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Open Inquiry Practicum: An Effective Strategy for Enhancing Science Process Skills of Prospective Biology Teachers

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Abstract: Practicum has been widely recognized as an effective approach to enhance science process skills. However, traditional practicums may not be sufficient in improving integrated process skills. To address this issue, the current study aimed to introduce the open inquiry practicum model and investigate its impact on basic and integrated process skills among prospective biology teacher students. The study was conducted during the odd semester of 2022-2023, where selected courses utilized practicums both in and outside of the laboratory to facilitate open inquiry learning. A quasi-experimental study with a non-equivalent control group design was conducted to assess the effect of open inquiry practicum on students' science process skills. Data was collected from observing the practicum process utilizing the open inquiry learning model, as well as pretest and posttest results of science process skills. Treatment effect was analyzed through Mann-Whitney test with an alpha level of 0.05. The open inquiry practicum model consisted of experimental design preparation, practical field and laboratory work, data collection and analysis, data presentation, and uploading practical activity products in the form of posters and videos to YouTube. The results indicated a significant improvement in students' science process skills through the implementation of the open inquiry practicum.

Keywords: Biology practicum; Open inquiry; Prospective biology teacher; Science process skill.

Introduction

The emergence of the COVID-19 pandemic in Indonesia since the beginning of 2020 has greatly impacted the learning process and outcomes of students, particularly in important areas such as science process skills. Science process skills refer to the cognitive and physical abilities that enable individuals to learn science and technology (Akinbobola & Afolabi, 2010), and they facilitate the integration of learning into everyday life (Ozturk et al., 2010). Science process skills are categorized into two main types: basic process skills and integrated process skills. Integrated process skills involve the combination of two or more basic process skills, such as measuring, calculating, observing, and inferring. An example of integrated process skills is the ability to conduct experiments, which requires a combination of several science process skills, including measuring, calculating, observing, and differentiating (Nur et al., 2013).

According to Duran et al. (2011), prospective biology teachers must possess strong science process skills in order to succeed in teaching. However, research conducted in various regions of Indonesia, including Banten, Jakarta, Bandung, and Surakarta, has shown that many prospective teachers exhibit weak science process skills (Anggraini, 2012; Maknum et al., 2012; Kurniawan & Fadloli, 2016). Specifically, students tend to struggle with integrated process skills, which are particularly challenging to master (Artayasa et al., 2017a). In fact, according to Artayasa et al. (2017a), students' integrated process skills in science learning are classified as low, with only 57% of students exhibiting these skills. Moreover, the COVID-19 pandemic has further hindered the development of students' science

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process skills, particularly as the implementation of biology practicums has been limited (Artayasa et al., 2021).

Prospective biology teachers' lack of science process skills is a concern as it may affect their ability to facilitate their students' biology practicum. Additionally, Indonesian students' inadequate science literacy levels have been noted in the PISA assessment due to their inability to apply science process skills when answering science questions (Odja & Payu, 2014). Teachers often struggle with planning and implementing science process skills during practicum, as stated by Sudargo (2012) and Sukarno et al. (2013). Consequently, the implementation of science practicum at school is often not scheduled, highlighting the weakness of teachers' science process skills. The Minister of Education and Culture of the Republic of Indonesia's Regulation No. 21 of 2016 concerning Science Content Standards for Primary and Secondary Education emphasizes the importance of students having a scientific attitude that allows them to question, observe, and report experiment outcomes. Therefore, urgent efforts must be made to improve learning methodologies at universities to enhance the science process abilities of future science teachers, so that they will be able to help develop their students' science process skills.

Nwagbo and Uzoamaka (2011) suggest that students' science process skills can be enhanced through practicum. Typically, practicum in biology courses follows instructions developed by instructors. However, Anggraini (2012) argues that the conventional biology practicum has not been very effective in boosting students' science process skills. As such, there is a pressing need to revamp the biology practicum model.

