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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 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 (Nuangchalem & 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; Haury, 1993; Karsli et al., 2010; Lincoln et al., 2004; Mutisya, S.M., Rotich, S., 2013; NRC, 2000; Özgelen, 2012; Rimalolas 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; Nuangchalem, 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; Miftakhurrohmah 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; Miftakhurrohmah 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 an 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

					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 students.

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 scores 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 shows 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.

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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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.

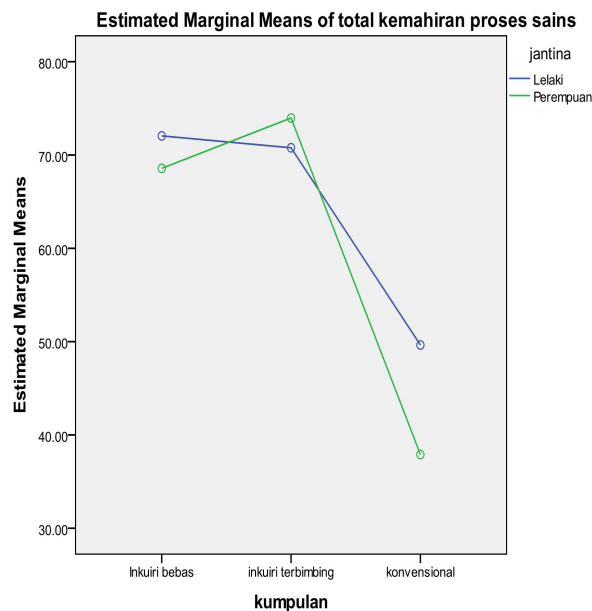
Meanwhile, Table 8 shows differences in mastery of concepts between male and female prospective teacher students which shows that between genders has a significance value ranging from $0.62 > 0.05$, meaning that there is a significant difference between gender and mastery of science process abilities.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

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

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					

<i>Title of Papers (Filled Out by the Editor)</i>						
<i>Author Name (Filled Out by the Editor)</i>						
	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
Class	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

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. 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. Discussion

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 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 & Fadlioli, 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; Leránoz-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 (Hafizan 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 for 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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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 Inquiry, Guided Inquiry

Comment[RV1]:

We ask authors to create abstracts that provide readers with a clear overview of the paper. This gives authors direction while they revise the remainder of their manuscript and aids in helping them arrange their thoughts. Please compose your abstract in 200 words or fewer to demonstrate how the paper is structured in a logical and precise manner. Putting your abstract into a five-sentence essay is one method to accomplish this:

You should describe the issue, the subject of your research, or the gap you hope to address in the first sentence. The research topic or hypothesis for your study would be discussed in the second sentence. You would discuss the subjects and methodology of your study in the third sentence. The fourth sentence should discuss the findings of your investigation. The key points of your discussion of the findings would be covered in the fifth sentence.

A. Introduction

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 (Nuangchalerms & 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

Comment[RV2]:

The introduction of the article is quite detailed in explaining the importance of science process skills (SPS) for prospective science teachers, which is relevant in the context of science education in Indonesia. However, there are several aspects that need improvement to improve the clarity and depth of the analysis.

First, although the article refers to various studies that show low SPS among prospective teachers, the specific and original research gap that the study aims to address is not clearly stated. The author should be more explicit in defining the specific knowledge gap that the study seeks to close, which would strengthen the argument for the novelty of the study.

Second, while the article uses many references to support its claims, several key claims seem to be more general in nature rather than based on specific empirical evidence from previous studies. The addition of a more in-depth literature analysis would help to emphasize the uniqueness and contribution of this study to the existing literature.

Third, the explanation of the research methodology that will be used to address the research gap is also not described in sufficient detail in the introduction. Providing a brief overview of the methodological approach in the introduction could improve the reader's understanding of how the study will be conducted and how the results are expected to provide new contributions.

Overall, while the introduction of the article has established the importance of SPS for prospective science teachers and includes a number of references, improvements in defining the research gap, demonstrating novelty, and explaining the research methods would make the argument stronger and clearer for academic readers.

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).

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; Haury, 1993; Karsli et al., 2010; Lincoln et al., 2004; Mutisya, S.M., Rotich, S., 2013; NRC, 2000; Özgelen, 2012; Rimalolas 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; Nuangchalerms, 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; Lerános-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; Nuangchalerms & 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).

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	Post-test
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 SP5 questions were given in the form of objective questions, where prospective teacher students had to 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 conducted in two experimental classes and one control class according to the study program (biology and physics). In experimental class I, environmental learning was conducted using an open inquiry module. In experimental class II, environmental learning was also conducted using guided inquiry module. Both modules are science learning modules that integrate the five steps of inquiry-based science learning (NRC, 2000).

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 (Lavrakas et al., 2019). 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

Comment[RV3]:

The methods section of the manuscript does provide information on the study design, subjects, data collection, and data analysis, but there are several areas that could be strengthened to improve clarity and allow for reproducibility of the study by other readers.

First, the study design is described as quasi-experimental with a "non-equivalent control group design." This is sufficient to provide a general overview, but adding more detail about how the experimental and control groups were constructed and whether there was randomization in subject assignment would have added methodological strength. These details are important because they affect readers' confidence in the interpretation of the results.

Second, the description of the study subjects, which involved 204 prospective science teachers, is clear. However, it would have been useful if the authors had included more information about the subject selection process and whether there were any inclusion or exclusion criteria used. This information would have helped in assessing the generalisability of the study findings.

Third, the data collection method is mentioned through the application of pretests and posttests, but there is little explanation about the instruments used (such as questionnaires, interviews, or observations) and how their validity and reliability were ensured or tested. Adding more detail about these data collection instruments would have increased transparency and allowed readers to gauge the accuracy and reliability of the results.

Fourth, in data analysis, the use of Two-way ANOVA, MANOVA, and factorial 3x2 MANOVA has been mentioned. A brief explanation of why these methods were chosen and how the hypotheses were tested in the context of specific variables will help readers understand the analytical choices and interpretation of the results.

As a suggestion, the author can expand the method section in more detail and systematically, ensuring that each element of the research design, subjects, instruments, and analysis is explained completely and clearly, but concisely. This will not only increase the credibility of the study but also allow this study to be reproduced or expanded by other researchers in the

Program studies	The number of student teacher candidates in the class			Total
	Experiment I (Open-ended inquiry)	Experiment 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.

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.

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	Standard Deviation	Mean	Standard Deviation
Open-ended	Biology	35	44.49	22.123	69.	14.426

Comment[RV4]:

Some aspects of the results section have been explained in sufficient detail, but there is still room for improvement so that the results can be better interpreted and in line with scientific research standards.

First, data analysis using Two-way ANOVA and MANOVA has been presented by including significance values and brief interpretations of the statistical data. However, the explanation of how these results are directly related to the hypotheses tested is less clear. Including tables or graphs that illustrate comparisons between groups and across time (pretest and posttest) would be very helpful in visualizing the data and strengthening the research argument.

Second, although the manuscript mentions some statistical findings, the lack of detail about the distribution of samples in the context of demographic variables such as gender or educational background may affect the reader's interpretation of the generalizability of the results. Adding subgroup analyses or examining interactions between variables could provide deeper insight into the dynamics that influence science process skills.

Third, there is little or no reference to the raw data or qualitative observations that may have been collected during the study. Presenting some qualitative examples or quotes from participants could enrich the quantitative analysis and provide broader context about how and why certain learning models impact prospective teachers' SPS.

