chemistry theory and inquiry-based learning theory. The second session was about practicum with a green chemistry-based inquiry experiment model. The steps for green chemistry inquiry experiment activities were oriented, conceptualization, investigation, conclusion, and discussion. The training's success was shown by the increase in the teachers' science process skills, namely the skills to formulate hypotheses, identify variables, experiment, interpret data, and communicate, as measured by employing Science Process Skills Test (SPST). The teachers' pre-and post-SPST scores in green chemistry inquiry experiment training had significant differences, suggesting that the green chemistry inquiry experiment had specific promoter actions for teachers' science process skills. The findings indicated that the green chemistry inquiry experiment's implementation improved the teachers' science process skills significantly.

Keywords: Science process skills; green chemistry inquiry experiment; training; teachers

I. INTRODUCTION

Quality teachers have become a global demand, as stated in the document of the United Nations Sustainable Development Goals 2015-2030, which reminds that by 2030, all governments in the countries of the world must be able to ensure that students are educated by qualified, trained, professional, and good motivator teachers. It is the teacher factor's importance; therefore, the quality education system and practices in almost all nations always develop policies that encourage an increase in competent and professional teachers.

Teachers who are qualified teachers have competencies in the pedagogical field, either pedagogical, knowledge, and professional. To meet the world's demands for quality teachers, teacher competence needs to be improved. The level of competence possessed by teachers will affect the quality of learning carried out with students. Teachers with high competence will carry out creative, innovative, and fun learning. Whereas, teachers who have low competence will conduct monotonous and boring learning so that students are less motivated.

Researchers have taken various ways to improve teacher competence. Igor et al. (2019) provided math teachers training to improve pedagogic content competence in teaching geometric concepts with an ethno-mathematic approach. For this reason, each teacher was asked to describe the ornament and constructed it, determining its geometric shape and measured it. The teachers' PCAK competency increased from the training results, and the students' feedback stated that the geometry was not difficult, interesting, and fun.

Various skills needed when teaching could be improved through microteaching activities. Microteaching activities were recorded in video form. The results of the video recordings were analyzed according to the items in Personal Mathematics Teaching Efficacy (PMTE) and eight items under Mathematics Teaching Outcome Expectancy (MTOE). The research results showed that after microteaching training, teachers' competency scores increased from 3.56 to 4.26 (Kadir et al., 2015).

Teacher professional competence can be seen from the learning model's suitability used with the subject matter's characteristics. For example, Jaitip & Siridej (2015) trained teachers to improve learning activities using the "classroom action research" method. In classroom action learning, the learning model utilized needed to be adjusted to the lesson's characteristics, such as playing roles in history subjects, training models in mathematics subjects, and learning science lessons equipped with project methods. The training results were shown by the teacher's ability to use various learning models according to the subject matter's characteristics.

Pavel & Maksim (2015) provided training on ICT to 46 English language lecturers at Derzhavin Tambov State University and National Research Tomsk State University. The training aimed to improve the competence of English lecturers in terms of ICT. The training curriculum consisted of (i) General aspects of using modern ICT in teaching a foreign language, (ii) Fila-mentality in teaching a foreign language, (iii) Synchronous and asynchronous communication in foreign language teaching, and (iv) Introduction of Web 2.0 technology for foreign language teaching, with a total time of 72 hours. The training results were exhibited by the teacher's ability to make modules, instructional videos, and mobile learning-based teaching materials.

Besides, lesson study is a learning model that effectively increases competence by learning, trying methods, strategies, or learning media carried out by other teachers. With the lesson study, a teacher observes another teacher from a student's perspective. Tijmen et al. (2017) observed the practice of lesson study of teachers aged 24-62 years, with teaching experience of 1.5 to 36 years. The development of teacher competence was analyzed using the Interconnected Model of Professional Growth (IMPG). The analysis results showed that the increase in teacher competence through lesson study was influenced by the observers' ability to oversee students, the teachers' activeness in lesson study activities, the facilitator's role, and the school's conditions, where the lesson study was held.

