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Guided Inquiry-Based Basic Chemistry Practicum Guidelines and Its Impact on Students' Science Process Skills and Critical Thinking Skills

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ABSTRAK

Keterampilan proses sains dan berpikir kritis merupakan keterampilan yang harus dimiliki mahasiswa sebagai calon guru profesional. Keterampilan proses sains dan berpikir kritis yang rendah dapat ditingkatkan melalui kegiatan praktikum yang berkualitas dengan dukungan bahan ajar yang berkualitas pula. Penuntun praktikum yang digunakan hanya meminta mahasiswa melakukan kegiatan praktikum sesuai prosedur yang ada, sehingga mahasiswa tidak mampu membangun keterampilan sendiri. Penelitian ini bertujuan untuk mengembangkan penuntun praktikum berbasis guide inquiry yang memenuhi kriteria valid, praktis, dan efektif terhadap keterampilan proses sains dan berpikir kritis. Penelitian ini adalah penelitian pengembangan berbasis model Hannafin & Peck dengan tiga tahap yaitu penilaian kebutuhan, desain, pengembangan dan implementasi yang diujicobakan pada skala kecil yaitu 20 mahasiswa pada mata kuliah kimia dasar. Hasil penelitian menunjukkan (1) Valid dengan nilai 3,5. Praktis dengan nilai 3,81 pada aktivitas dosen dan nilai 3,3 pada aktivitas mahasiswa. Efektif dengan 90,5% memperoleh respon positif. (2) Keterampilan proses sains sangat baik dengan nilai 88,54% dan keterampilan berpikir kritis dengan hasil uji hipotesis nilai Sig (0.001) > 0.05 sedangkan uji gain score sebesar 0,45 kategori sedang. Penuntun praktikum berbasis guided inquiry ini dapat digunakan karena mahasiswa merancang, merumuskan hipotesis dan menyimpulkan secara mandiri, sehingga keterampilan proses sains dan keterampilan berpikir kritis dapat meningkat.

ABSTRACT

Science process and critical thinking skills must be possessed by students as prospective professional teachers. Quality practicum activities with quality teaching materials can improve science process skills and low critical thinking. The practicum guide only asks students to carry out practical activities according to existing procedures, so students cannot build their skills. This study aims to develop an inquiry-based practicum guide that meets the valid, practical, and effective criteria for science process skills and critical thinking. This research is development research based on the Hannafin & Peck model with three stages, namely needs assessment, design, development, and implementation, piloted on a small scale, namely 20 students in basic chemistry courses. The results showed (1) Valid with a value of 3.5. Practical with a score of 3.81 on lecturer activities and 3.3 on student activities. Effective with 90.5% getting a positive response. (2) Science process skills are very good, with a score of 88.54%, and critical thinking skills with the results of hypothesis testing Sig (0.001) > 0.05, while the gain score test is 0.45 in the medium category. This guided inquiry-based practicum guide can be used because students design, formulate hypotheses, and conclude independently to improve their science process and critical thinking skills.

1. INTRODUCTION

Chemistry is the science of matter, studying substances' composition, properties, structure, and changes, namely elements and compounds (matter) and the accompanying energy (Sastrohamidjojo, 2012). Chemistry can only be developed with memorization, but a knowledge-construction process is needed to

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create meaningful learning. Amineh & Asl (2015) found that constructivist learning is constructing meaning and generating knowledge through one's own experiences. Students can construct chemical knowledge not only by receiving material in the classroom but also through the learning process in the laboratory, which leads to active involvement (Sugrah, 2020). A laboratory is a place used by students to explore and develop their potential in terms of cognitive, psychomotor, and affective (Nuha et al., 2015).

Practicum activities in the laboratory have a variety of positive impacts on students. The results of the research include stating that in practicum activities, students can understand the concepts of science so that they are interested and motivated to learn science (Demircioğlu & Yadigaroğlu, 2011) increase student experience in understanding chemical principles and concepts (Sundari et al., 2017) doing direct proof of theory so that critical thinking skills increase (Azzahra, 2019), improve process skills such as skilled in using chemical tools (Candra & Hidayati, 2020), improve science process skills such as observing, classifying, interpreting, predicting and formulating hypotheses (Emda, 2017). So it can be concluded that by doing practicum activities, students can be motivated, understand concepts, form science process skills, and think critically.