As a suggestion, the authors should expand the results section by adding more data visualizations and qualitative examples that support the quantitative findings. Also, explaining more about how these results respond to the proposed hypotheses would help readers understand the relevance of this study in a broader context. Linking the findings to existing literature and discussing their implications for educational practice would also increase the strength and relevance of this article.

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inquiry	Physics	33	40.69	19.842	59. 69. 91	14.807
	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 pretest average for biology and physics study programs is around 42.64%, while the posttest score is around 69.74%. this shows a significant increase when using a learning model using a guided inquiry-based module. In guided inquiry, the average score on the pretest is around 40.51% while the posttest is around 72.92%. while in conventional inquiry the average pretest shows 46.68% and posttest ranges from 41.30%. 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	97.68 6	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			

Comment[RV5]:

Pay attention to writing tables in this journal

Based on the ANOVA test results, it can be concluded that the science process skills of physics and biology teacher candidates have significant differences. This can be seen from the significance value

between study programs and classes that have sig. values ranging from 0.894 > 0.05, can be seen in table 6.

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 SPS research using Two Way Anova and Scheffe's Post Hoc test as shown in Tables 4, 5, and 6 shows that there is no significant difference in mastery of SPS between prospective teacher students who use open inquiry and prospective teacher students who use guided inquiry. This means that prospective teacher students who use independent inquiry have the same mastery of SPS as prospective teacher students in guided inquiry classes.

Mastery of science process skills can be influenced by several aspects including the learning model provided, gender, and several other factors. Table 7 will provide an overview of the differences in average scores between male and female prospective teachers in mastering KPS.

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

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Conventional	Total	67	40.51	16.837	72.92	13.536
	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
5						

Pillai's Trace is used for one class of dependent variable (pretest or post-test 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 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

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), $p > 0.05$.

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
	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
	Hypothesis	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
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
	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
	Carry Out Experiments	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
	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				
		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				
		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				

<i>Title of Papers (Filled Out by the Editor)</i>					
<i>Author Name (Filled Out by the Editor)</i>					
Application of The Concept	Biology	Open-ended	35	46.66	27.057
		inquiry	33	50.50	31.316
		Guided Inquiry	36	24.99	23.059
		Conventional	104	40.38	29.257
		Total			
	Physics	Open-ended	33	45.45	27.410
		inquiry	34	47.05	32.945
		Guided Inquiry	33	23.23	22.798
		Conventional	100	38.66	29.860
		Total			
Communicate	Biology	Open-ended	35	78.09	22.784
		inquiry	33	75.75	22.473
		Guided Inquiry	36	49.07	24.543
		Conventional	104	67.30	26.675
		Total			
	Physics	Open-ended	33	77.77	21.516
		inquiry	34	75.49	20.611
		Guided Inquiry	33	46.46	23.482
		Conventional	100	66.66	25.950
		Total			

The results of the analysis of the mean and standard deviation of the SPS construct show that the average value in the ability to observe between biology and physics students is higher for physics students (80.50). In terms of hypothesizing ability, physics students obtained higher scores (60.50), physics prospective teacher students had higher ability to design experiments (61.00), biology students had higher concept application ability (40.38), and biology students had higher communication skills (67.30).

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 Program	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					
	Carry Out	9.578	1	9.578	.012	.912
	Experiments					
	Application of The Concept	233.759	1	233.759	.306	.581

	Communicate	57.738	1	57.738	.113	.737
Class	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	34267.114	2	17133.557	21.726	.000
	Experiments					
	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	94.665	2	47.333	.060	.942
	Experiments					
	Application of The Concept	45.577	2	22.789	.030	.971
	Communicate	61.235	2	30.617	.060	.942

2. Discussion

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 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

Comment[RV6]:

In the Discussion section, the author has begun to develop an argument by linking the research results to existing literature, but the critical analysis of the findings still feels less in-depth. Discussions around the results indicating significant differences or absence of differences in SPS mastery between learning groups are explained, but the explanation of why this happened—based on theory or previous research—has not been fully explored. This is important to strengthen the argument and provide a better understanding of the implications of the study.

In addition, although the author mentions a theoretical framework in the methodology, the application of this framework in discussing the results is not clear. Using a conceptual framework as a lens to interpret the results can help in constructing a more focused and structured discussion. This will add analytical depth and strengthen the validity of the arguments built by the author.

The presentation style in the discussion section also needs to be more systematic. Restructuring this section to clearly separate the analysis of the findings, theoretical implications, and practical recommendations can make the discussion easier to follow. The addition of subheadings that distinguish between interpretation of the results, theoretical consequences, and practical implications will clarify the structure of the discussion.

To enrich the discussion, the author can add comparisons with other studies that have similar or different findings, explaining in detail the potential reasons behind the similarities or differences. This will provide a broader perspective and demonstrate a deeper understanding of the topic at hand.

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 3×2 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 (Hafizan 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

Comment[RV7]:

The conclusion needs to be discussed comprehensively. That section needs to be synthesized comprehensively, especially in terms of the author's critical evaluation of research findings, and must explain your contribution to knowledge.

Correspondence of conclusions with results is highly recommended. Conclusions must certainly be able to answer the purpose of this study.

Learning environmental education using the inquiry module has had a positive impact on improving SPS mastery for 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.

Additional Notes

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Comment[RV8]:

The manuscript contains a lot of detail about the methodology, results, and discussion. This is positive in terms of providing comprehensive information, but it can make it difficult for readers to grasp the main points quickly. If the goal

Comment[RV9]:

Extensive editing is needed to ensure that there are no errors in the sentence structure so that the manuscript is free from grammatical errors.

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regarding your submission about "SCIENTIFIC SCIENCE PROCESS SKILLS OF PRE-SERVICE TEACHERS THROUGH OPEN ENDED AND GUIDED INQUIRY MODULE".

Our decision is: Revisions Required.

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Thank you for your contribution and cooperation.

Best Regards,

Ade Ikhsan Kamil
Malikussaleh University, Indonesia
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Reviewer A:

This article presents a comprehensive study on the effectiveness of open-ended and guided inquiry modules in enhancing science process skills among pre-service teachers. While the study is rich in data and thorough in its experimental approach, the overall clarity and conciseness of the text could be improved to enhance readability and impact. The manuscript would benefit from a tighter narrative that more directly connects the research questions with the results and discussion sections, avoiding redundancy and focusing on key findings that contribute new insights to the field. Structurally, this article could be more aligned with the expectations of scholarly articles by strengthening the transitions between sections, ensuring each part logically flows into the next. This would help in maintaining the reader's engagement and understanding throughout the paper. Moreover, refining the use of language to ensure consistency and academic rigor and adherence to grammatical norms will polish the presentation and readability of the manuscript. In terms of alignment with the Jurnal Ilmiah Peuradeun, this manuscript fits within the scope. However, it could further enhance its relevance by explicitly discussing the implications of the findings for broader educational practices and policy, particularly in diverse and multicultural settings. Highlighting how these inquiry modules can be adapted or implemented in different educational contexts could offer valuable contributions to the journal's focus on educational developments in Asia. This approach would not only broaden the manuscript's appeal but also underline its practical relevance in line with the journal's aim to publish impactful educational research. (We have marked everything in the attached script).

Reviewer B:

regarding your submission about "SCIENTIFIC SCIENCE PROCESS SKILLS OF PRE-SERVICE TEACHERS THROUGH OPEN ENDED AND GUIDED INQUIRY MODULE".

Our decision is: Revisions Required.

It is a very interesting topic. Although we appreciate the work you have put into the paper, we have determined that your paper needs several developments to be considered for publication in the Jurnal Ilmiah Peuradeun. Several points of view should be considered in particular, which may construct the paper.