Moreover, 21st-century skills are skills that teachers and students must have. Somprach et al. (2014) developed a training program to upgrade 21st-century skills for primary school teachers in Thailand. The training program consisted of three modules, and at the end of the training, the teachers' 21st-century skills were analyzed. 21st-century skills program comprised the ability to communicate, collaborate, innovate, and competence of leadership, ethics and professionalism, and critical thinking. From the training results, almost 80% of teachers could make various innovations in the learning process.

Specifically, on students' critical thinking skills, the teacher has a role in improving them. Therefore, teachers need to be trained to be able to think critically. Eva et al. (2019) conducted a study on the effect of training on teachers' critical thinking skills and science teaching abilities. The training material was focused on attitudes and critical thinking skills through practice and discussion. The research results are consistent with those reported by Van & Walma (2015) that teachers' ability to think critically could significantly improve their competencies in teaching science.

In addition to teaching competence in class, teachers' Science Process Skills (SPS) also need to be improved through practicum activities. Bülent et al. (2013) compared the guided practicum method with the inquiry-based experiment (IBE) method on prospective physics teachers' science process skills. Their research results indicated that prospective physics teachers' science process skills could be improved with the IBE method.

SPS is one of the 21st-century competencies that every teacher needs to develop to predict, measure, analyze, describe, and convey matters related to practicum. Regarding this, one of the programs in the Jakarta Chemistry Teachers Association in 2019 was to increase the SPS for chemistry teachers through a practicum. In this study, the primary goal was to conduct empirical research to examine the effectiveness of the Green Chemistry Inquiry Experiment (GCIE) in improving the chemistry teachers' science process skills.

II. METHODS

Materials and Tools

Each teacher arranged the necessary tools and materials according to the experiment to be carried out.

Participants

Participants were 18 chemistry teachers from public high schools and private high schools in Jakarta and six chemistry education students at Jakarta State University. Discussion with the chemistry teacher trainers before the workshop suggested that participants had little experience with GCIE in the laboratory (an assumption confirmed by teachers' reactions to the workshops).

Procedures

For the present study, a three-day inquiry-based experiments program was conducted based on green chemistry. The goal of the unit was to understand: (1) the evaluation of the greenness of the reaction-based principle of green chemistry (eco scale, green star, and green metric), (2) green solvent, and (3) green energy.

In this study, a series of nine chemical experiments were chosen as the primary instructional materials because they were part of green chemistry's conceptual development (see Table 1).

Table 1. Experiments Topic

No	Experiment Topics
1	Assessment of Sustainability Indicators for Biodiesel Production
2	Assessment of Sustainability Indicators for Bioethanol Production
3	Analytical eco-scale for assessing the greenness of analytical procedures
4	Green solvents for the extraction of curcumin
5	Green solvents for the extraction carotenoid
6	Synthesis nanoparticle AgNPs using aqueous extract plant
7	Synthesis nano zero-valent using aqueous extract plant
8	Identification pH with natural extract dye as an indicator

A pre-test of the SPS level was administered to all the participants before the program. At the beginning of the program, the researchers randomly divided the teachers into small groups of three. There were nine experimental groups in this study, and each experimental group could choose three experiments in the scheduled topics (which could not be repeated).

Teachers had to conduct experiments in an inquiry way; the experiments which they conducted were called GCIE. These experiments should include designing and planning the experiment, interpreting the results, and arriving at a scientific conclusion.

The detailed descriptions of the experimental process, including focused inquiry activities and the instructions given, are tabulated in Table 2.

Table 2. Components of Inquiry-Based Experiments (IBE)

No	IBE Components	Activities	Outcomes
1	Orientation	Focusing on stimulating interest and curiosity concerning the problem, what is the problem?	Finding topic
2	Conceptualization	The process of generating hypothesis and research question based on the stated problem	Formulating hypothesis or key question Predicting what can be tested
3	Investigation	Exploration: The process of systematic and planned data generation based on a research question experiment	Choosing material, equipment, methods, procedurals, and action
		The process of designing and conducting an experiment to test a hypothesis	Collecting data
		Interpretation: The process of making meaning out of collected data and synthesizing new knowledge	Analyzing data