Science process skills and critical thinking must be possessed by students as prospective professional chemistry teachers. As found by Oktariani et al. (2020), Critical thinking skills must be possessed by prospective chemistry teachers in order to be able to compete in the industrial revolution 4.0 era Hidayah & Imaduddin (2015) said that as chemistry teacher candidates, they must be able to design practicums so that the learning process is meaningful, so they must have science process skills. The skills students build in carrying out scientific discoveries, namely applying a concept, rules, and nature that exist in science, are called science process skills (Putri et al., 2022). Science process skills consist of two levels, where the basic level includes predicting, classifying, communicating, predicting, inferring, and identifying activities. At a high level, it includes manipulating, interpreting, operational definitions, modeling, designing experiments, making hypotheses, and making conclusions. Meanwhile, skills through mental processes carried out by students through managing information from observations, then being analyzed by their minds and producing output as problem-solving are critical thinking skills (Changwong et al., 2018). Menurut Karakoc (2016) how to organize learning so that students can have critical thinking skills can be done by emphasizing all stages of the learning process at once or only several stages.

Students with scientific process skills and high critical thinking skills will consistently have a deep level of thinking and can use their intuitive abilities to solve various problems they face (Nugraha et al., 2017). Students with high science process skills will inadvertently also be able to develop their critical thinking skills (Rahayu, 2020). As also found by Redhana (2019) that critical thinking skills must be sharpened and developed deliberately by teachers or lecturers in order to be able to solve problems and be able to answer the demands of 21st-century learning. Thus, students must practice critical thinking skills through the learning process in the classroom or the laboratory as early as possible (Changwong et al., 2018). In addition, steps to improve students' critical thinking skills can also be obtained through experimental activities, observation, and group discussions (Andayani et al., 2020).

Science process skills and critical thinking skills that are formed in practicum activities are, of course, supported by quality teaching tools as well. One of the teaching tools that can be prepared is a practicum guide. The practicum guide is a learning resource that facilitates the experimental process, from practicum instructions, preparation of tools and materials, work procedures, and conclusions to making reports (Ristekdikti, 2019). Various research results related to innovation in the preparation of chemistry practicum guides include the use of mechanochemistry-integrated practicum guides, which can increase student activity in the involvement of constructing concepts independently in practicum activities (Asmaningrum et al., 2018), The use of green chemistry-based practicum instructions can provide understanding to students to carry out practicums that are safe and do not endanger the environment (Rizkiana et al., 2020), the use of practicum guides harms knowledge, attitudes, and skills (Lubis et al., 2016), and student's understanding of concepts from material practiced through direct experience can increase due to the impact of practicum instructions with the guided inquiry model (Syamsu, 2017).

The practicum guide that has been developed has proven to impact the advancement of students' skills and knowledge positively. However, based on the results of observations in the implementation of student practicums in basic chemistry courses in the Chemistry Education Study Program, the Teaching and Education Faculty of USN Kolaka still use practicum guides which are only divided into several items, namely from the purpose of the experiment, study of experimental material (theory), equipment and materials used and work steps. The practicum process shows a condition where students are only fixated on the guide, namely following step by step according to what is stated in the practicum guide without knowing and understanding the concept of the material being practiced. Hence, students' science process skills still need to improve. In addition, based on the tests' results, it also shows that most students still have low critical thinking skills. This problem must be solved to ensure that the practicum process runs effectively and efficiently. One way that can be done is by applying the guide inquiry learning model in the practicum process in the laboratory.