The Indonesian Ministry of Education and Culture's Regulation No. 22 of 2016 emphasizes the use of inquiry-based learning to enhance students' questioning, experimentation, reasoning, and creativity skills. Research conducted by Artayasa et al. (2017b) supports the effectiveness of inquiry-based learning in improving students' science process skills. Among the three levels of inquiry-based learning (structured, guided, and open), the study concluded that open inquiry learning is the most effective in improving science process skills. Nwagbo and Uzoamaka (2011) also found that practicum is a suitable method for training science process skills. Therefore, implementing open inquiry in biology practicum may serve as a viable strategy to improve the science process skills of prospective biology teachers. The study aims to investigate the effectiveness of the open inquiry practicum model for biology teacher candidates and its significant impact on the students' basic and integrated process skills.

Method

The first phase of the study involved developing open-inquiry biology practicum instructions to address the first research problem. The development process of the learning tools followed the ten-step Dick and Carey development model, as suggested by Setyosari (2013). Meanwhile, to address the second research problem, an essay test was developed to assess the students' science process skills. The test included questions on various skills, such as observation, inference, grouping, problem determination, lab work preparation, report writing, and conclusion drawing. The development of the test was informed by previous studies by Chabalengula et al. (2012) and Nur et al. (2013).

A quasi-experimental study was conducted to examine the effect of open inquiry practicum on students' science process skills. The study used an un-equivalent control group design, which divided the students into a control group and an experimental group (Ali & Asrori, 2014). The control group received traditional practicum, which was based on the lecture's guidelines, while the experimental group received the open inquiry practicum model. All groups were given pre-tests and post-tests on science process skills, as described below.

Experimental group	O1	X	O2
Control group	O3		O4

Description:
O1 and O3 = pretest
O2 and O4 = post-test
X = treatment (open inquiry practicum)

The study was carried out in the Biology Education Study Program at the Faculty of Teacher Training and Education (FKIP) Universitas Mataram, specifically in the Invertebrate Zoology course. The course was selected because it involved both indoor and outdoor practicum activities, which allowed students the freedom to develop practicum that incorporated open inquiry learning.

The population of this study is the odd semester students of the Biology Education program at the Faculty of Teacher Training and Education, Universitas Mataram in the academic year 2022/2023. The sampling technique used in this study is purposive sampling. The sample consists of 35 students divided into two classes, one class as the experimental group and the other class as the control group. The control group has 20 individuals, while the experimental group has 15 students.

The research data included pretest and posttest scores on science process skills for both control and experimental groups. To test the impact of the open inquiry practicum model on science process skills, Mann Whitney test was used since the data did not exhibit a normal distribution and had homogeneous variance (Prayitno, 2012; Sarwono, 2015). All statistical analyses were conducted using the SPSS 22 statistical package. A summary of the research stages is presented in the following scheme.

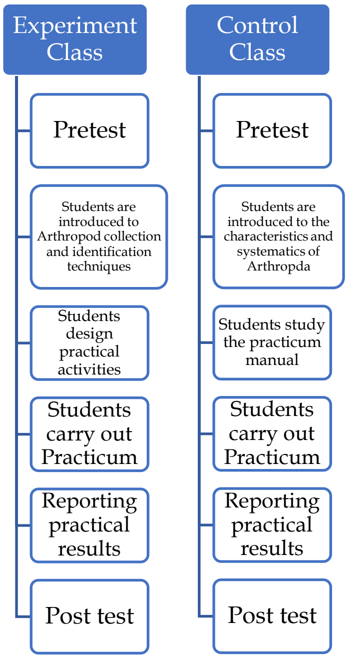

Figure 1. Schematic of research stages

Result and Discussion

In this study, the open inquiry model practicum was implemented by allowing students to have the freedom to design their own practicum activities. The lecturer's role was to motivate students and guide them in designing, conducting, and reporting their practicum activities related to the topic of arthropod diversity. In the beginning of the open inquiry practicum activities, the lecturer presented phenomena and data related to the diversity of invertebrate animals, specifically arthropods. The presentation was done by sharing the results of insect research conducted in several areas of Lombok Island, such as Suranadi and Kerandangan Nature Tourism Park (NTP). Additionally, the students were provided with instructions on various techniques for collecting, preserving, and identifying animal specimens, particularly arthropods.