4	Conclusion	The process of drawing conclusions from the data, comparing inferences made based on data with hypotheses or research question	
5	Discussion	The process of presenting findings of particular phases or the whole inquiry cycle by communicating with others and/or controlling the whole learning process or its phases by engaging in reflective activities	Teachers store a representation of their whole inquiry to facilitate communication of their activities to others. It may be in the form of a report, a poster, or a video Reflection: The process of describing, critiquing, evaluating, and discussing the whole inquiry cycle or a specific phase

(Source: Margus et al., 2015)

Instruments

Understanding the Science Process Skill Test (SPST) was developed corresponding to Burns et al.'s (1985) context to measure teachers' science process skills. The SPST consisted of 30 multiple-choice items, in which each item had four choices. Multiple opportunities were prepared to demonstrate competency for each SPS. The test was to be suitable for group administration within 60 minutes. As such, reading level, item context, response format, and cogitative decision were essential considerations. The test was validated by three experienced chemistry educators. The reliability of the SPST was provided using alpha Cronbach's value above 0.7, indicating an acceptable reliability level. The validity test employed Pearson correlation product-moment. The number of items for each component of science process skill is listed in Table 3.

Table 3. Number of Items for Each Component of Science Process Skill

No	Component SPS	Item Number	Number of Items
1	Formulating hypotheses	1,10,15,16,24,27	5
2	Identifying variable	2,9,14,17,23,30	5
3	Experimenting	3,8,13,18,22,29	5
4	Interpreting data	4,7,12,19,21,28	5
5	Communicating	5,6,11,20,25,26	5

One point was given for each correct answer, with a maximum score of 30. The test generated a total score and four subscale scores. The measured teacher's science process skill by SPST was mainly understood in good and excellent level from four rating scales (low, medium, good, and excellent). The five-rating scale was defined by a range of a percentage of teachers who answered correctly of science process skills, as in Table 4.

Table 4. Qualification Score of SPS

No	Score (%)	Qualifications
1	>80	Excellent
2	66-79	Good
3	56-65	Medium
4	46-55	Low

Data Analysis

To find out the difference between the SPS score before and after attending the training, the t-test was carried out. The t-test was used for independent samples in comparing the mean score obtained from the before and after chemistry teachers following the training, and the paired t-test was employed to determine the significance of the t-test results.

III. RESULTS AND DISCUSSION

Evaluation of Chemistry Teachers' SPS

Summary statistics (descriptive) of the chemistry teacher's SPS score before and after the GCIE training are presented in Figure 1.

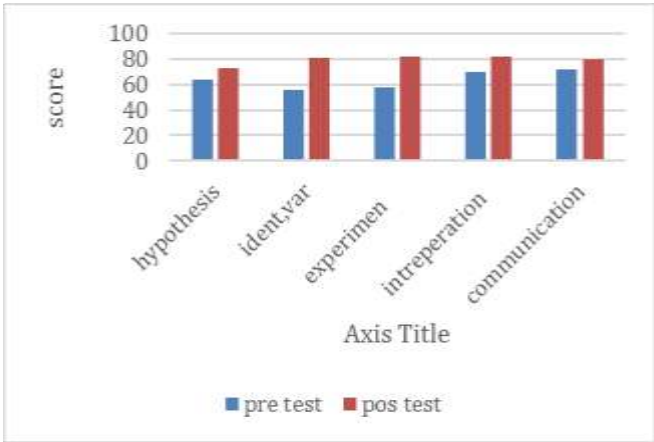

FIGURE 1. Chemistry Teachers' SPS Score

Figure 1 shows that before participating in the GCIE training, the teachers' identification and experimenting skills were low with a score of <65, while the scores for hypothesis skills, interpreting data, and communication were classified as good> 66. Almost chemistry teachers who answered incorrectly had chosen the choice from the variables of identification and experiment. After attending the training, the variable of identification skills increased from 56 ± 1.25 to 81 ± 1.79 and experimenting skills increased from 58 ± 3.15 to 83 ± 2.38. Likewise, other skill scores increased to be better with a score> 65. Increased scores of identification and experimenting variables were because the chemistry teachers proposed various hypotheses from various aspects, making it possible to conduct experiments or practicum with various variables.
The results of the SPS score from 6 students are shown in Figure 2.

