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SCRUTINIZING SCIENCE PROCESS SKILLS OF PRE-SERVICE TEACHERS THROUGH OPEN ENDED AND GUIDED INQUIRY MODULE

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Abstract

Science process skill (SPS) is very important for developing science concept knowledge and scientific attitude. This skill was a challenge for pre-service science teachers, especially in the Indonesian curriculum. Thus, pre-service science teachers require SPS to implement science learning using the inquiry module. This study aims to investigate the Science Process Skills (SPS) of pre-service teachers in Environmental Education classes, based on groups, gender, and educational streams through open ended and guided inquiry modules. 204 pre-service science teachers participated in this quasi-experimental design namely "non-equivalent control group design" using open-ended inquiry module, guided inquiry module, and conventional module. Using Two-way ANOVA, MANOVA and MANOVA factorial 3x2 analysis, the results revealed that there were statistical significances found at $p=0.00$ of SPS based on the groups. Meanwhile, the analysis of statistics based on gender ($p=0.70$) and the educational stream ($p=0.70$) reveals no significant difference. There were also no significant differences in the Mean score test of SPS constructs based on educational stream and groups. These findings indicate that open-ended inquiry and guided inquiry modules can enhance pre-service teachers' SPS. The implication of this study leads to the suggestion of the enhancement of SPS pre-service teachers by using inquiry-based learning.

Keywords: Science Process Skill, Pre-Service Science Teachers, Open Ended

A. Introduction

Science process skills (SPS) are students' ability to apply the scientific method to understand, develop science and discover knowledge (Dilek et al. 2020; Lestari & Diana 2018). SPS is also a skill that requires students to acquire knowledge (Damopolii et al. 2019; Lestari & Diana 2018; Rumalolas et al. 2021) and understand the knowledge acquired (Erkol & Ugulu, 2014). SPS is an adaptation of the skills used by scientists to gather knowledge, think about problems and make conclusions (Dwianto et al. 2017; Lestari & Diana 2018). Mastery of SPS has a very large influence in developing high-level mental processes such as critical thinking and making decisions (Adnyana & Citrawathi 2017; Koray et al. 2007) so that someone who has this ability will be able to think creatively and be able to develop it in other disciplines (Demir & Sahin, 2018; Thompson, 2017; Wirayuda et al., 2022). Skills in SPS need to be seen as a way that will help students gain their own knowledge and understand how that knowledge is acquired (Bati et al., 2010; Turiman et al., 2012). Therefore, SPS is very important to be trained and developed in the learning process because this is a basic competency for developing scientific attitudes and students' skills in solving problems, so as to form creative, innovative, critical and competitive personalities in global competition in society (Turiman et al., 2012).

In the context of education in Indonesia and other countries, SPS has become an important component at all levels (Ango, 2002; Chabalengula et al., 2012; Fitriani et al., 2021; Özgelen, 2012). However, a large number of studies evidenced that students continue to have low SPS and little training (Al-rabaani, 2014; Athiyyah et al., 2020; Kjærnsli & Lie, 2004; Nicol et al., 2023), there is less encouragement for the tools and practical resources' availability (Nuangchalerm & Prachagool, 2010; Walshe, 1998). To teach SPS, a very suitable approach is through scientific inquiry. Scientific Inquiry is a learning model where students need to understand science concepts through experimentation (Bain et al., 2023; Hall & Hampden-Thompson, 2022; Mikropoulos & Iatraki, 2023; Sudirman et al., 2023; Valdez-Ward et al., 2023; Weder et al., 2023).

Through Scientific Inquiry can stimulate thinking skills and increase interest and motivation to learn science because it is a 'hands on' and 'minds on' activity (Bell, 2010; Haury, 1993; Jarrett & Laboratory, 1997; Margunayasa et al., 2019; NRC, 2000; Perla et al., 2023) and also can increase positive attitude and scientific attitude (Hafizan et al., 2012; Haury, 1993; Sadi & Cakiroglu, 2011; Thuneberg et al., 2017).

There are four reasons why you should use SPS for training. *First*, scientific development is accelerating, making it impossible for educators to convey all the facts and concepts to their students. Therefore, SPS is a skill that requires student knowledge acquisition (Karsli & Ayas, 2014; Karsli et al., 2010) and also understand the knowledge acquired (Bati et al., 2010). *Second*, students understand complex and abstract concepts better when concrete examples are presented. Third, scientific discoveries are relative, not absolute. All concepts found are still open to questioning and investigation. *Fourth*, in learning, the development of concepts should not be separated from the development of process competencies and values. (N. Y. Rustaman, 2007). Therefore, it is expected that if educators can successfully use SPS, they will be able to successfully introduce SPS in the classroom. Proper mastery of the SPS requires a strong focus on practical and spiritual activity (Aini & Dwiningsih, 2014; Ateş & Eryilmaz, 2011; Park, 2010; Sadi & Cakiroglu, 2011).

The importance of SPS in the concept of science and the scientific attitude of prospective teacher students (Ango, 2002; Dwianto et al., 2017; Erkol & Ugulu, 2014; Lestari & Diana, 2018; Sadi & Cakiroglu, 2011) Students must also be taught to conduct scientific research and develop a better understanding of the concepts under study (Misbahul J, 2020), solve the problem (Hafizan et al., 2012), as well as developing higher mental processes such as critical and creative thinking skills and decision-making skills (Adnyana & Citrawathi, 2017; Koray et al., 2007). Teachers who have good knowledge of science concepts can usually master SPS well too (Radford et al., 1992).

However, several previous SPS studies of prospective student-teachers in Indonesia, the United States, Malaysia, and Turkey have been unsatisfactory and fall in the lower category (Adlim et al., 2020; Aminaha Wahab, 2018; Chabalengula et al., 2012; Danilo Gomes de Arruda, 2021; ERYILMAZ & KARA, 2016; Susilawati et al., 2019; Tan Ming Tang & Chin Teoi Peng, 2001; Zeha, 2014). Research result Aminaha Wahab (2018) shows that the stage of achieving basic science process skills (SPSD) of teachers in learning is in the high category while the stage of achieving integrated science process skills (SPST) is simple. Research result Tan

Ming Tang and Chin Teoi Peng (2001) shows that the achievement level of teachers who are taking courses for 14 weeks at the university is unsatisfactory.