We have received comments and decisions from reviewers for your manuscript. Your manuscript should be pending publication due to some minor revisions that may construct it. Attached are the overall comments of the peer reviewer about your manuscript (*please see the attached file*).

Please help to make revisions so that this paper can meet the standards set in this journal. Make sure you revise the manuscript based on the suggestions and comments from the reviewers. In addition, the revised manuscript you re-submitted to us is final, is already in the JIP template, and has followed the [JIP author's guidelines](#).

And then, **please highlight the results of corrections and revisions to your paper in yellow directly in the manuscript**. This will greatly assist us in examining and re-evaluating the paper. In addition, **please make a [Table of Corrections](#)** to make it easier for editors to assess your revised manuscript. **The Table of Corrections contains the reviewer's comments, your revision, and the page**. You can see the **Table of Correction format** on the journal's website in the author's guidelines section. The Table of Corrections is sent with your revised manuscript as a separate file.

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Reviewer B:



[peuradeun] Reminder for Revision

1 pesan

Tabrani ZA <tabraniza@scadindependent.org>
Balas ke: Tabrani ZA <tabraniza@scadindependent.org>
Kepada: Misbahul Jannah <misbahulj@ar-raniry.ac.id>

Kam, 16 Jan 2025 pukul 16.02

Article ID: 1174

Dear Authors,

We have sent you the **revision request** for your submission to **Jurnal Ilmiah Peuradeun**, entitled " **SCRUTINIZING SCIENCE PROCESS SKILLS OF PRE-SERVICE TEACHERS THROUGH OPEN ENDED AND GUIDED INQUIRY MODULE**", with a revised time of two weeks from the date of the notice. However, until now, when we sent this email, you had not responded and sent the results of your revised manuscript to us.

Please immediately revise your manuscript. Make sure you revise the manuscript based on the suggestions and comments from the reviewers. In addition, the revised manuscript you re-submitted to us is final, is already in the JIP template, and has followed the [JIP author's guidelines](#).

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Thank you for your contribution and cooperation.

Best Regards,

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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 skills (SPS) are essential for fostering scientific understanding and attitudes, yet their development poses challenges for pre-service science teachers, particularly in the Indonesian curriculum. This study examines the SPS of pre-service teachers in Environmental Education classes, focusing on groups, gender, and educational streams, using open-ended and guided inquiry modules. A quasi-experimental "non-equivalent control group design" involved 204 pre-service teachers, with data analyzed using Two-way ANOVA, MANOVA, and 3x2 factorial MANOVA. Results revealed significant differences in SPS based on instructional groups ($p = 0.00$), while gender ($p = 0.70$) and educational streams ($p = 0.70$) showed no significant impact. Additionally, no interaction effects were observed between groups and educational streams. Both open-ended and guided inquiry modules effectively enhanced SPS, demonstrating their potential to prepare pre-service teachers for inquiry-based science learning. These findings underscore the importance of incorporating inquiry-based strategies into teacher education programs to improve SPS development. Further studies are recommended to assess their long-term impact on teaching efficacy and student learning outcomes.

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

A. Introduction

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 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 (Nuangchalem & 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).

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; Haury, 1993; Karsli et al., 2010; Lincoln et al., 2004; Mutisya, S.M., Rotich, S., 2013; NRC, 2000; Özgelen, 2012; Rumalolas 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. The research gap identified in this study highlights a focus on pre-service teachers in Environmental Education within the Indonesian curriculum. However, it does not address the extent to which these findings can be generalized to other contexts, subjects, or curricula. Furthermore, this study suggests the importance of investigating the development of science process skills (SPS) in other scientific disciplines (e.g., physics, biology, chemistry) and diverse educational settings (e.g., rural versus urban schools, international contexts). Such research would offer a more comprehensive understanding of the effectiveness of open-

ended and guided inquiry-based learning modules. (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; Leránoz-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. The current study evaluates the development of science process skills (SPS) within the context of a specific course and over a limited timeframe. This narrow scope raises critical questions regarding the long-term retention of these skills and their subsequent application in teaching practices. Future Research Directions: Longitudinal studies are needed to explore whether the observed improvements in SPS endure over extended periods. Additionally, such research should examine how pre-service teachers effectively implement these skills in their professional practice, providing valuable insights into the sustainability and practical utility of SPS development in teacher education (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.

In addition, the study does not consider the use of digital tools or resources to enhance open-ended and guided inquiry approaches, an omission that contrasts with the increasing prominence of technology in

contemporary education. The integration of digital technologies, such as virtual laboratories, simulation-based platforms, or other technology-enhanced learning environments, represents a promising area for future investigation. Proposed Research Agenda: Future studies should explore how these digital tools can be systematically incorporated into inquiry-based learning modules to support and enhance the development of science process skills (SPS). Such research could contribute to a deeper understanding of how technology can complement pedagogical strategies, foster engagement, and provide scalable solutions for diverse educational contexts. Additionally, examining the effectiveness of these tools across various demographic and curricular settings would offer valuable insights into their adaptability and potential for improving educational outcomes.

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).

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 pre-test/post-test 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	Post-test
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 were given in the form of objective questions, where prospective teacher students had to 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 conducted in two experimental classes and one control class according to the study program (biology and physics). In experimental class I, environmental learning was conducted using an open inquiry module. In experimental class II, environmental learning was also conducted using guided inquiry module. Both modules are science learning modules that integrate the five steps of inquiry-based science learning (NRC, 2000).

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 (Lavrakas et al., 2019). 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
	Experiment	Experiment II	Control	

	I (Open- ended inquiry)	(Guided Inquiry)	(Convention al)	
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.

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.

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

Class	Study Program	N	Pretest		Post-test	
			Mean	Standard Deviation	Mean	Standard Deviation
Open-ended inquiry	Biology	35	44.49	22.123	69.59	14.426
	Physics	33	40.69	19.842	69.	14.807

	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 pretest average for biology and physics study programs is around 42.64%, while the posttest score is around 69.74%. this shows a significant increase when using a learning model using a guided inquiry-based module. In guided inquiry, the average score on the pretest is around 40.51% while the posttest is around 72.92%. while in conventional inquiry the average pretest shows 46.68% and posttest ranges from 41.30%. 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 ANOVA test results, it can be concluded that the science process skills of physics and biology teacher candidates have significant differences. This can be seen from the significance value between study programs and classes that have sig. values ranging from 0.894 > 0.05. can be seen in table 6.

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 SPS research using Two Way Anova and Scheffe's Post Hoc test as shown in Tables 4, 5, and 6 shows that there is no significant difference in mastery of SPS between prospective teacher students who use open inquiry and prospective teacher students who use guided inquiry. This means that prospective teacher students who use independent inquiry have the same mastery of SPS as prospective teacher students in guided inquiry classes.

Mastery of science process skills can be influenced by several aspects including the learning model provided, gender, and several other factors. Table 7 will provide an overview of the differences in average scores between male and female prospective teachers in mastering KPS.

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

Class	Gender	N	Pretest		Post-test	
			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
Convention	Man	20	46.42	11.703	49.64	13.409

al

Woman	49	46.79	14.139	37.90	14.883
Total	69	46.687	13.394	41.30	15.342

5

Pillai's Trace is used for one class of dependent variable (pretest or post-test 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 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

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), $p > 0.05$.

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

The results of the analysis of the mean and standard deviation of the SPS construct show that the average value in the ability to observe between biology and physics students is higher for physics students (80.50). In terms of hypothesizing ability, physics students obtained higher scores (60.50), physics prospective teacher students had higher ability to design experiments (61.00), biology students had higher concept application ability (40.38), and biology students had higher communication skills (67.30).