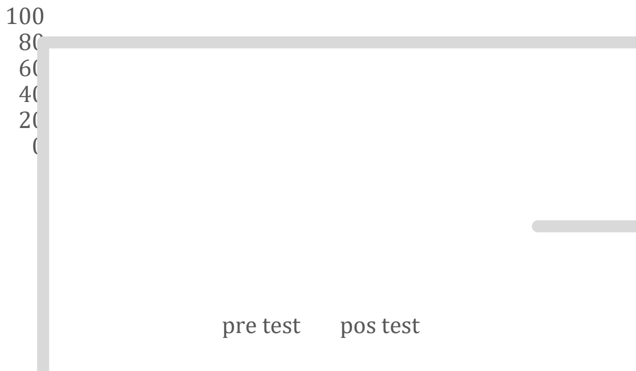

FIGURE 2. Chemistry Students' SPS Score

Figure 2 displays that before participating in the GCIE training, the students' communication and identification skills were low with a score <65, while the scores for hypothesis skills, interpreting data, and experiment were classified as good >66. In the communication test, students made many mistakes regarding data interpretation.
After attending the training, the identification skill variable increased from 54 ± 2.05 to 71 ± 1.86 and communication increased from 55 ± 1.96 to 69 ± 2.03. Likewise, the other skill scores increased to good or <65. However, the understanding of the SPS levels of most students was at a good and excellent level. Due to the practicum, these results might be one of the compulsory courses that students had to take during their lectures.

From Figure 1 and Figure 2, it can be seen that the pre-test and post-test scores of science process skills, both chemistry teachers and students, differed significantly. It showed that learning using the green chemistry inquiry experiment (GCIE) model could improve teachers and prospective teachers' science process skills.

In the same context, Zhou et al. (2012) investigated the effects of chemical inquiry experiments in chemistry teaching in promoting pre-service teachers' critical thinking skills. The results found significant differences in the "analysis" and "evaluation" categorization of decoding significance and clarifying meaning on the subscale scores of the experimental group's critical thinking skills after the inquiry experiments were implemented. These results are consistent with the evidence reported by Miri et al. (2007). The pre-and post-test of the experimental group also differed significantly on evaluation, reflecting a person's abilities to justify and assess the arguments. According to Facione (1990), the evaluation may be related to the focus on experimental procedure, during which pre-service teachers assess the credibility of statements and justify their reasoning based on relevant evidence, concepts, methods, or standards. To enhance undergraduates' conceptual understanding of organic acid-base-neutral extraction, Saksri (2012) employed inquiry-based experiments. Students had a chance to define the investigated problem from their observations and generate hypotheses, devise a plan and conduct the investigation, make explanations from experimental evidence and communicate the findings. Results showed that the students' average score in the post-achievement test was higher than the average pre-achievement test in the separation and purification of the mixture of acid-base-neutral organic compounds. It could be implied that the inquiry-based experiment used in conjunction with ICESE was effective in the enhancement of student conceptual understanding and mental models of organic acid-base-neutral separation and purification, helping low-achieving students to understand the key experiment concepts throughout the experiment gradually.

Sarantos et al. (2012) used the Inquiry-Based-Computational Experiment (IBCE) model to improve prospective primary school teachers' metacognitive experiences. With IBCE, students were stimulated to develop modeling skills, engage in inquiry tasks, and develop strategies to solve particular problems to enhance their metacognitive awareness and evaluate their strategies' efficacy. Spiritual task of teacher can also improv the students' skill (Karim & Hartati, 2020). The study results by Sarantos et al. (2012) revealed that the pre-test and post-test scores for primary school teachers from a Greek University increased from 139.87 ± 50.41 to 166.22 ± 41.56. The test results showed that the pre-test score was significantly different from the post-test score. It could be concluded that ICBE could improve students' metacognitive behavior.