Indonesia and other countries take SPS development seriously for student teacher candidates. There are several factors that influence SPS for prospective teacher students in several countries. These factors include differences in study programs (Jarrett & Laboratory, 1997; Rustaman, 2008; Santa, 2008) and gender (Al-rabaani, 2014; Chabalengula et al., 2012; Haurry, 1993; Karsli et al., 2010; Lincoln et al., 2004; Mutisya, S.M., Rotich, S., 2013; NRC, 2000; Özgelen, 2012; Rumlolas et al., 2021; N. Rustaman, 2008). Research result (Misbahul J, 2020; N. Rustaman, 2008) shows that the SPS of prospective teachers of the Biology Study Program is higher than that of prospective teachers of the Physics Study Program. While the research results (Mutisya, S.M., Rotich, S., 2013) We can see that the SPS of the physics teacher training students is higher than that of the biology teacher training students. Gender influences the outcome of inquiry-based her SPS learning, with a much higher proportion of females than males.

Therefore, to develop SPS, professional educators are needed ((NSTA), 2006; Boyle & Cook, 2023; Irwanto, 2023; Orion & Kali, 2005; Siantuba et al., 2023; Stockard, 1990; Totten, 2008; Walshe, 1998; Widick, 1976). In order to be able to teach the skills effectively and meaningfully to students, the teacher should possess a strong understanding and must exhibit competence in SPS to be able to effectively teach the skills in their classroom (Nicol et al., 2023). Professional educators also have conceptual knowledge (Hafizan et al., 2012; Nuangchalerm, 2012; Sumarni et al., 2017; Turiman et al., 2012; Vergara et al., 2021) scientific skills and attitudes (Misbahul J, 2020; NRC, 2000; N. Rustaman, 2008; Turiman et al., 2012), and good pedagogy (Access, n.d.; Astalini et al., 2023; García-Vandewalle García et al., 2023; Krauskopf et al., 2018; Leránóz-Iglesias et al., 2023) He explained that professional educators can plan and implement different learning strategies as they see fit for science learning, and even use different learning methodologies and models. A teacher's success in delivering learning in the classroom depends on knowledge of the content and how the learning is delivered appropriately (Evriani et al., 2017; Lestari & Diana, 2018; McLure, 2023; Sudirman et al., 2023).

To produce memorable learning as well and to improve SPS for student teacher candidates, inquiry is a suitable model to be applied in the classroom (Areepattamannil et al., 2020; Astalini et al., 2023; Eltahir et al., 2023; Ramadani et al., 2021; Ramma et al., 2018; Sajidan et al., 2020; Tang et al., 2017; Uludağ & Semra Erkan, 2023; Veloo et al., 2013). Through

inquiry student teacher candidates can have a good impact and can be applied when they carry out learning in class. The effectiveness of inquiry-based science learning, especially guided inquiry for prospective teacher students, has been studied by several researchers, including (Ceylan & Ozdilek, 2015; Lamminpää et al., 2023; Nuangchalerm & Prachagool, 2010; Stamer et al., 2021). Overall the results of their research reported that guided inquiry is a learning model that can increase self-confidence, develop various skills, develop understanding of content knowledge and scientific knowledge of prospective teacher students.

Although learning through guided inquiry can lead to good science learning, the implementation of learning using inquiry is still a problem for educators (N. Rustaman, 2008; N. Y. Rustaman, 2007). The main problem is the quality of teacher learning. SPS development occurs indirectly when students carry out activities given by the teacher. The teacher feels that SPS will occur indirectly when students do the experiment (Evriani et al., 2017). The quality of teacher learning has not changed much even though they have attended various workshops and training. Teachers who have attended and frequently attended workshops and conferences related to their areas of expertise should be able to increase their knowledge of the concepts they teach (Al Mamun & Lawrie, 2023; Jarrett & Laboratory, 1997; Sudirman et al., 2023; Uludağ & Semra Erkan, 2023). Furthermore, teachers who do not have good creativity and knowledge in developing independent learning (Pamenang et al., 2020; Peretz et al., 2023; N. Rustaman, 2008; Widiyanti & Kurniawan, 2021). This is influenced by the teacher's habit of teaching conventionally because when they were at university they were taught through lectures (Brouwer et al., 2022; Chang & Mao, 1999; De Leon Saura & Mamaoag, 2023; Mohajer et al., 2023; Palennari, 2016; Peretz et al., 2023; Setyorini et al., 2011; Thambu et al., 2020; Wirayuda et al., 2022).

Some of the weaknesses in implementing college learning for student teachers in the current curriculum include: 1) Teacher candidates are often not given the opportunity to combine content knowledge with experimentation. Because they think of her two things as separate things. 2) Part of science education is provided by teachers who have no experience teaching science in schools. I can't give you an example. 3) The enrichment of scientific concepts is academic that it is difficult for students to understand (Bouzit et al., 2023; Zuhri et al., 2023). Finally, the learning model through inquiry that has been obtained while in college is not implemented by the teacher when teaching in class (Astalini et al., 2023; Zuhri et al., 2023). This situation is very unfortunate

even though they realize that learning with inquiry will have a good impact, especially in improving student SPS (Evriani et al., 2017; Lusidawaty et al., 2020; N. Y. Rustaman, 2007).