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 Program	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					
	Carry Out	9.578	1	9.578	.012	.912
	Experiments					
	Application of The Concept	233.759	1	233.759	.306	.581

Title of Papers (Filled Out by the Editor)						
Author Name (Filled Out by the Editor)						
	Communicate	57.738	1	57.738	.113	.737
Class	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	34267.114	2	17133.557	21.726	.000
	Experiments					
	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	94.665	2	47.333	.060	.942
	Experiments					
	Application of The Concept	45.577	2	22.789	.030	.971
	Communicate	61.235	2	30.617	.060	.942

2. Discussion

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 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.

The lack of significant gender differences in the mastery of science process skills (SPS) observed in this study may be attributed to several factors: Equity of Inquiry-Based Learning, Inquiry-based science learning modules are designed to engage all students actively in the learning

process, emphasizing critical thinking, problem-solving, and hands-on exploration. Such modules may minimize gender disparities in learning outcomes by providing equal opportunities for all students to develop and practice SPS. **Similar Learning Environments:** The study suggests that both male and female prospective teacher candidates experienced the same learning environment and instructional strategies, which may have led to similar mastery of SPS. This uniformity in the educational experience could be a key factor in eliminating gender differences in performance. **Gender-Neutral Content:** Inquiry-based modules may focus on scientific content and skills that are not inherently gender-biased. This approach allows both male and female students to engage with the material without the influence of stereotypes or preconceived expectations about their abilities in science. In conclusion, the absence of significant gender differences in SPS mastery may reflect the effectiveness of inquiry-based learning in providing equitable opportunities for all students, regardless of gender, to develop critical scientific skills.

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 3×2 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 (Hafizan 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 for 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 of this study emphasize the effectiveness of inquiry-based modules in fostering the development of science process skills (SPS) among students in both Biology and Physics teacher education programs. This demonstrates the flexibility and applicability of these modules across diverse scientific disciplines, positioning them as valuable tools for improving SPS development.**

Furthermore, by highlighting the success of these modules within the context of Environmental Education, the study presents a compelling case for their broader adoption within teacher education curricula. The integration of such modules can offer meaningful contributions to curriculum reform, providing insights for curriculum designers and policymakers seeking to modernize science education. Beyond confirming the pedagogical value of inquiry-based approaches, this research illustrates their effectiveness across varied educational contexts and student demographics. These findings have significant implications for the enhancement of teacher education programs, potentially leading to improved science teaching practices and contributing to the overall advancement of science literacy within the broader educational landscape. Consequently, the study calls for further exploration into the long-term impact of inquiry-based modules and their scalability across diverse educational settings, offering avenues for future research to better understand their role in shaping future educators' competencies and science education at large.

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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 Inquiry, Guided Inquiry

A. Introduction

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 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 (Nuangchalem & 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).

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; Haury, 1993; Karsli et al., 2010; Lincoln et al., 2004; Mutisya, S.M., Rotich, S., 2013; NRC, 2000; Özgelen, 2012; Rumalolas 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; Nuangchalerms & 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).

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 an 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	Post-test
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 were given in the form of objective questions, where prospective teacher students had to 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 conducted in two experimental classes and one control class according to the study program (biology and physics). In experimental class I, environmental learning was conducted using an open inquiry module. In experimental class II, environmental learning was also conducted using guided inquiry module. Both modules are science learning modules that integrate the five steps of inquiry-based science learning (NRC, 2000).

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 (Lavrakas et al., 2019). 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
	Experiment I (Open-ended inquiry)	Experiment 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.

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.

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	Standard Deviation	Mean	Standard Deviation
Open-ended	Biology	35	44.49	22.123	69.	14.426

Title of Papers (Filled Out by the Editor)						
Author Name (Filled Out by the Editor)						
inquiry	Physics	33	40.69	19.842	59.	14.807
					91	
	Total	68	42.64	20.978	69.	14.503
Guided Inquiry	Biology	33	41.55	17.076	74	12.630
	Physics	34	39.49	16.795	73.	14.549
	Total	67	40.51	16.837	68	13.536
Conventional	Biology	36	45.83	13.376	92	15.960
	Physics	33	47.61	13.559	42.	14.813
	Total	69	46.68	13.394	26	15.342
					40.	
					25	
					30	

Based on the results of the analysis of open-ended inquiry scores, the pretest average for biology and physics study programs is around 42.64%, while the posttest score is around 69.74%. this shows a significant increase when using a learning model using a guided inquiry-based module. In guided inquiry, the average score on the pretest is around 40.51% while the posttest is around 72.92%. while in conventional inquiry the average pretest shows 46.68% and posttest ranges from 41.30%. 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	97.68	0.000
Study Program	26.174	1	26.174	6	0.726
Class*Study Program	47.798	2	23.899	0.123	0.894
Standard Error	42120.376	198	212.729		
Total	846985.063	204			

Based on the ANOVA test results, it can be concluded that the science process skills of physics and biology teacher candidates have significant differences. This can be seen from the significance value

between study programs and classes that have sig. values ranging from 0.894 > 0.05. can be seen in table 6.

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 SPS research using Two Way Anova and Scheffe's Post Hoc test as shown in Tables 4, 5, and 6 shows that there is no significant difference in mastery of SPS between prospective teacher students who use open inquiry and prospective teacher students who use guided inquiry. This means that prospective teacher students who use independent inquiry have the same mastery of SPS as prospective teacher students in guided inquiry classes.

Mastery of science process skills can be influenced by several aspects including the learning model provided, gender, and several other factors. Table 7 will provide an overview of the differences in average scores between male and female prospective teachers in mastering KPS.

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

Title of Papers (Filled Out by the Editor)						
Author Name (Filled Out by the Editor)						
Conventional	Total	67	40.51	16.837	72.92	13.536
	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
5						

Pillai's Trace is used for one class of dependent variable (pretest or post-test 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 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

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), $p > 0.05$.

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

The results of the analysis of the mean and standard deviation of the SPS construct show that the average value in the ability to observe between biology and physics students is higher for physics students (80.50). In terms of hypothesizing ability, physics students obtained higher scores (60.50), physics prospective teacher students had higher ability to design experiments (61.00), biology students had higher concept application ability (40.38), and biology students had higher communication skills (67.30).

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 Program	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					
	Carry Out	9.578	1	9.578	.012	.912
	Experiments					
	Application of The Concept	233.759	1	233.759	.306	.581

	Communicate	57.738	1	57.738	.113	.737
Class	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	34267.114	2	17133.557	21.726	.000
	Experiments					
	Application of The Concept	24994.602	2	12497.301	16.346	.000
	Communicate	38580.510	2	19290.255	37.676	.000
Study Program*	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	94.665	2	47.333	.060	.942
	Experiments					
	Application of The Concept	45.577	2	22.789	.030	.971
Class	Communicate	61.235	2	30.617	.060	.942

2. Discussion

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 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 & Fadlioli, 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 3×2 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 (Hafizan 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 for 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.

Additional Notes

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[peuradeun] Your Manuscript Needs to be Revised Again

1 pesan

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Kam, 27 Mar 2025 pukul 00.42

Article ID: 1174

Dear Authors:

Thank you for submitting your revised manuscript entitled "**SCRUTINIZING SCIENCE PROCESS SKILLS OF PRE-SERVICE TEACHERS THROUGH OPEN ENDED AND GUIDED INQUIRY MODULE**".

We appreciate your efforts in revising the manuscript according to the previously given suggestions. However, upon further evaluation, we have found that several parts still require attention and more detailed improvements to meet our publication standards. Please review the notes from the reviewers and editors that were previously sent to you.