The guided inquiry learning model, or guided inquiry, is student-centered, namely learning activities or practicums that students dominate. The lecturer is only a facilitator/guide, while students must conduct investigations and formulate their answers or experimental procedures (Rifa'i, 2022). Thus, students can find and construct their knowledge in the guided inquiry-based learning process in the classroom or laboratory (Sadeh & Zion, 2012). The guided inquiry model is a model that requires students to formulate questions based on the stimulus provided and then formulate answers as a form of problem-solving given to the conclusion stage, all of which are done independently but still under the guidance of the lecturer (Bunterm et al., 2014). It is supported by several studies which state that the guided inquiry model in the learning process can increase activity so that students can develop skills in practicum activities, one of which is science process skills (Fitriyani, 2017). The inquiry model applied in learning activities significantly correlates with students' critical thinking skills (Fuad et al., 2017). Likewise, the analysis results by Sarlivanti et al. (2014) showed a significant and positive relationship between science process skills and critical thinking skills with r = 0.910 in practical activities based on the guided inquiry learning model.

Based on this description, it is necessary to renew basic chemistry practicum guides in the chemistry education study program FKIP USN Kolaka so that students can create meaningful learning processes, where students themselves design, formulate hypotheses and conclude experimental results so that science process skills and critical thinking skills can be increase. This study aimed to develop a quick inquiry-based basic chemistry practicum guide for students' critical thinking and science process skills.

2. METHOD

This development research adheres to the Hannafin and Peck model consisting of a needs assessment stage, the second design stage, and the third stage of development and implementation, where each stage is evaluated and revised (Tegeh et al., 2014). The first is a need assessment (needs analysis phase), namely, analyzing learning problems, student characteristics, objectives, and learning settings. The second design (design phase) is the preparation and design of a basic chemistry practicum guide based on guided inquiry. The third is develop and implement (development and implementation phase). The development stage starts with the validation process by three experts, namely material experts, linguists, and design experts, using the validation sheet instrument. Valid guides are then implemented on a small scale for students of the Chemistry Education Study Program who have programmed Basic Chemistry courses for the 2021/2022 academic year. The implementation phase is intended to obtain effective and practical data from the guidelines that have been developed. Practicality was measured using the Observation Sheet instrument for practicum and lecturer activities. At the same time, effectiveness was obtained in 3 ways, Student Responses using a questionnaire, science process skills using observation sheets, and critical thinking skills using a written test.

The assessment on the validation sheet, observation, and questionnaire uses a Likert scale from 1-4. Furthermore, the analysis results determined the average value of the total aspects for all indicators for validity, practicality, and effectiveness. The average total value is converted into categories in Table 1.

Table 1. Conversion of valid, practical, and effective scores

Interval	Category	Interval Description
$X > X_i + 1,8 \times sb_i$	Very good	X = Total Average
$X_i + 0.60\ sb_i < X \le X_i + 1.80\ sb_i$	Good	X_i = Mean Ideal = $\frac{1}{2}$ (Ideal max score + Ideal min score)
$X_i - 0.60\ sb_i < X \le X_i + 0.60\ sb_i$	Enough	sb_i = Ideal Standard Deviation = $\frac{1}{6}$ (Ideal max score − Ideal min score)
$X_i - 1.80\ sb_i < X \le X_i - 0.60\ sb_i$	Not Enough	
$X \le X_i - 1.80\ sb_i$	Less	

(Widoyoko, 2012)

The analysis of critical thinking skills tests was carried out using the one-group pretest-posttest method. The test given is in the form of essay questions. The guidelines for scoring each item are based on the cognitive level of the questions that adhere to the guidelines Zubaidah et al. (2018). Before and after the practicum activities using the practicum guide, the development results can be obtained data on improving students' critical thinking skills by determining the value of the gain score. Then, an initial test was carried out, namely homogeneity and normality tests as prerequisites. If the data was normal and homogeneous, then the Paired Samples t-test was carried out as a significance test through SPSS Statistics 26.

3. RESULT AND DISCUSSION

Result

The results of developing practicum guides include aspects of validity, practicality, and effectiveness through student responses are presented in Table 2.