Modular learning is learning that can increase student motivation so that learning is more effective and productive so that the feedback they receive is faster and more precise (Astalini et al., 2023; Hasanah et al., 2023; Irwanto, 2023; Miftakhurrohman et al., 2023; Natália Gil Canto; Marcelo Albuquerque de Oliveira; Gabriela de Mattos Verenoze., 2022; Noris et al., 2023). Modular learning can also increase student activity both individually and in class within a predetermined time (Astalini et al., 2023; Hasanah et al., 2023; Juanamasta et al., 2023; Perla et al., 2023; Sudirman et al., 2023). Learning by using modules is considered more effective and efficient, practical, usability, reusable, and compatibility (Hasanah et al., 2023; Herlina et al., 2022; Irwanto, 2023; Miftakhurrohman et al., 2023; Noris, M., Saputro, S., 2021b; Noris et al., 2023; Saraswati et al., 2019). For this reason, in this study through the use of inquiry-based science learning modules it is hoped that it can improve the SPS of prospective teacher students.

The Inquiry-Based Science Learning Module (MPSBI) developed in this study aims to assist lecturers in teaching environmental education courses effectively in class, and being able to solve environmental problems in everyday life through inquiry-based learning. MPSBI is a learning module which consists of information that can facilitate lecturers in developing student teacher candidate SPS in learning environmental knowledge. MPSBI also consists of five sections, namely, 1) SAP; 2) learning objectives; 3) hands-on activities; 4) Learning materials, and 5) assessment. The MPSBI developed in this module consists of a open-ended inquiry module (MIB) and a guided inquiry module (MIT). The difference between MIB and MIT is in hands-on activities, where the hands-on MIB activities of prospective teacher students carry out experiments freely and these experiments are fully controlled by prospective teacher students. Whereas at MIT student teacher candidates carry out experiments through the guidance of lecturers and according to the five phases of inquiry proposed by (Grimm et al., 2023; NRC, 2000) namely 1) formulating problems and hypotheses, 2) planning and carrying out experiments, 3) collecting data, 4) analyzing data and 5) communicating the results of the investigation. The similarity of this module is that at the beginning of learning, videos are given and the problems given are based on environmental issues contained in

newspapers or events that occur in everyday life. While the form of assessment given is the same. Therefore, the hypothesis in this study is:

H0: The Open Ended and Guided Inquiry modules have a significant effect on Pre-service Teacher Science Process Skills

H1: The Open Ended and Guided Inquiry modules have no significant effect on Pre-service Teacher Science Process Skills

B. Method

1. Research Design and Sample

The research design of this study was a quasi-experimental non-equivalent control group pretest/posttest design (Creswell 2012). The quasi experimental design is done with purpose on identifying the differences between control group and treatment group. Quasi-experimental research was carried out using a 3x2x2 factorial. The first independent variable is the learning model used (guided inquiry module, open-ended inquiry module and conventional learning). The second independent variable is study program (biology and physics) and the three genders (male and female). The design of this study is shown in table 1 below:

Table 1. Research design

Class	Pretest	Treatment	Posttest
Experiment I (Open-ended inquiry)	O ₁	X ₁	O ₂
Experiment II (Guided Inquiry)	O ₁	X ₂	O ₂
Control (Conventional)	O ₁	X ₃	O ₂

Based on table 1, at the initial meeting the three classes were given a pretest. Thirteen SPS questions are given in the form of objective questions, where prospective teacher students should choose the correct answer based on their initial knowledge in environmental learning about the basic concepts of environmental knowledge and its problems.

Furthermore, the treatment was carried out in two experimental classes and one control class according to the study program (biology and physics). In the experimental class I, environmental learning was carried out using the open-ended inquiry module. This module develops the skills of prospective teacher students in independent inquiry aimed at improving SPS. In the experimental class II, environmental learning was also carried out using the guided inquiry module. These two modules are science learning modules that integrate the five steps of inquiry-based

science learning (NRC, 2000). The integration of the five inquiry steps is also intended to increase SPS mastery. while in the control class conventional learning was carried out. In this class, prospective teacher students are not given treatment and activities related to inquiry-based learning. the learning model is in accordance with what is usually carried out by lecturers in class.

The sample used in this study were 204 student teacher candidates consisting of 104 student teacher candidates in the biology study program and 100 student teacher candidates in the Physics study program at the Tarbiyah and Teacher Training Faculty of Ar-Raniry State Islamic University Banda Aceh. The sampling method that was used in this study is random group assignment. Random group assignment is a method to randomly put participants in samples into different treatment groups. Participants will then have an equal chance of being placed in a treatment group or control group in an experimental research method without any bias conditions (Lavrakas et al., 2019). Due to the unbiased sample and ability to present the findings for the entire population, random group assignment will also offer a great level of validity in experimental research methodology output. Table 2 below shows the profile of prospective student teacher respondents in the research.

Table 2. Number of prospective teacher students according to study program

Program studies	The number of student teacher candidates in the class			Total
	Eksperimen t I (Open-ended inquiry)	Eksperiment II (Guided Inquiry)	Control (Conventional)	
Biology	35	33	36	104
Physics	33	34	33	100
Total	68	67	69	204

Table 2 shows that the research respondents were 204 prospective teacher students from two study programs, namely Biology and Physics. Of the 204 respondents who were involved in this study, 104 students (50.98%) were student teacher candidates from the Biology study program and 100 people (49.02%) student teacher candidates from the Physics study program. then the prospective teacher students were again divided into three different learning model classes. 68 student teacher candidates (33.33%) were in the open-ended inquiry class (Experimental class I), 67

people (32.84%) were in the guided inquiry class (Experimental class II), and 69 people (33.82%) were in the conventional class (control class).

Profile of prospective teacher students according to gender in the three classes, there were 139 women (68.14%) more than 65 men (31.86%). In detail according to the type of sex of each class, the open-ended inquiry class of Biology study program has a total of 35 people, of which 10 are male and 25 are female. For the Physics study program there are 33 people, of which 13 are men and 20 are women. then for the class that received guided inquiry in biology study program there were 33 people, 11 boys and 22 girls. For the Physics study program there are 34 people, 11 men and 23 women. Whereas in the conventional class in the biology study program there were 36 people, 10 men and 26 women. The class of prospective teacher students in the Physics study program consisted of 33 people, 10 men and 23 women.