In their research, Cai et al. (2020) reported that the Inquiry-Based Teaching (IBT) method could motivate student learning, encourage students to conduct experiments actively, and improve students' scientific literacy. The results of the student's science skill score analysis exposed that high-achieving students from schools could more engage in scientific inquiry, focusing on designing experiments based on the inquiry question and experiment principle and making conclusions based on the collected data evidence. Rinto et al (2020) argue that process skills approach and character implanting. The application of this approach had a positive effect on cognitive, affective, and psychomotor learning outcomes and has reached the established classical completeness, i.e., a lot students who took learning. In comparison, low-achieving students tended to practice their 32 inquiries by generating more hypothesis nodes, conducting more trials, and creating more data analysis nodes.

Meanwhile, Lennart et al. (2015) utilized the guided Inquiry-Based Instruction (IBI) model to improve primary school students' understanding of physics concepts in everyday life. Students engaged in an active and self-directed exploration of complex phenomena and situations in the guided inquiry model-based instruction. For example, they created, tested, and evaluated their hypotheses in experimentation activities. Students' knowledge of physics concepts in floating and sink material, air and atmosphere, pressure, sound & spreading of sound, and bridges' stability was tested using Concept-Variable Strategy (CVS). The pre-test and post-test results exposed that the students' understanding of the four materials' concepts increased sharply. It indicated that the IBI inquiry-based instruction model could improve students' understanding of physics concepts in everyday life.

Prospective teacher communication skills in the form of the debate were trained using argument-driven inquiry (ADI). Activity in ADI included six steps: (i) defining the problem, (ii) proposing an inquiry method, (iii) developing arguments, (iv) compiling a lab report, which answered what they were trying to do and why, what they did and why, what their arguments were, and (v) in a peer-reviewed double-blind ADI written report, the students designed their research questions and achieved the results themselves. Moreover, in traditional laboratory activities, students did the experiments step by step, given the lab manual. The quality of the argued assessment was divided into six levels, and the score for each level was given a value of 1 to 4. The effect of argument-driven inquiry on pre-service science teachers' attitudes and argumentation skills suggested that the ADI instructional method effectively improved the argumentation quality, improved their lab report argumentation skills, and helped them use rebuttals in their reports.

Evaluation of the Training

Evaluation is one part of training activities that functions to determine the training program's success level. According to Peter et al. (2020), "evaluation activities are inseparable from education and training activities, especially in teaching and learning activities. The success or failure of the training program will depend a lot on the evaluation activities carried out, so that further training can take place better. In this study, the purpose of evaluation on training was to (i) evaluate GCIE material and (ii) assess the impact of GCIE training on participants' learning interest and self-confidence.

Evaluation of the Program Materials

Process evaluation aimed to evaluate the implementation of GCIE training related to the material. Evaluation of material, according to participants, was measured employing a questionnaire adopted from Hadi & Francisco (2019), as follows:

Table 6. Questionnaire for Evaluation Material on GCIE

No	Questionnaires	Strongly agree	Agree	Disagree	Strongly disagree
1	Do you agree this GCIE helps learn about green chemistry?				
2	Do you agree this GCIE makes you impressed?				
3	Do you agree this GCIE pleases you?				
4	Do you agree this GCIE is easy to understand?				
5	Do you agree this GCIE application can be used in the learning process?				
6	Are you satisfied with this GCIE model?				

The score for each statement consisted of strongly agree = 4, agree = 3, disagree = 2, and strongly disagree = 1. The results of the questionnaire are depicted in Figure 4 below.