Here are some additional comments we have regarding your revised manuscript that you should consider:

While we acknowledge the substantial efforts you have made to improve your manuscript, we have carefully reviewed the third revision and regret to inform you that **further substantial revision is still required before it can proceed to publication**. The main issues are outlined as follows:

1. Language and Grammar

The manuscript still contains significant grammatical issues and awkward sentence constructions. Many expressions are direct translations from Indonesian and are not idiomatic in English. These issues hinder clarity and must be corrected throughout the paper.

- Example: "*This aims to assess the extent to which pre-service teachers can carry out construct orientation from SPS*" – this sentence is grammatically flawed and unclear.
- Please consider **professional academic language editing** to bring the manuscript in line with international publishing standards.

2. Weak Argumentation and Lack of Research Gap

The introduction is overextended, filled with citations, but lacks clear organization and fails to establish a solid **research gap**. The novelty of the study remains implicit rather than explicitly argued. We strongly recommend rewriting the introduction to clearly articulate:

- The specific problem being addressed
- A concise gap in the existing literature
- The unique contribution or novelty of your study

3. Methodology: Overly Descriptive and Unfocused

While detailed, the methodology section is **too long and repetitive**, including descriptions that are better suited for appendices (e.g., demographic data). The explanation of the instruments is not sufficient, and the **low Cronbach's Alpha (0.079)** raises concern about the reliability of the measurement tools.

- Please provide a clearer explanation of the instrument, its validation, and justification for its use.
- Consider summarizing demographic details more concisely or placing detailed tables in appendices.

4. Results: Overloaded with Data, Under-Interpreted

The results section contains **numerous tables** with raw data, but lacks **meaningful interpretation** and is not adequately linked to the research objectives. Some statistical results are repeated without explanation of their significance. We recommend:

- Prioritizing key results that support your arguments
- Adding visualizations (charts/graphs) where appropriate
- Interpreting statistical outcomes meaningfully rather than merely reporting p-values

5. Discussion: Needs Deeper Analysis and Theoretical Engagement

The discussion tends to restate findings instead of **engaging them critically with the literature** or drawing theoretical insights.

- There is little reflection on **why** certain findings emerged or **how** they compare to existing research.
- The implications for teaching practice and policy are underdeveloped.

- For example, the lack of significant differences based on gender or program is an opportunity for deeper reflection that is currently missed.

6. Conclusion: Too Generic

The conclusion summarizes the findings but does not articulate the broader academic or practical significance of the study. Please improve the conclusion by:

- Highlighting the theoretical and practical implications
- Suggesting specific policy or curriculum reforms
- Mentioning clear future research directions

7. Reference List: Formatting and Consistency Issues

The bibliography is extensive, but there are inconsistencies in formatting (journal names, capitalization, DOI, etc.) and several entries lack proper structure.

- Please revise the references to conform strictly to **APA 7th edition**.
- Check that all in-text citations match their entries in the reference list.

Final Note:

We also see that you have not heeded the editor's notes in the previous email. We hope you will not repeat the same mistake. Please read all our comments and the editor's comments that have been sent to you, and follow the guidelines of this journal.

This manuscript has potential, particularly in its focus on improving pre-service teachers' science process skills through inquiry-based modules. However, to meet the standards of an international peer-reviewed journal, **the issues listed above must be thoroughly addressed**. Once the necessary revisions have been made, the manuscript may be reconsidered for peer review.

As an additional note to remember:

1. Make sure you revise the **final version** of the manuscript you sent to us;
2. You need to improve the structure and grammar. Extensive editing should be undertaken since there are some errors in some parts of sentences in order to make sure there are zero errors.
3. The manuscript should be written in American English (English US), between 4000-7500 words including text, all tables, figures, notes, references, and appendices intended for publication;
4. The body of the manuscript follows IMRAD guidelines (Introduction, Method, Result, Discussion, Conclusion, and Bibliography). All citations and references must use the Mendeley app ([Follow this journal template](#));
5. Customize overall reference writing with APA Style 7th Edition. If you use APA style, in-text citations must be in APA style. **For citations and references, it is mandatory to Use the Mendeley App;**
6. For details, visit: <http://journal.scadindependent.org/index.php/jipeuradeun/authorguidelines>;
7. As a side note, **you must also complete all author names, affiliations, and correspondence email in your revised manuscript;**
8. **The revised manuscript you submit must be final, and there are no more reviewer notes in the manuscript;**
9. After you have revised it, please **UPLOAD** your final revised manuscript in the **Revisions** section.

Please revise again your manuscript. The deadline for revision and re-submission of your revised is **ONE WEEK from the date of the notice**. And then, **please highlight the results of corrections and revisions to your manuscript in yellow directly in the manuscript**. This will greatly assist us in examining and re-evaluating your manuscript. In addition, **please make a [Table of Corrections](#)**. The Table of Corrections contains the reviewer's comments, your revision, and the page. You can see the **Table of Correction format** on the [journal's website](#), in the author's guidelines section. The Table of Corrections is sent with your revised manuscript as a separate file. Please make sure the revision that you submitted has been in the JIP Template and has followed the [JIP author's guidelines](#).

We kindly ask you to review all the notes from the reviewers and the editor's comments, as well as the sections we mentioned above. It is very important to us that each part of the manuscript conveys clear and accurate information in accordance with the established scientific framework. Please pay attention again to the details that need to be corrected and adjusted. We believe that with these improvements, your manuscript will have greater potential for a significant contribution to the field you are studying. We look forward to your response to the next revision and hope to continue the process to the next stage. If you have any questions, please do not hesitate to contact us.

Thank you for your dedication, contribution, and cooperation.

Regards,

Editor

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SCRUTINIZING SCIENCE PROCESS SKILLS OF STUDENT TEACHERS THROUGH OPEN ENDED AND GUIDED INQUIRY MODULE

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Abstract

Every science teacher needs to have Science Process Skills (SPS) for developing science concept knowledge and scientific attitude. However, research on learning the skills by science student teachers in Indonesia during the implementation of Kurikulum Merdeka (Independent Curriculum) is scant. Thus, it is crucial to do research on the science student teachers' knowledge on SPS in implementing science learning using the inquiry module. This study aims to investigate the Science Process Skills (SPS) of student teachers in Environmental Education classes based on class, gender, and study program through open-ended and guided inquiry modules. 204 science student teachers participated in this quasi-experimental design, namely "non-equivalent pretest posttest control group design," using open-ended inquiry module, guided inquiry module, and conventional module. The two-way ANOVA, MANOVA, and MANOVA factorial 3x2 analysis reveal statistical significance at $p=0.00$ for SPS based on the groups. The analysis of statistics based on gender ($p=0.02$) indicate that female student teachers in the guided inquiry had higher SPS than male. Meanwhile, in the open-ended inquiry, male have higher SPS than female. The study program ($p=0.70$) reveals no significant difference. There were also no significant differences in the Mean score test of SPS constructs based on study program and groups. These findings indicate that open-ended and guided inquiry modules can enhance student teachers' SPS. This study suggests the enhancement of SPS student teachers by using inquiry-based learning.

Keywords: *Science Process Skill, Science Student Teachers, Open Ended Inquiry, Guided Inquiry*

A. Introduction

Science process skill (SPS) is crucial for developing science concept knowledge and scientific attitude at all levels of education. However, a large number of studies evidenced that students continue to have low SPS and little training (Al-rabaani, 2014; Athiyyah et al., 2020; Nicol et al., 2023), there is less encouragement for the tools and practical resources' availability (Nuangchalermsirakul & Prachagool, 2010).