Table 2. Results of data analysis on validity, practicality and effectiveness

No	Data	Evaluator	Components assessed	Average Score	Category
1	Valid	Material Expert	Presentation of material	3.51	Good/valid
		Design Expert	Design/appearance	3.56	Good/valid
		Linguist	language use	3.44	Good/valid
2	Praktis	Observers	Lecturer/assistant activities	3.81	Very good
		Observers	Practical activity	3.33	Good
3	Efektif	Student	Responses using development results guide in basic chemistry practicum	3.60	Good

Effective data through the measurement of science process skills and critical thinking skills. Science process skills are measured involving observers who observe students in their groups. Observation results obtained data are shown in Table 3.

Table 3. Results of data analysis of science process skills

No	KPS Indicator	Vi	%	Category
1	classify	3.78	94.46	Very good
2	Measurement	3.75	93.64	Very good
3	Observe	3.24	80.97	Good
4	predict	3.52	88.10	Very good
5	Applying Concepts	3.39	84.78	Good
6	Data Interpretation	3.55	83.68	Good
7	Conclude	3.77	94.18	Very good
	Average		88.54	Very good

The analysis of critical thinking skills tests was carried out using the one-group pretest-posttest research design and was measured using a test instrument. The test given is a description test based on indicators of critical thinking skills. The results of the pretest and posttest tests for measuring critical thinking skills are first carried out with an initial test, namely the normality and homogeneity tests as prerequisite tests.

The results of the normality and normality tests show that Sig is greater than 0.05, so it is concluded that the data obtained to measure students' critical thinking skills is normally distributed and homogeneous. The hypothesis test is that the sig value is smaller than 0.05, so using a guided inquiry-based basic chemistry practicum guide as a result of the development can improve students' critical thinking skills. The increase in critical thinking skills can be compared before the value of the treatment or pretest and after the treatment or posttest using the score gain test. The results of the score gain test are shown in Table 4.

Table 4. Gain test for critical thinking skills indicator score

No.	Critical Thinking Skills Indicator	Percentage of Results		Gain Score			
		Pretest	*Post-test*	*Spre*	*Spost*	*N-gain*	Category
I	Describe	48	67	48	67	0,3	Medium
2	Reflect	44	85	44	85	0,7	High
3	Analyze	33	84	33	84	0,7	High
4	Criticize	9	32	9	32	0,2	Low
5	Reasoning	30	86	30	86	0,8	High
6	Evaluate	1	0	1	0	0,0	Low
	Average			27	67	0,45	Medium

Discussion

The assessment results of the three validators in Table 2 show that the Guided Inquiry-based basic chemistry practicum guide is declared valid in terms of material, language, and design with several inputs. Therefore, the input given by the expert team was revised so that a valid development result practicum guide was obtained for further testing. The material expert's assessment showed that the material presented had a theoretical quality that was by the objectives of the basic chemistry practicum, and the presentation of the material was by the steps of the Guided Inquiry model. Sitepu (2020) found that the aspect of the material that needs attention is the suitability of the material with the learning objectives. The linguist's assessment showed that the preparation of the practicum guide in terms of language was easy to understand, according to language rules, the accuracy of sentence structure, the accuracy of spelling, and consistency in the use of terms. Language is important in communication to achieve learning objectives verbally and nonverbally (Wicaksono, 2016). The design expert's assessment shows that the preparation of the practicum guide from a design perspective has an attractive appearance in terms of cover and content, accuracy in the use of colors, attractiveness in the use of images, the accuracy of image sizes, image clarity, and image sharpness. As said (Hernawa & Rinaningsih, 2013) that the attractiveness of the design of a teaching media or teaching material presented interactively is an added value in the learning process. Based on these assessments, the basic chemistry practicum based on Guided Inquiry regarding language, material, and design is feasible to try out. These results are the same as the analysis by Nazar et al. (2018), that the guided inquiry-based student worksheet with a validator rating of 97.8% is categorized as very valid and feasible. A valid guide means that it is feasible to try out. The implementation phase will provide practical and effective data.