2. Research Instruments

To determine the effectiveness of the inquiry-based science learning module for SPS, the authors provide thirteen questions about the basic concept of the environment and its problems, namely questions about testing SPS mastery of prospective teacher students. The questions in this construct are in the form of questions that can determine the skills of prospective teacher students related to scientific concepts that occur in everyday life. The SPS questions developed in this study are the skills of observing, hypothesizing, designing experiments, carrying out experiments, applying concepts and communicating.

3. Data Analysis

The statistics used in analyzing this research are descriptive statistics and inference statistics for quantitative data. The analysis of this study uses the SPSS "Statistical Package for Social Science" to determine the mean, percentage, standard deviation. then to determine the effectiveness of using the inquiry module in improving SPS mastery using two-way Anova and 3x2 Factorial Manova.

C. Result and Discussion

The initial study was conducted to determine the teacher's initial capacity regarding the mastery of science process skills.

1. Result

This aims to assess the extent to which pre-service teachers can carry out construct orientation from SPS. The research results can be seen in table 3.

Table 3. Preliminary Study of SPS Construction

SPS Construction	1	2	3	4	5	6
1. Observe	0.79					
2. Hypothesis	0.	0.61				
3. Design Experiments	0.	0.	0.73			
4. Carry Out Experiments	0.	0.	0.	0.65		
5. Application of The Concept	0.	0.	0.	0.	0.70	
6. Communicate	0.	0.	0.	0.	0.	0.60
Mean			6.06			
Standard Deviation			2.44			
Skewness			0.170			
Alpha Cronbach			0.079			

Based on the results of the initial analysis of the ability of pre-service teachers, it shows that the ability to observe (0.79), hypothesize (0.61), design experiments (0.73), carry out experiments (0.65), apply concepts (0.70), and ability to communicate (0.60). This shows that in the initial study the teacher's ability was relatively low in the ability to design experiments, carry out experiments, and communicate. Even though this ability is a crucial ability that must be mastered by the teacher. While the mean value indicates that the overall interpretation of scientific process ability is well oriented with a mean value of around 6.06. while Cronbach's alpha value shows $0.079 > 0.05$. that is, the instruments used in research are relatively constant or reliable.

In general, differences in SPS mastery of prospective teacher students between classes based on study program can be seen in Tables 4, 5, and 6 below. The three tables show the mean, standard deviation, pretest and posttest, two way ANOVA analysis and Post Hoc Scheffe analysis. Prior to that, a prerequisite test was carried out to see.

Table 4. Mean and standard deviation of pretest and posttest SPS strengthening of prospective teacher students between classes based on study program.

Kelas	Study Program	N	Pretest		Posttest	
			Mean	Standar Deviasi	Mean	Standar Deviasi
Open-ended inquiry	Biology	35	44.49	22.123	69.59	14.426
	Physics	33	40.69	19.842	69.	14.807

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					91	
	Total	68	42.64	20.978	69.74	14.503
Guided Inquiry	Biology	33	41.55	17.076	73.16	12.630
	Physics	34	39.49	16.795	72.68	14.549
	Total	67	40.51	16.837	72.92	13.536
Conventional	Biology	36	45.83	13.376	42.26	15.960
	Physics	33	47.61	13.559	40.25	14.813
	Total	69	46.68	13.394	41.30	15.342

Based on the results of the analysis of open-ended inquiry scores, the mean pretest for biology and physics study programs was around 42.64%, while the posttest score was around 69.74%. this shows a significant increase when using the learning model using guided inquiry based modules. In guided inquiry the mean value at the pretest was around 40.51% while the posttest was around 72.92%. whereas in conventional inquiry the mean pretest showed 46.68% and posttest ranged from 41.30%. From the inquiry model used to empower SPS abilities of prospective teacher students, it shows that the use of the guided inquiry module is far more effective than the other two modules, namely open-ended inquiry and conventional inquiry. From the results of the analysis above, a two-way ANOVA analysis was then carried out to find out the differences in SPS mastery of prospective teacher students based on class distribution and study program. This can be seen in table 5 below:

Table 5. Two-way ANOVA analysis of differences in SPS mastery of prospective teacher students between classes based on study program

	Type III Sum of Squares	Df	Mean Power Two	F	Sig.
Class	41561.333	2	20780.666	97.686	0.000
Study Program	26.174	1	26.174	0.123	0.726
Class*Study Program	47.798	2	23.899	0.112	0.894
Standard Error	42120.376	198	212.729		
Total	846985.063	204			

Based on the results of the ANOVA test, it can be concluded that the science processing abilities of physics and biology teacher candidates have significant differences. This can be seen from the significance value between study programs and classes having a sig value. It ranges from $0.894 > 0.05$, meaning that there is a significant difference between classes and study programs in mastering the SPS concept for prospective teacher student.

Scheffe's Post-Hoc analysis was then used to see the difference between the treatment using inquiry and class models. This can be seen in table 6 below:

Table 6. Scheffe's Post-Hoc Examination of differences in SPS mastery of prospective teacher students by class

Class (I)	Class (J)	Difference Means (I-J)	Standard Error	Sig.
Open-ended inquiry	Guided inquiry	-3.1728	2.510	0.451
	Conventional	28.4449*	2.492	0.000
Guided Inquiry	Open-ended inquiry	3.1728	2.510	0.451
	Conventional	31.6177*	2.501	0.000
Conventional	Open-ended inquiry	-28.4449*	2.492	0.000
	Guided Inquiry	-31.6177*	2.501	0.000

Analysis of the results of the SPS research using the Two Way Anova and the Post Hoc Scheffe test as shown in Tables 4, 5, and 6 shows that there is no significant difference in SPS mastery between student teacher candidates who use open-ended inquiry and student teacher candidates who use guided inquiry. This means that student teacher candidates who use independent inquiry have the same SPS mastery as student teacher candidates in guided inquiry classes. while the class of prospective teacher students who used open-ended inquiry had higher SPS mastery compared to student teacher candidates who used conventional learning. student teacher candidates who use guided inquiry also have higher SPS mastery than student teacher candidates who use conventional learning. These results indicate that the use of inquiry-based

science learning modules is effectively used in environmental learning in improving student teacher candidate SPS.