To train students with SPS is relevant to use 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). Scientific Inquiry can stimulate thinking skills and increase interest and motivation to learn science because it is a 'hands on' and 'minds on' activity (Margunayasa et al., 2019; NRC, 2000; Perla et al., 2023) and also can increase positive attitude and scientific attitude (Hafizan et al., 2012; Thuneberg et al., 2017).

There are four reasons why SPS is relevant for training students. *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) 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. (Rustaman, 2008). Therefore, educators' good understanding of SPS will enable them to use it in the classroom.

Since teachers' SPS is crucial, it is also important to train prospective teacher students. 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), and develop higher mental processes such as critical and creative thinking skills and decision-making skills (Adnyana & Citrawathi, 2017). Teachers

who have good knowledge of science concepts can usually master SPS well too (Radford et al., 1992).

However, previous SPS studies on prospective student-teachers in Indonesia, the United States, Malaysia, and Turkey show unsatisfactory results and fall in the lower category (Adlim et al., 2020; Chabalengula et al., 2012; Eryilmaz & Kara, 2016; Susilawati et al., 2019). There are several factors that influence SPS for student teachers in several countries. These factors include differences in study programs (Rustaman, 2008) and gender (Al-Rabaani, 2014; Lincoln et al., 2004; Özgelen, 2012; Rumalolas et al., 2021; Rustaman, 2008). Therefore, it is necessary for professional educators to develop SPS.

Teachers should possess a strong understanding and must exhibit competence in SPS to enable to effectively teach the skills (Nicol et al., 2023). Professional educators should also have conceptual knowledge (Vergara et al., 2021), scientific skills and attitudes (Misbahul J, 2020; NRC, 2000), and good pedagogical skills (Astalini et al., 2023; García-Vandewalle García et al., 2023) because they must plan and implement different learning strategies for science learning, different learning methodologies and models.

To produce good memorable learning and improve SPS for student teachers, inquiry is suitable to apply (Astalini et al., 2023) as they need to apply it when teaching. The effectiveness of inquiry-based science learning, especially guided inquiry for student teachers, can increase self-confidence, develop various skills, develop understanding of content knowledge and scientific knowledge of prospective teacher students. (Lamminpää et al., 2023; Stamer et al., 2021).

Although guided inquiry can lead to good science learning, the implementation of learning using inquiry is still a problem for educators in Indonesia (Rustaman, 2008). Previous studies show that SPS develop when students do activities given by the teacher, such as experiment (Evriani et al., 2017), the quality of teacher learning has not changed much after they have attended various workshops and training. Only those who have frequently attended workshops and conferences related to their areas of expertise improve their knowledge of the concepts they teach (Al Mamun & Lawrie, 2023; Sudirman et al., 2023; Uludağ & Semra Erkan, 2023). It was also found that many teachers do not have good creativity and knowledge in developing independent learning (Pamenang et al., 2020; Peretz et al., 2023), as most teach conventionally as they were taught at university (Mohajer et al., 2023; Peretz et al., 2023).

This study intends to assist lecturers in teaching Environmental Education courses and to solve environmental problems in everyday life through inquiry-based learning by developing an Inquiry-Based Science Learning Module (IBSLM). IBSLM is a learning module consisting of information that can facilitate lecturers in developing SPS in learning environmental knowledge of student teachers. IBSLM consists of five sections: 1) Learning plan; 2) learning objectives; 3) hands-on activities; 4) learning materials, and 5) assessment. The IBSLM developed in this module consists of an open-ended inquiry module and a guided inquiry module. The former is that student teachers carry out experiments freely and these experiments are fully controlled by student teachers, whereas the latter the activities are guided by the lecturers.

B. Method

1. Research Design and Sample

The research design of this study is a quasi-experimental non-equivalent pretest posttest control group design (Creswell 2012). The quasi experimental design aimed to identify the differences between the results of control group and treatment group. It used a 3x2x2 factorial. The first independent variable is the learning model using guided inquiry module, open-ended inquiry module and conventional learning. The second independent variable is study programs (Biology and Physics) and the third variable is gender (male and female). The design of this study is shown in Table 1 below:

Table 1. Research design

Class	Pretest	Treatment	Post-test
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

Table 1 shows that the three groups received a pretest at the initial meeting. Fourteen SPS questions were given in the form of objective questions, where students teachers chose the correct answer based on their initial knowledge on environmental learning about the basic concepts of environmental knowledge and its problems. Next, the treatment was carried out in two experimental classes and one control

class based on the study programs (Biology and Physics). In experimental class I, environmental learning was conducted using the open inquiry module, whereas in experimental class II, Environmental learning used guided inquiry module. Both modules are science learning modules that integrate the five steps of inquiry-based science learning (NRC, 2000).

The sample used in this study, as can be seen in Table 2, were 204 student teachers studying at the Tarbiyah and Teacher Training Faculty of Universitas Islam Ar-Raniry Banda Aceh. The sampling method was random group assignment (Lavrakas et al., 2019).

Table 2. Number of students teachers according to study program

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

Table 2 shows that a total of 204 student teachers from two study programs, namely Biology and Physics, participated in this study. Of the 204 respondents who were involved in this study, 104 students (50.98%) were student teachers from the Biology study program and 100 people (49.02%) student teachers from the Physics study program. They were again divided into three different learning model classes: 68 (33.33%) were in the open-ended inquiry class (Experimental class I), 67 (32.84%) were in the guided inquiry class (Experimental class II), and 69 (33.82%) were in the conventional class (control class).

By gender, the respondents were 139 females (68.14%) and 65 males (31.86%). The open-ended inquiry class of Biology study program involved a total of 35 student teachers, 10 males and 25 females. For the Physics study program were 33, 13 males and 20 females. The class that received guided inquiry in the Biology study program consisted of 33 student teachers, comprising 11 males and 22 females. The Physics study program involved 34 people, 11 males and 23 females. The conventional class of the Biology study program involved 36 people, 10 males and 26 females. The Physics study program involved 33 students, 10 males and 23 females.

The instrument used fourteen multiple-choice questions that refer to the six constructs of science process skills, namely observe, hypothesis, design experiment, carry out experiment, application the concept and communicate. The questions given in these six constructs are in the form of questions that enhance science process skills related to environmental concepts that occur in daily life. The questions of each construct are developed based on the independent curriculum.

Furthermore, validity and reliability are two important things in the data collection procedure. To determine these two things, it is analyzed using Kuder Richardson 20 (KR 20) . The validity of these six constructs is 0.80, while the results of reliability are depicted 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
<i>Mean</i>				6.06		
<i>Standard Deviation</i>				2.44		
<i>Skewness</i>				0.170		
<i>KR 20</i>				0.079		

The results of the KR 20 analysis show 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. Meanwhile the mean value indicates that the overall interpretation of scientific process ability is well oriented with a mean value of around 6.06. while Kuder Richardson 20 (KR 20) value shows $0.079 > 0.05$. This means that the instruments used in research are relatively constant or reliable.

All data obtained from pretest and posttest research instruments were analyzed using SPSS 22. The statistics used in the analysis of this study are descriptive statistics and inference statistics. For descriptive analysis, it is used to thoroughly describe the research subject such as

class, gender, and study program of the respondents. The statistics used are frequency, percentage, mean, and standard deviation. Inference analysis was used to analyze the relationship between three independent variables and three dependent variables. The first independent variable is the class (open-ended inquiry module, guided inquiry module, and conventional learning). The second independent variable is gender (male and female). The third variable is the study program (Biology and Physics). To determine the effectiveness of using the inquiry module in improving SPS involved two-way ANOVA and 3x2 Factorial MANOVA. The two-way ANOVA test is used to determine differences in science process skills based on class, gender, and study program. The MANOVA test was used to analyze the hypothesis of the independent variable that produces the same mean vector for the dependent variable and used the Box's M test ($p > 0.05$). Meanwhile, the MANOVA Factorial 3x2 test was to analyze the impact of class and study programs on the six constructs of SPS.