The next step was to assign students to create instructions for the activities to be carried out and select locations for data collection. The goal of this set of activities was to identify the diversity of arthropods in the sampling location. The lecturer functioned as a motivator in this phase, encouraging students to put in their best efforts to develop and execute their practicum designs both in the field and in the laboratory. Furthermore, the lecturer provided guidance to students during the process of designing, conducting, and reporting their practicum results.

The invertebrate zoology practicum was conducted by the students at the Nature Tourism Park (NTP) and then continued in the biology laboratory of FKIP Universitas Mataram. At NTP Kerandangan, students collected arthropods by using insect nets and traps to capture arthropods that were active on the ground. The student practicum activities in the field were shown in Figure 1.

Once the arthropods were collected, students proceeded to bring them to the laboratory where they would identify them at the order and family level. The lecturers provided assistance to students during this process of arthropod identification. The students' laboratory activities are illustrated in Figure 2.

Figure 2. Arthropod sampling in Kerandangan National Park using nets (top) and pitfall traps (bottom)

Figure 3. Open inquiry practicum activities in the biology laboratory

To evaluate the initial abilities of the students, a pretest was administered before the Invertebrate Zoology practicum was conducted. The pretest consisted of a science process skills test in the form of an essay question and was given to both the control and experimental groups. After completing the practicum, a post-test was conducted to assess the students' learning outcomes. The practicum topic focused on the collection and identification of arthropod animal groups, which was carried out by both the control and experimental classes. The control class was given practicum instructions, while the experimental class designed experiments based on literature searches and discussions with the practicum lecturer. Table 1 presents the results of the post-test, which assessed the science process skills of both the control and experimental groups.

Table 1. Pretest and Posttest Scores of Science Process Skills in Control and Experimental Classes

		N	Mean	Std. Error
Pretest Score	Experimental Class	15	14.73	3.364
	Control Class	20	20.90	4.881
	Total	35	18.26	3.143
Posttest Score	Experimental Class	15	83.20	1.631
	Control Class	20	64.25	5.056
	Total	35	72.37	3.349

Non-parametric statistical tests, specifically the Mann-Whitney test, were employed to test the hypothesis. The test was conducted to determine whether there was a significant difference between the average scores of the control and experimental groups. The results of the Mann-Whitney test revealed that there was no significant difference between the two groups, as evidenced by a p-value of 0.882, which was higher than the alpha value of 0.05. This finding indicates that both the control and experimental group students had similar levels of initial ability in terms of science process skills. Table 2 provides the detailed results of the Mann-Whitney test.

Table 2. Mann-Whitney Test Results on Science Process Skills Pretest

	Pretest Score
Mann-Whitney U	145.500
Wilcoxon W	265.500
Z	-.151
Asymp. Sig. (2-tailed)	0.880
Exact Sig. [2*(1-tailed Sig.)]	0.882[b]

a. Grouping Variable: Treatments
b. Not corrected for ties.

The post-test results showed a significant difference between the experimental and control classes in terms of science process skills. The experimental class had a significantly higher average score compared to the control class, as shown in Table 1. The Mann-Whitney test was used to analyze the results, and the significance value was 0.003 (Table 3), which is less than the alpha value of 0.05. This implies that the open inquiry practicum model used in the experimental class led to a significant improvement in their science process skills.

Table 3. Mann-Whitney test results on the posttest of control and experiment classes

	Posttest Score
Mann-Whitney U	62.000
Wilcoxon W	272.000
Z	-2.955
Asymp. Sig. (2-tailed)	0.003
Exact Sig. [2*(1-tailed Sig.)]	0.003[b]

a. Grouping Variable: Treatments
b. Not corrected for ties.

Science process skills refer to a set of abilities required in conducting practical activities such as observing, measuring, designing experiments, collecting and analyzing data, and presenting findings. The findings of this study reveal that the average score of science process skills in the class that applied the open inquiry practicum model was significantly higher than the control class. These results suggest that the implementation of the open inquiry model has been effective in enhancing students' science process skills. These results are consistent with the research findings of Gormally et al. (2009), Kanli and Yagbasan (2014), Baskoro et al. (2017), and Sahyar and Hastini (2017), which indicate that the implementation of inquiry learning leads to higher achievement of science process skills than conventional learning.