Mastery of science process skills can be influenced by several aspects including the treatment model given, gender, and several other factors. Table 7 will provide an overview regarding the difference in average scores⁵⁸ between male and female prospective teachers in mastering SPS. Based on the results of the prerequisite test, it shows that the Kolmogorov-Smirnov score for men ranges from 0.987 and for women 1.415 > 0.05, meaning that between men and women are normally distributed. While the Kolmogorov-Smirnov value of the independent inquiry model ranges from 1.019, guided inquiry 0.727, and conventional inquiry ranges from 1.706. which shows⁷⁶ that all inquiry models are normally distributed. Table 7 below shows that the mean and standard deviation of pre-test and post-test as well as two-way ANOVA analysis to see differences in student teacher candidate SPS mastery between classes based on gender.⁸⁴

Table 7. The mean values and standard deviations of the pretest and posttest of SPS mastery of prospective teacher students between classes based on gender

Class	Gender	N	Pretest		Posttest	
			Mean	Standard deviation	Mean	Standard deviation
Open-ended inquiry	Man	23	35.09	17.879	72.05	15.215
	Woman	45	46.50	21.569	68.57	14.154
	Total	68	42.64	20.978	69.74	14.503
Guided Inquiry	Man	22	41.55	14.727	70.77	13.208
	Woman	45	40.00	17.914	73.96	13.718
	Total	67	40.51	16.837	72.92	13.536
Conventional	Man	20	46.42	11.703	49.64	13.409
	Woman	49	46.79	14.139	37.90	14.883
	Total	69	46.687	13.394	41.30	15.342

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¹³ The two-way ANOVA test analysis was carried out to see differences in SPS mastery of prospective teacher students based on gender, indicating that there were no significant differences in student teacher candidate SPS mastery based on gender. Meaning, male student teacher candidates did not show any significant differences with female student teacher candidates in SPS mastery. This shows that the use of

inquiry-based science learning modules has the same impact on male and female student teacher candidates on SPS mastery.

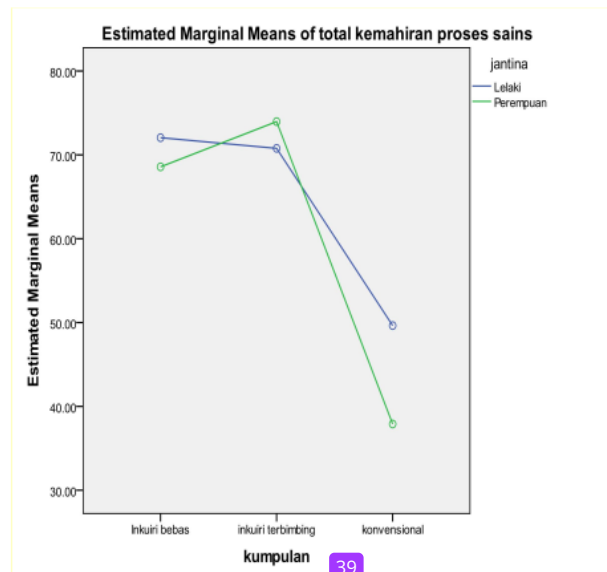
Meanwhile, Table 8 shows differences in mastery of concepts between male and female prospective teacher students which shows that between genders has a significance value ranging from $0.62 > 0.05$, meaning that there is a significant difference between gender and mastery of science process abilities. This can be seen in table 8 below:

Table 8. Two-way ANOVA analysis. Differences in SPS mastery of prospective teacher students between classes based on gender

	Total Power of Attorney of Two Types III	Dk	Mean Squared	F	Sig.
Class	29405.295	2	14702.648	72.956	0.000
Gender	710.150	1	710150	3.524	0.062
Class * Gender	1618.459	2	809.230	4.015	0.020
Standard Error	39902.629	198	201.528		
Total	846985.063	204			

Furthermore, between classes based on gender, the two-way ANOVA test analysis showed that there were significant differences in the SPS of prospective teacher students between open-ended inquiry classes, guided inquiry classes and conventional classes. This shows that there is a relationship or interaction between class and gender on SPS mastery. The SPS owned by male and female prospective teacher students using open-ended inquiry learning modules, guided inquiry and conventional classes are significantly different. This shows that learning using inquiry-based modules is successful in increasing the SPS mastery of male and female prospective teacher students.

Figure 1. Interaction between class and student gender on science process skills



Based on figure 1, it shows that there are differences in science process proficiency between the open-ended inquiry group, the guided inquiry group and the conventional group with gender. There is a significant interaction between inquiry level and gender in science process skills. The interaction that occurs between the group and the sex of the pre-service teacher in science process proficiency, where the female pre-service teacher in the guided inquiry group has higher science process proficiency than the male teacher. However, at the level of free and conventional inquiry male teachers have higher science process skills than female teachers. That is, there is a significant relationship (interaction) between the inquiry model and gender in the teacher's science process skills.

The Box's M test is used to test MANOVA which requires that the variance matrix of the dependent variable is the same (Supranto, 2004). The result of the Box's M test score was 97.243 and the F test value was 0.855 with sig = 0.855 significance, $p > 0.05$ so that the null hypothesis which states the variant matrix of the dependent variable (scientific process skills) is accepted. This shows that the variance matrix of the SPS construct variable (observing, hypothesizing, designing experiments, carrying out experiments, applying concepts and communicating) is homogeneous so that the MANOVA test may be continued for analysis.