Therefore, this study hypothesizes that:

- H01: The open-ended and guided inquiry modules have a significant effect on student teachers' SPS based on study program
- Ha1: The open-ended and guided inquiry modules have no significant effect on student teachers' SPS based on study program
- H02: The open-ended and guided inquiry modules have a significant effect on student teachers' SPS based on gender
- Ha2: The open-ended and guided inquiry modules have no significant effect on student teachers' SPS based on gender
- H03: The open-ended and guided inquiry modules have a significant effect on the six constructs of SPS student teachers based on gender and study program
- Ha3: The open-ended and guided inquiry modules have no significant effect on the six constructs of SPS student teachers based on gender and study program

C. Result and Discussion

1. Result

This study aims to assess the extent to which student teachers can carry out construct orientation from SPS.

In general, the differences in SPS mastery of student teachers based on the study programs can be seen in tables 4, 5, and 6.

Table 4. Mean and standard deviation of pretest and posttest SPS

Kelas	Study Program	N	Pretest		Posttest	
			Mean	Standard Deviation	Mean	Standard Deviation
Open-ended inquiry	Biology	35	44.49	22.123	69.59	14.426
	Physics	33	40.69	19.842	69.91	14.807
	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

The analysis of open-ended inquiry scores shows that the pretest average for Biology and Physics study programs is around 42.64%, while the posttest score is around 69.74%. This shows a significant increase when using a learning model using a guided inquiry module. In guided inquiry, the average score on the pretest is around 40.51% while the posttest is around 72.92%. while in conventional inquiry the average pretest shows 46.68% and posttest ranges from 41.30%. This can be seen in Table 5 below:

Table 5. Two-way ANOVA analysis of differences in SPS mastery

	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			

The ANOVA test results show that the SPS of Physics and Biology student teachers have significant differences. This can be seen from the significance value between study programs and classes that have sig. values ranging from 0.894 > 0.05. can be seen in Table 6.

Table 6. Scheffe's post-hoc examination of the differences in SPS mastery of student teachers 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

The analysis using two way ANOVA and Scheffe's Post Hoc test as shown in tables 4, 5, and 6 shows that there is no significant difference in mastery of SPS between the student teachers who used open inquiry and who used guided inquiry. Hence, student teachers who use open-ended inquiry have the same mastery of SPS as those in the guided inquiry class.

Mastery of SPS can be influenced by several aspects, such as learning model provided, gender, and several other factors. Table 7 shows the differences in average scores between male and female student teachers in mastering SPS.

Table 7. The results of the pretest and posttest of SPS mastery of student teachers between classes by gender

Class	Gender	N	Pretest		Posttest	
			Mean	Standard Deviation	Mean	Standard Deviation
Open-ended inquiry	Male	23	35.09	17.879	72.05	15.215
	Female	45	46.50	21.569	68.57	14.154
	Total	68	42.64	20.978	69.74	14.503
Guided Inquiry	Male	22	41.55	14.727	70.77	13.208
	Female	45	40.00	17.914	73.96	13.718
	Total	67	40.51	16.837	72.92	13.536
Convention	Male	20	46.42	11.703	49.64	13.409

al						
	Female	49	46.79	14.139	37.90	14.883
	Total	69	46.68	13.394	41.30	15.342

The analysis shows that open ended inquiry, male student teachers had higher SPS than females. Meanwhile, for the guided inquiry, the SPS of female student teachers were higher than those of male. The difference is statistically significant, as shown in Table 8.

Table 8. Two-way ANOVA analysis of differences in SPS mastery based on gender

	Type III Sum of Squares	Df	Mean Power Two	F	Sig.
Class	576.287	2	288.143	72.946	0.001*
Gender	13.922	1	13.922	3.524	0.06
Class*Gender	31.727	2	15.863	4.016	0.02*
Standard Error	782.114	198	3.950		
Total	16601.000	204			

The significant value of the difference in student teacher SPS between groups based on gender was with a value of $F = 4.016$ and a significant value (p) = 0.02 ($p < 0.05$). This suggests that bases on class*gender there is a significant difference in student teachers' SPS between the open-ended inquiry and the guided inquiry. There is also an interaction between class and gender on SPS. The interactions that occur are as shown in Figure 1.

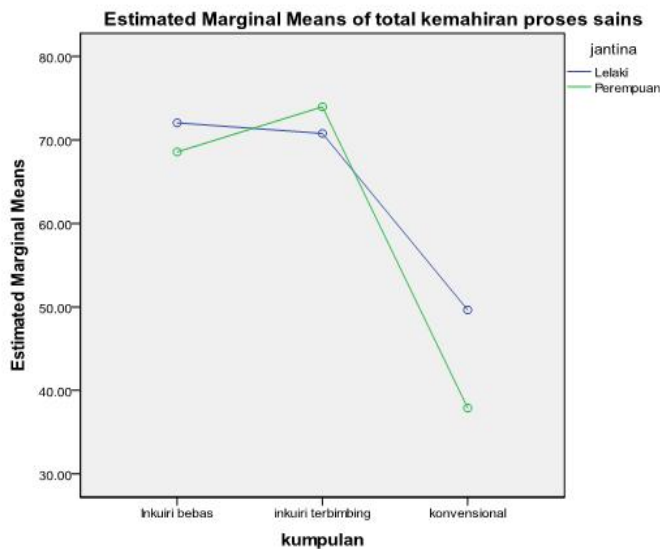


Figure 1 Interaction between groups and gender of preservice teachers on science process skills

Based on Table 8 and Figure 1 shows that there is a significant interaction between groups and gender in science process skills. The interaction that occurred between the group and the gender of student teachers on SPS, where female student teachers in the guided inquiry had higher SPS than males. Meanwhile, in the open-ended inquiry and conventional class, male student teachers have higher SPS than females. This suggests that there is a significant interaction between groups and gender in student teachers' SPS.

Pillai's Trace is used for one class of dependent variable (pretest or post-test only of science process skills). Pillai's Trace test results in the Multivariate Test Table show that overall, there is a significant relationship between open-ended inquiry, guided inquiry and conventional class [$F(12,388) = 13.23$, sig 0.000 $p < 0.05$] to the SPS construct of 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 in observing skills,

hypothesizing skills, experiment designing skills, conducting experiments skills, concept application skills and communication skills.

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

The analysis as depicted in Table 8 shows the significance value of Lavene's test for the skill construct observes the sig value. = 0.000, $p < 0.05$. Meanwhile 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), $p > 0.05$.