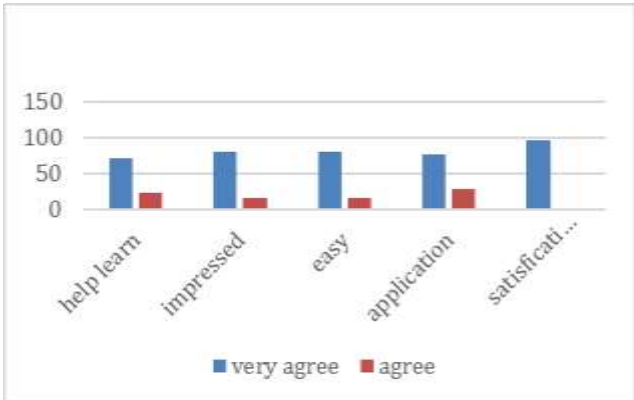

FIGURE 4. Evaluation Material Training GCIE

Figure 4 reveals that the material presented could encourage teachers to learn using the GCIE model for the teaching and learning process. Besides, overall, all participants, both teachers and students, were satisfied with the material provided. Free interviews with participants also supported the questionnaire results, as presented by the participants below:
"The teaching model is enjoyable, making us explore green chemistry."
"We are very satisfied because the material is the latest issue, adding to our insight."
"The explanation from the coach is easy to understand, so it starts to encourage us to study."
"The materials and tools used are simple, so the practice of Kum green chemistry can be developed in our school."
"Designing the experiment itself is a very nice work."

This training's success could also be proven by an increase in the average score of the pre-test and post-test results of the participants' science process skills.

Evaluation of Teacher Learning Interest

One of the training objectives was to increase interest in learning, indicated by a strong will, a desire, and a feeling of pleasure to achieve what was desired. In the teaching and learning process, interest acts as a force that will encourage students to study thoroughly. According to Renninger & Hidi (2002), what is meant by an interest in learning chemistry is the feeling of pleasure experienced after participating in the learning process. This aspect is influenced by the environment and stimulates individual interest through fun learning. Karim et al (2020) argue that students' care can improved by environment. In this study, the teacher's interests in learning studied encompassed a pleasure in learning and self-confidence, measured by questionnaires and interviews, as shown in Table 7.

Table 7. Questionnaire for Interest Learning on GCIE

No	Questionnaires	Always	Sometimes	Seldom	Never
1	I enjoy learning green chemistry.				
2	I listen to the teacher giving a lecture-style presentation.				
3	I read chemistry textbooks and other resource materials.				
4	I ask the teacher about what is not understood,				
5	I do assignments on time.				
6	I relate what we are learning in green chemistry to our daily lives.				
7	I need to do well in green chemistry to get the job I want.				
8	We design or plan a GCIE learning experiment model.				
9	We make observations and describe what we see.				
10	We interpret data in tables, charts, or graphs.				

Questionnaires 1 to 5 aimed to measure participants' interest in learning, and questionnaires no 6 to 10 aimed to evaluate participants' self-confidence. The questionnaire results showed that more than 90% of participants always did the things stated in the questionnaire. It reflected that the participants' interest and confidence were very good. It was supported by free interviews conducted outside the classroom. The following are participants' answers in the interview session and writings in the reflective journal.

"We worked together, discussed what the task, shared idea, tested it, and found evidence, making us all happy."

"Doing practicum by making procedures make practicum not boring."

"Applying the green chemistry concept and using green solvent make practicum less scary to us."

Based on the interest theory, Katz et al. (2014) stated that someone with interests has confidence in doing what he is interested in. According to Hidi (2006), the greater the interest, the greater the self-confidence. From the observation results during learning, participants' interest in learning was shown from self-confidence, which could be observed during the training and the presentation. Likewise, from interviews, the participant stated that:

"*Learning with the GCIE model requires me to find out the problem myself, solve it, and prove it. The success of solving problems by showing the evidence was a very enjoyable experience and made me feel confident."*

"Discussions, group work, and do it all together give a sense of togetherness, and each member supports each other to increase our self-confidence."

"Every time we experiment, we always say the chant "working, it gets easier. The yell is a motivator to increase our confidence in conducting experiments."

IV. CONCLUSION

Experiment model with inquiry-based experiment engaged and challenged teachers in all experimental process steps (searching topic experiment, hypothesis, choosing material, equipment, methods, procedurals and action, collecting data, and analyzing data). Their understanding of the experimental concepts was enhanced and enhance students' SPS skills. The results uncovered that after participating in the teacher competency training in making hypotheses, the variables of identification and experimenting skills significantly increased compared to before participating in the training. The survey results also showed that the training provided could increase teacher learning motivation, learning interest, and self-confidence. Designing, doing, and solving problems, as well as obtaining data done in groups, could increase each participant's interest, motivation, and self-confidence. Besides, a practicum based on green chemistry with the topic of current issues using not dangerous materials and simple tools made this training very enjoyable.

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