The implementation stage is important because students are the target of the developed product test. Practicum activities were observed by two observers whose job was to observe the practicum activities and lecturers in the process of practicum activities. The observation sheets for practicum activities of practitioners and lecturers aim to obtain data on the practical results of a Guided Inquiry-based basic chemistry practicum. The results of data analysis in Table 2 can be concluded with the use of practical or easy-to-use guides so that lecturer activities in guiding students and student activities carrying out practicum activities run effectively and efficiently. The results of the implementation of a Guided Inquiry-based basic chemistry practicum are in line with the results of the analysis by Atmaja et al. (2019) that the use of inquiry-learning-based practicum guides can improve learning outcomes with an average assessment using observation sheets from three observers, namely 81.6.

The guide that has been developed is effective if it is successfully used in the learning process and provides consistent changes in terms of achieving learning outcomes. The effectiveness of the Guided Inquiry-based basic chemistry practicum guide includes student responses, science process skills, and critical thinking skills. Assessment of student responses aims to determine the effective level of using Guided Inquiry-based basic chemistry practicum guides in practicum activities. According to the research results in Table 2, it was found that students gave good responses. A good response to using practical guides in the learning process is needed so that these guides can be used repeatedly (Siahaan et al., 2019). While the results of the analysis by Zumronah et al. (2019) stated that using the POGIL model of process-oriented guided inquiry learning in practicum activities received a good response from its users.

The results of the questionnaire recapitulation obtained 90.5% positive responses in its use in practicum activities. It means that students are interested in using Guided Inquiry-based basic chemistry practicum guides and are enthusiastic about participating in practicum activities, as evidenced by comments such as The practicum guides used can help me improve my science process skills, the practicum guides used can help me know or understand more about the experiments being carried out, using a practicum guide is very good to apply because it can hone the brain and can also provide an overview of what will be practiced, using a practicum guide can help me understand the practicum process that will be carried out in the laboratory, and help us students, especially entry-level students, in doing a practicum. No matter how well the lecturer guides practicum activities, they still need good guides to create a student-centered practicum process (Fauza et al., 2022). Based on student responses, Guided Inquiry-based practicum guides were accepted by students for use in basic chemistry practicum activities. It is the same with research by Pamenang et al. (2020), using a Guided Inquiry-based practicum guide with the results of a student response questionnaire obtained 61.5% stated that they understood the material and added understanding and insight into chemistry. At the same time, the analysis results by Arifin et al. (2015), namely practicum worksheets based on practical inquiry learning to use and get a good response from its users.

In addition to knowing student responses, effectiveness is seen by measuring science process skills during practicum. The data in Table 3 shows the differences in each indicator of science process skills. The first indicator is the ability to classify in the very good category, meaning that students can classify and select tools and chemicals according to the concept based on the stimulus given clearly and precisely by the objectives of the practicum. As Sari et al. (2019) stated, understanding the concept is needed so that someone can classify the components of the experiment. The second indicator is the skill of taking measurements in the very good category, meaning that students can carry out practicum activities based on work procedures formulated from the stimulus provided by skillfully using chemical tools; for example, students are skilled at carrying out the titration process until they reach the equivalent point. Measurement skills will improve if they continue to be trained along with the routine implementation of practicum activities in the laboratory (Kartini, 2019). The third indicator is observing skills in the good category, meaning that students can function with their senses of sight, taste, hearing, smell, and touch to formulate questions, make hypotheses, and formulate conclusions by the objectives of the experiment and based on the experimental results obtained. As stated by Suhanda & Suryanto (2018), if someone has good observation skills, it will impact other aspects, such as skills in formulating questions and hypotheses.