Furthermore, the multivariate test was used to test whether each independent factor, namely the study program and learning groups, influenced the dependent variable, namely the SPS construct (observing, hypothesizing, designing experiments, carrying out experiments, applying concepts and communicating). Pillai's Trace is used for one class of dependent variable (pretest or posttest only of science process skills). Pillai's Trace test results in the Multivariate Test table show that overall, there is a significant relationship between independent inquiry class, guided inquiry class and conventional class [$F(12,388) = 13.23$, sig 0.000 $p < 0.05$] to the SPS construct which includes observing skills, hypothesis skills, experimental design skills, experiment carrying out skills, concept application skills and communication skills. However, there is no relationship between the independent variables of biology study program and physics study program [$F(6,193) = 0.078$, sig 0.998 $p > 0.05$] and the effect of study program*class interaction [$F(12,388) = 0.061$, sig 1.000 $p > 0.05$] on the dependent variable, namely SPS construct which includes observing skills, hypothesizing skills, experiment designing skills, conducting experiments skills, concept application skills and communication skills. Table 8 below shows the results of Levene's test to determine the similarity of the variables being compared.

Table 9. Analysis of homogeneity of variance using Lavene's test

SPS Construction	F	df1	df2	Sig.
Observe	7.968	5	198	0.000
Hypothesis	1.794	5	198	0.116
Design Experiments	1.857	5	198	0.103
Carry Out Experiments	2.216	5	198	0.054
Application of The Concept	2.082	5	198	0.069
Communicate	0.570	5	198	0.723

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Based on the results of the analysis as in table 8, the significance value of Lavene's test for the skill construct observes the sig value. = 0.000, $p < 0.05$. while the significant values of the hypothesis constructs, designing experiments, carrying out experiments, applying concepts and communicating sequentially are (0.116, 0.103, 0.054, 0.069 and 0.723), $p > 0.05$. This shows that the variances in the dependent variables and the categories in the independent variables are the same. Furthermore, to see the mean and standard deviation of the SPS construct for student teacher candidates based on study program and class, MANOVA analysis is used as shown in Tables 9 and 10 below.

Table 10. Mean and standard deviation of the SPS construct of prospective teacher students based on study program and class

SPS Construction	Study Program	Class	N	Mean	Standar Deviasi
Observe	Biology	Open-ended	35	85.71	25.928
		inquiry	33	90.90	23.233
		Guided Inquiry	36	61.11	38.005
		Conventional	104	78.84	32.450
		Total			
	Physics	Open-ended	33	89.39	24.230
		inquiry	34	92.64	21.785
		Guided Inquiry	33	59.09	38.435
		Conventional	100	80.50	32.485
		Total			
Hypothesis	Biology	Open-ended	35	77.14	30.541
		inquiry	33	78.78	28.035
		Guided Inquiry	36	44.44	28.729
		Conventional	104	66.34	33.006
		Total			
	Physics	Open-ended	33	77.27	30.849
		inquiry	34	79.41	27.846
		Guided Inquiry	33	42.42	28.287
		Conventional	100	66.50	33.374
		Total			
Design Experiments	Biology	Open-ended	35	65.71	33.806
		inquiry	33	83.33	27.003
		Guided Inquiry	36	34.72	35.495
		Conventional	104	60.57	37.953
		Total			
	Physics	Open-ended	33	65.15	31.831
		inquiry	34	83.82	26.743
		Guided Inquiry	33	33.33	34.610
		Conventional	100	61.00	37.321
		Total			
Carry Out Experiments	Biology	Open-ended	35	71.42	30.403
		inquiry	33	69.69	24.809
		Guided Inquiry	36	44.44	28.729
		Conventional	104	61.53	30.553
		Total			
	Physics	Open-ended	33	72.72	30.849
		inquiry	34	69.11	24.663
		Guided Inquiry	33	42.42	28.287
		Conventional	100	61.50	30.858
		Total			

Application of The Concept	Biology	Open-ended inquiry	35	46.66	27.057
		Guided Inquiry	33	50.50	31.316
		Conventional	36	24.99	23.059
		Total	104	40.38	29.257
	Physics	Open-ended inquiry	33	45.45	27.410
		Guided Inquiry	34	47.05	32.945
		Conventional	33	23.23	22.798
		Total	100	38.66	29.860
Communicate	Biology	Open-ended inquiry	35	78.09	22.784
		Guided Inquiry	33	75.75	22.473
		Conventional	36	49.07	24.543
		Total	104	67.30	26.675
	Physics	Open-ended inquiry	33	77.77	21.516
		Guided Inquiry	34	75.49	20.611
		Conventional	33	46.46	23.482
		Total	100	66.66	25.950

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The results of the analysis of the mean and standard deviation of the SPS construct showed that the mean value in observing ability between biology and physics students was higher than physics students (80.50). In terms of hypothesis ability, physics students scored higher (60.50), physics teacher candidates had higher experimental design skills (61.00), biology students had higher concept applications (40.38), and biology students had higher communication skills (67.30). based on the results of the analysis, it can be seen that the guided inquiry class has a higher value than the open-ended inquiry class and conventional inquiry. Further analysis of the differences in SPS constructs for prospective teacher students based on study program and class can be seen in table 11.