The outcomes of this study were influenced by the implementation of the open inquiry practicum model, which assigns more responsibility to the students in completing the experiment than those given to the control class students. The significant difference in responsibility between the two groups can be observed in the open inquiry class students being assigned tasks ranging from creating experimental problems, developing experimental designs, gathering experimental data, and presenting experimental results (Llewellyn, 2013). In contrast, the control class had a smaller burden of responsibility since the experiments carried out were guided by comprehensive work instructions from problem-solving to presenting experimental data, and students only had to follow those instructions (Gormally et al., 2009).

The allocation of higher responsibility to students in the open inquiry class has resulted in various efforts and cooperation from students to fulfill these responsibilities, leading to increased cohesiveness, cooperation, and more concrete learning. This is consistent with the findings of Akinoglu (2008); Bayram et al. (2013); Lin et al. (2017), who reported that assigning greater responsibility in inquiry activities can increase students' motivation, interest, and scientific attitude toward the lesson. Additionally, Aljaafreh (2013) highlighted that the increase in students' motivation and scientific attitude can contribute to their desire to explore various scientific activities, which ultimately leads to the improvement of science process skills in experiments.

The student activities involved in the open inquiry practicum, such as formulating experimental questions, brainstorming possible answers, creating experimental designs, analyzing data, and drawing conclusions, can stimulate critical thinking among students. This is consistent with the findings of Fuad et al. (2017) that the implementation of inquiry-based strategies promotes critical thinking among students. The enhancement of critical thinking skills is known to improve students' understanding of science process skills in experiments (Azizmalayeri et al., 2012; Kitot et al., 2010).

The control class students conducted experiments using complete instructions and are commonly referred to as "cookbook labs" (Gormally et al., 2009). Although cookbook labs provide opportunities for students to practice basic process skills, such as observing, measuring, and calculating, they do not provide sufficient training for higher process skills such as problem formulation, hypothesis formulation, variable identification, and experimental design (Anggraini, 2012). This finding aligns with the results of the current study, which show that both experimental and control class students were able to answer a question regarding the parts of the insect's body correctly, but the open inquiry class students provided better answers when asked to design a method for collecting and preserving insects. The ability of the experimental class students to solve problems that involve integrated process skills, such as designing experiments, may have contributed to their significantly higher average score in science process skills compared to the control class. This suggests that implementing the open inquiry practicum model can lead to greater development of science process skills in students compared to cookbook labs.

The application of the open inquiry practicum model, which allows students to design their own activities, positively impacts students' science process skills. As mentioned by Sadeh and Zion (2009) and Zion and Mendelovici (2012), students in open inquiry classes exhibit higher abilities in literature search, idea generation, problem-solving techniques, understanding work procedures, variable control, working methods, and statistical analysis compared to students who do not apply open inquiry learning.

The higher science process skills of the open inquiry class may also be attributed to the greater autonomy that students have in choosing their own experimental problems, which allows them to select activities that align with their interests. As a result, their investigations become more meaningful and engaging to them. When students work on investigations that are relevant to their interests, they tend to be more motivated to succeed (Rosenshine, 2012), and they may engage in a variety of activities during their investigations, which can facilitate the development of integrated process skills (Nworgu & Otum, 2013).

Although the study's findings demonstrate that the open inquiry practicum model is more effective in improving science process skills than the control class, it is important for educators to recognize that not all students are able to fully implement open inquiry learning, which can negatively impact their learning motivation. Arslan (2014) noted that not all students are capable of implementing open inquiry directly, as shown by his investigation of prospective teacher students who often have difficulty applying integrated process skills, such as making experimental designs, when implementing open inquiry. This indicates that it may be better to prepare students for the highest level of inquiry by implementing lower levels of inquiry, such as guided inquiry, when students are not ready to implement higher levels of inquiry.

Conclusion

To summarize, the study shows that implementing the open inquiry practicum model has a significant impact on improving the science process skills of prospective biology teacher students, especially in terms of higher-level skills such as integrated process skills. Therefore, it is recommended that the practicum adopts the open inquiry learning model as much as possible to enhance the science process skills of students.

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