The fourth indicator, namely predicting skills in the very good category, means that students can formulate hypotheses based on the formulation of the questions asked before experimenting clearly and precisely. It is supported by the results of observations, which are seen when students interpret the stimulus as questions and make hypotheses. Predictive skills are obtained from good processing skills, whereas processing skills are built from good mastery of concepts (Khery et al., 2019). The fifth indicator is the skill of applying concepts in the good category, meaning that students can apply concepts and theories obtained in lecture halls or based on theoretical studies in formulating the stimulus given. As stated by Sumarti et al. (2018) that students who have science process skills can solve problems correctly based on concepts that have been previously studied. The sixth indicator, namely the skill of interpreting data in the good category, means that students can apply theory from various references and experimental data to analyze experimental data clearly and precisely. Very good means students can formulate a concept's essence according to the practicum guide's objectives clearly and precisely. As stated by (Sarlivanti et al., 2014), students can use experimental results to explain things that might happen or interpret the data obtained to decide conclusions from the practicum activities.

Based on the description of each of these indicators, it is stated that the use of practicum guides that have been developed using the Guided Inquiry model in practicum processes in the laboratory can improve students' science process skills with an average percentage of 88.54% in the very good category Gultepe, (2016) states that science process skills are effective if carried out in practicum activities in the laboratory. It is by the results of the analysis by Koksal & Berberoglu (2014) showed that science process skills will increase when using guided inquiry-based learning models in practicum activities if compared to conventional learning models, and Siregar et al. (2020) suggests that effective science process skills are enhanced through scientific inquiry models.

Measurement of critical thinking skills is also a variable of effective measurement. Critical thinking skills are measured using pretest and posttest essay tests. The data in Table 6, where the n-gain shows differences in critical thinking, can be classified into three categories: high, medium, and low. The high category, namely the skills of reflection, analysis, and reasoning, means that students can answer questions by reconsidering the topic with existing concepts, comparing each material concept with one another, and understanding the causes and effects of these concepts. It can be seen in the answer sheets that most students formulate and detail the main points of the material according to the problem questions to formulate solutions to answer them. Supported by statements (Dewi & Setyaningsih, 2016), a good understanding of the material impact inquiry learning because self-answered questions can stimulate students to think critically, especially regarding reasoning. Inquiry learning also helps students balance the processes of equilibration and assimilation so that there is an intellectual improvement (Rachmawaty et al., 2021). The medium category describes skills, meaning that students have yet to be able to explain clearly and specifically the problems given. As evidenced in the results of student answers, some students needed to write down the analysis results as they were known and asked questions. Cahyono (2017) states that the ability to describe the question is seen from the ability to write down things that are known and asked about the problem precisely and briefly. While the low category, namely the skills to criticize and evaluate, means that students, in answering questions, have yet to be able to carry out further descriptions of a concept and provide conclusions from existing problems. Evidenced by the results of student answers, most students, after reasoning and describing concepts, did not do any more detailed explanations, and after obtaining the final answer, students no longer gave explanations or concluded again, for example, in the matter of determining moles.

Based on these results, it was suggested that there was an increase in critical thinking skills in basic chemistry practicum courses after using guided inquiry-based practicum guides. The medium category is because students have yet to be able to identify and examine the weaknesses and strengths of a concept and comment on the success and failure of something, as evidenced by low criticizing and evaluating indicators.

In general, there is an increase in critical thinking skills after using Guided Inquiry-based practicum guides. In addition, it shows that Guided Inquiry-based practicum guides make students more independent to hone their thinking skills, especially critical thinking. It is to the results of the analysis by Rahma (2012). Using inquiry model-based learning tools with the SETS approach, an N-gain value of 0.72 was obtained for students' critical thinking skills apart from that from research by Marisa & Fradisa (2019), Ningsyih et al. (2016) dan Budiarti et al. (2016) concluded that student activity and students' critical thinking skills were higher using the guided inquiry learning model compared to conventional learning.

4. CONCLUSION

The quality of the Guided Inquiry-based basic chemistry practicum guide refers to the Hannafin & Peck model, which is valid from the assessment of material, language, and design experts. Practical because all aspects of practicum activities can be carried out. It is effective because students give positive responses, have good science process skills, and have increased critical thinking skills but in the medium category, so an emphasis is needed on describing, criticizing, and evaluating indicators. Guided inquiry-based practicum guides are appropriate for basic chemistry practicum courses and effectively improve students' science process and critical thinking skills.

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