Table 11. MANOVA analysis Differences in SPS constructs for student teacher candidates based on study program and class

Category	Leaning variable	Type III Sum of Squares	Df	Mean Squared	F	Sig.
Study Programe	Observe	65.333	1	65.333	.075	.784
	Hypothesis	9.078	1	9.078	.011	.918
	Design	12.090	1	12.090	.012	.913
	Experiments					

Title of Papers (Filled Out by the Editor)						
Author Name (Filled Out by the Editor)						
Class	Carry Out Experiments	9.578	1	9.578	.012	.912
	Application of The Concept	233.759	1	233.759	.306	.581
	Communicate	57.738	1	57.738	.113	.737
	Observe	40416.826	2	20208.413	23.208	.000
	Hypothesis	55063.044	2	27531.522	32.563	.000
	Design	85576.284	2	42788.142	42.223	.000
	Experiments					
	Carry Out Experiments	34267.114	2	17133.557	21.726	.000
	Application of The Concept	24994.602	2	12497.301	16.346	.000
	Communicate	38580.510	2	19290.255	37.676	.000
Study Program* Class	Observe	287.457	2	143.729	.165	.848
	Hypothesis	67.461	2	33.731	.040	.961
	Design	30.089	2	15.045	.015	.985
	Experiments					
	Carry Out Experiments	94.665	2	47.333	.060	.942
	Application of The Concept	45.577	2	22.789	.030	.971
	Communicate	61.235	2	30.617	.060	.942

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The results of the inference analysis carried out using the 3 × 2 factorial MANOVA test found that based on the study program and class on the constructs of observing skills, hypothesizing skills, skills of designing experiments and skills of applying concepts showed that prospective teacher students who used guided inquiry in Biology and Physics study programs had a Mean score higher than the open-ended inquiry class and the conventional class. while for the skill construct of carrying out experiments and communication skills, it was found that student teacher classes using open-ended inquiry in the Biology and Physics study program had a higher Mean score than the guided inquiry class and the conventional class. These results show that in both biology and physics study programs, student teachers who use open-ended inquiry have higher observing skills, hypothesizing skills, experiment designing skills and applying concept skills compared to class teacher candidates using guided inquiry and open-ended inquiry.

2. Discussion¹³

The two-way ANOVA test analysis was carried out to see differences in SPS³⁴ mastery of prospective teacher students based on gender, indicating that there was no significant difference in SPS mastery of prospective teacher students based on gender. Meaning, male student teacher candidates did not show any significant differences with female student teacher candidates in SPS mastery. This shows that the use of inquiry-based science learning modules has the same impact on male and female student teacher candidates on SPS mastery. The results of this study are consistent with the results of the study (Al-rabaani, 2014; Astalini et al., 2023; Erkol & Ugulu, 2014; Nicol et al., 2023) and contrary to the results of the study (Evriani et al., 2017; Kurniawan & Fadloli, 2016) which shows that the SPS of female prospective teacher students is higher than that of male students.

An analysis of the two-way ANOVA test on differences in SPS mastery of prospective teacher students based on study programs shows that there is no significant difference in SPS mastery of prospective teacher students based on study programs. This means that the science lessons received by prospective Biology and Physics teacher students are both effective. The effectiveness of this learning is due to the fact that each topic of student teacher candidate learning is required to think critically and actively so that they can develop SPS. In line with the results of this study (Krathwohl, 2002; Marzano et al., 2009). Students who have gone through an active learning process are able to demonstrate complex thinking skills such as; communicate effectively, cooperate and collaborate and be able to process information properly and effectively (Anónimo, 1988; Knezek et al., 2023; Krathwohl, 2002; Madhuri et al., 2012). The process of mastering active thinking skill strategies is also needed in assisting professional teachers in developing teaching and learning strategies (Ango, 2002; Leránóz-Iglesias et al., 2023; Sudirman et al., 2023). There is no difference in the SPS of prospective teacher students for both biology and physics study programs because the lecturers have attended seminars and workshops related to innovative learning that can improve SPS. The results of this study are different from the results of previous studies (Jarrett & Laboratory, 1997; Misbahul J, 2020; N. Rustaman, 2008). The results of their research showed that the SPS of prospective biology teacher students and physics teacher education candidates had significant differences.

The results of the inference analysis carried out using the 3 x 2 factorial MANOVA test found that based on the study program and class on the constructs of observing skills, hypothesizing skills, skills of designing experiments and skills of applying concepts showed that prospective teacher students who used guided inquiry in Biology and Physics study programs had a Mean score higher than the open-ended inquiry class and the conventional class. As for the skill constructs of carrying out experiments and communication skills, it was found that prospective teacher classes using open-ended inquiry in the Biology and Physics study program had a higher Mean score than the guided inquiry class and the conventional class. These results show that in both Biology and Physics study programs, student teachers who use open-ended inquiry have high observing skills, hypothesis skills, experimental design skills and concept applying skills compared to prospective teacher classes using guided inquiry and open-ended inquiry. These skills are included in the high-level skills (Krathwohl, 2002) which includes the activity of formulating problems, designing and carrying out a simple investigation, analyzing and interpreting data and activities identifying and analyzing other explanations to be made as well as activities communicating procedures and results of investigations, as well as creating (Marzano et al., 2009).

In this study, each hands-on activity in guided inquiry-based learning of prospective teacher students in both study programs had observation skills, hypothesis skills, experimental design skills and good concept application skills. For hands-on and LKM activities designed to train teachers to observe, they carry out observations using various media according to the concepts being studied such as real objects, models or pictures or graphs. In addition to observing skill aspects, hypothesising skills, experiment designing skills and concept applying skills are also seen through activities designed at the LKM and hands on. In the guided inquiry class in Biology and Physics Study Program. the skills of making hypotheses for prospective teacher students have not shown good results. This is shown when prospective teacher students are given the opportunity to make hypotheses, they are still not used to making temporary conjectures before the experiment is carried out. The ability of student teacher candidates in making hypotheses is the ability of each individual to guess or estimate from a problem (Margunayasa et al., 2019; Yolanda et al., 2019) This means that the ability to make a hypothesis is the ability to connect between two variables or make assumptions or conjectures.

The skills of prospective teacher students in planning investigations and applying the concepts in this study have shown good improvement. prospective teacher students in guided inquiry classes in Biology and Physics study programs have prepared learning tools and materials before learning begins according to the concepts to be studied. The skills needed in designing experiments such as determining the tools and materials to be used, the objects to be studied, the factors or variables that need to be considered, the criteria for success, the methods and work steps and how to record and process data to draw conclusions (Al Salami et al., 2017; Evriani et al., 2017; Lestari & Diana, 2018; N. Y. Rustaman, 2007). At the time of designing and experimenting the teacher can direct the experiment under study and during the experiment being carried out the teacher must act as a facilitator.

The skills of carrying out experiments and communication skills in the open-ended inquiry class of the Biology and Physics Study Program are higher than the guided inquiry class and the conventional class. The results of the analysis of this study indicate that the activities of carrying out and communicating procedures and results of investigations at each meeting of prospective teacher students are very active in class discussions. The activeness of prospective teacher students in this skill can be seen when each class finishes presenting the results of their group work, other groups respond to groups that present investigations through question and answer. However, there are some groups that are not active in this skill. This indicated that the inactivity of student teacher candidates in conducting question and answer was due to the weak ability of middle school teachers in communicating the results of investigations. The ability to communicate is a crucial skill that must be possessed, guided inquiry is able to encourage students' ability to communicate effectively, practically, and flexibly (Amin & Mahmud, 2016; Lusidawaty et al., 2020; Siantuba et al., 2023). A learning experience that is geared towards increasing scientific literacy (Wenning, 2010).

Inquiry learning should develop SPS. This is in accordance with what is stated (Çoruhlu et al., 2023; Evriani et al., 2017; Kuhlthau et al., 2015; Misbahul J, 2020; NRC, 2000; Susilawati et al., 2019) that the essence of inquiry-based science learning generally involves students in the activity of formulating problems, designing and carrying out a simple investigation, analyzing and interpreting data and activities identifying and analyzing other explanations that will be made as well as activities communicating procedures and results of investigations, and creating (Marzano et al., 2009). Meanwhile according to (Krathwohl, 2002) consists

of recall, analysis, comparison, inference, and evaluation. The results of the study show that the initial hypothesis (H0) is accepted, where learning with the Open Ended and Guided Inquiry Modules has a significant effect on Pre-service Teacher Science Process Skills. Inquiry-based learning encourages to improve science process abilities (Arantika et al., 2019; Astalini et al., 2023; Putra et al., 2016; Zuhri et al., 2023).

The importance of SPS in learning using inquiry (Al-rabaani, 2014; Astalini et al., 2023; Kurniawati et al., 2016; Turiman et al., 2012; Zuhri et al., 2023). Teachers play an important role in developing students' SPS. Five aspects of the teacher's role in facilitating students with learning experiences that can develop process skills are: first, providing opportunities to use SPS in exploring equipment and materials as well as phenomena directly (Oztay et al., 2022; Porter & Peters-Burton, 2021). This allows students to use their feelings and collect evidence so as to raise questions and form hypotheses based on existing ideas. Second, provide opportunities for discussion in class. All participants in the class are given the opportunity to share ideas and other participants listen to or refute the ideas given. Third, listen to students who give ideas and evaluate products to get the process they use in forming ideas. For all stages of SPS, teachers can choose how students gather information and use evidence. Fourth, encourage a critical review of how experimental results are obtained. During and after the experiment students discussed how to get better data. Fifth, it provides the necessary techniques for advanced skills such as graphic drawing examples.

In this study, each activity in the hands-on activities and student teacher worksheets (LKM) was designed to train them to have SPS. SPS developed in hands-on and LKM activities such as observing skills, hypothesizing skills, experiment designing skills, conducting experiments skills, applying concept skills and communication skills. Therefore, to improve SPS student teacher candidates learning is done by inquiry or discovery. This is intended so that prospective teacher students can develop high-level mental processes such as critical thinking and making decisions (Koray Özlem, Köksal Mustafa Serdar, Özdemir Muhammet, Presley, 2007; Nicol et al., 2023).

Learning through discovery is not just science learning, but a way of using science to teach students to think (Huzan et al., 2012; Herlina et al., 2022; Noris, M., Saputro, S., 2021a; Singh et al., 2018; Sunday et al., 2022; Wartono et al., 2018). Through SPS in this study such as observing, skills, hypothesizing, skills designing experiments, skills carrying out experiments, skills applying concepts and communication skills provide

opportunities for prospective teacher students to discover new concepts and be able to develop their knowledge so that learning becomes meaningful. Supports Ausubel's theory (1986) that learning must be meaningful, in other words the use of inquiry-based science learning modules can relate the knowledge possessed by prospective teacher students to the knowledge they have just learned. Activities and exercises provided through hands-on and student teacher worksheets are able to relate the knowledge possessed by prospective teacher students to the knowledge learned.

SPS is the essence of science that must be understood by science educators and students. This relates to the limitations of science as a process, that science is not just facts but is the ability to use basic knowledge to predict or explain various natural phenomena. Therefore, the emphasis on the need for SPS for student teacher candidates must be increased again to improve the quality of abilities when teaching in schools. Thus, learning that emphasizes the active process of science can change teacher behavior in teaching science.

D. Conclusion

Learning environmental education using the inquiry module has had a positive impact on improving SPS mastery of prospective students of Biology and Physics Study Program teachers at the Faculty of Tarbiyah and Teaching, State Islamic University of Ar-Raniry Banda Aceh Indonesia. The results of the study show that learning using the open-ended inquiry module and the guided inquiry module can improve SPS mastery for pre-service teachers. Therefore, the experimental class using the inquiry module is more effective than the control using conventional learning. Based on the study program, it was also found that learning Biology and Physics study programs using modules was more effective. Furthermore, the use of inquiry-based modules also has the same impact on male and female prospective teacher students so that they succeed in increasing their SPS mastery.

The results also showed that in both biology and physics study programs, the class of student teachers who used open-ended inquiry had higher observing skills, hypothesis skills, experimental design skills and concept applying skills compared to the class of student teachers who used guided inquiry and conventional classes. However, student teacher candidates do not fully have hypothesis skills and good communication

skills. It is therefore hoped that the development of hypothesising skills and communication skills will be further improved for student teacher candidates to produce prospective teachers who can integrate all SPS constructs into classroom learning.

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