Table 10. Mean and standard deviation of the SPS construct of student teachers based on study programs and classes

SPS Construction	Study Program	Class	N	Mean	Standard Deviation
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	35	46.66	27.057
		inquiry	33	50.50	31.316
		Guided Inquiry	36	24.99	23.059
		Conventional	104	40.38	29.257
		Total			
	Physics	Open-ended	33	45.45	27.410
		inquiry	34	47.05	32.945
		Guided Inquiry	33	23.23	22.798
		Conventional	100	38.66	29.860
		Total			
Communicate	Biology	Open-ended	35	78.09	22.784
		inquiry	33	75.75	22.473
		Guided Inquiry	36	49.07	24.543
		Conventional	104	67.30	26.675
		Total			
	Physics	Open-ended	33	77.77	21.516
		inquiry	34	75.49	20.611
		Guided Inquiry	33	46.46	23.482
		Conventional	100	66.66	25.950
		Total			

The results of the analysis of the *mean* and standard deviation of the SPS construct show that the average value in the ability to observe between Biology and Physics students is higher for Physics students (80.50). In terms of hypothesizing ability, Physics students obtained higher scores (60.50), Physics student teachers had higher ability to design experiments (61.00), Biology student teachers had higher concept application ability (40.38), and Biology student teachers had higher communication skills (67.30).

Table 11. MANOVA analysis differences in SPS constructs for student teachers based on study program and class

Category	Leaning variable	Type III Sum of Squares	Df	Mean Squared	F	Sig.
Study Program	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					
	Carry Out	9.578	1	9.578	.012	.912
	Experiments					
	Application of The Concept	233.759	1	233.759	.306	.581
	Communicate	57.738	1	57.738	.113	.737
Class	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	34267.114	2	17133.557	21.726	.000
	Experiments					
	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	94.665	2	47.333	.060	.942
	Experiments					

<i>Title of Papers (Filled Out by the Editor)</i>						
<i>Author Name (Filled Out by the Editor)</i>						
	Application of The Concept	45.577	2	22.789	.030	.971
	Communicate	61.235	2	30.617	.060	.942

2. Discussion

The two-way ANOVA test analysis indicates that there was significant difference in SPS mastery of students teachers between open-ended inquiry, guided inquiry, and conventional group based on gender. This means that female student teachers in the guided inquiry had higher science process skills than males. Meanwhile, in the open-ended inquiry groups, male pre-service teachers have higher science process skills than females. This shows that the use of guided inquiry-based science learning modules has impact on female whereas open-ended inquiry impact on male teachers on SPS mastery. The results are contrary to those of some previous studies (Al-Rabaani, 2014; Astalini et al., 2023; Nicol et al., 2023), but consistent with those of other previous studies (Evriani et al., 2017; Kurniawan & Fadloli, 2016) showing that the SPS of female student teachers is higher than that of males.

An analysis of the two-way ANOVA test shows that there is no significant difference in SPS mastery of student teachers based on study programs. This means that the science lessons received by Biology and Physics student teachers are both effective. The effectiveness of this learning is due to the fact that each topic of student teachers candidate learning is required to think critically and actively to develop SPS. This is in line with the results of the studies by Krathwohl (2002) and Marzano et al. (2009). It was also found that students who have gone through an active learning process are able to demonstrate complex thinking skills such as effective communication, cooperation, and collaboration and ability to process information properly and effectively (Knezek et al., 2023; Krathwohl, 2002).

The process of mastering active thinking skill strategies is also needed in assisting professional teachers in developing teaching and learning strategies (Sudirman et al., 2023). There is no difference in the SPS of student teachers for both Biology and Physics study programs because the lecturers had attended seminars and workshops related to innovative learning that improve their SPS. The results of this study are different from those of previous studies by Misbahul J, (2020) and

Rustaman (2008) that the SPS of prospective Biology and Physics student teachers had significant differences.

The results of the inference analysis using the 3 x 2 factorial MANOVA test 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 the *mean* of the scores student teachers who used guided inquiry in Biology and Physics study programs is higher than that of the open-ended inquiry class and the conventional class students. As for the skill constructs of carrying out experiments and communication skills, their means of the scores of student teacher classes using open-ended inquiry in the Biology and Physics study program is higher than that of students of the guided inquiry class and the conventional class. The 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 those using guided inquiry and open-ended inquiry. All the skills fall into high-level skills (Krathwohl, 2002), which include the activities 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, and creating (Marzano et al., 2009).

In this study, each hands-on activity in the guided inquiry-based learning, the student teachers in both study programs have observation skills, hypothesis skills, experimental design skills and good concept application skills. For hands-on activities designed to train teachers to observe, they carried out observations using various media based on the concepts being learned, such as real objects, models or pictures or graphs. In addition to observing skill aspects, the student teachers' hypothesising skills, experiment designing skills and concept applying skills were also investigated through activities designed at the hands on activity. In the guided inquiry class in Biology and Physics Study Program, the skill of creating hypotheses the student teachers have is not a good result. This is shown when student teachers were asked to create hypotheses before the experiment was carried out. The ability of student teachers in generating hypotheses is their ability to guess or estimate from a research problem, or the ability to make a hypothesis to connect between two variables or make assumptions or conjectures (Margunayasa et al., 2019).

The skills of student teachers in planning investigations and applying the concepts in this study have improved. Student teachers in the guided inquiry classes in Biology and Physics study programs have skills to prepare learning tools and materials before learning begins based on the concepts to be learned. The skills needed in designing experiments such as determining the tools and materials to be used, the objects to be investigated, the factors or variables considered, the criteria for success, the methods and work steps and how to record and process data to draw conclusions (Lestari & Diana, 2018). At the time of designing and experimentation, the teacher should direct the experiment under study and during the experiment carried out and the teacher should act as a facilitator.

The skills of doing experiments and communication in the open-ended inquiry class of the Biology and Physics Study Program are higher than those of the guided inquiry class and the conventional class. The results of this study indicate that the activities of doing and communicating procedures and results of investigations at each meeting of student teachers are good as they were seen very active in classroom discussions. The activeness of student teachers in using this skill can be seen when each class finishes presenting the results of their group work, other groups responded to groups presenting the investigations through questions and answers.

However, there are some groups that were not active using this skill. This indicates that the inactivity of student teachers 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 (Lusidawaty et al., 2020; Siantuba et al., 2023). A learning experience that is geared towards increasing scientific literacy (Wenning, 2010).

Inquiry learning should develop students' SPS. According to scholars (Misbahul J, 2020; NRC, 2000; Susilawati et al., 2019), 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 (Krauthwohl, 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 student teachers SPS. Inquiry-based learning encourages to improve science process abilities (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; 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 was designed to train them to have SPS. SPS develop in hands-on and teacher worksheets activities such as observing skills, hypothesizing skills, experiment designing skills, conducting experiments skills, applying concept skills and communication skills. Therefore, to improve SPS student student teachers learning is done by inquiry or discovery. This is intended so that students teacherscan develop high-level mental processes such as critical thinking and making decisions (Nicol et al., 2023).

Learning through discovery is not just science learning, but a way of using science to teach students to think (Hafizan et al., 2012; Noris, M., Saputro, S., 2021; Sunday et al., 2022). Through SPS such as observing, skills, hypothesizing, skills designing experiments, skills carrying out experiments, skills applying concepts and communication skills, this study provides opportunities for student teachers 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 students teachers 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 students teachers to the knowledge learned.

SPS is the essence of science educators and students must understand. This relates to the limitations of science as a process, that science is not just facts. It is the ability to use basic knowledge to predict or explain various natural phenomena. Therefore, the emphasis on the need for SPS for student student teachers must be improve to enhance their abilities of teaching. Thus, learning that emphasizes the active process of science can change teacher behavior in teaching science.

D. Conclusion

The study was carried out to determine the student teachers' mastery of science process skills. After analysing and discussing the findings, it can be concluded that SPS, including doing observation, hypothesis development, the creation of research instruments, and the application of concepts, among student teachers enrolled in two programs: Physics and Biology, as well as to analyze differences by gender. The findings indicate a significant difference in SPS mastery based on gender, but not between the study programs.

Students who used an inquiry module demonstrated a positive improvement in SPS mastery for those studying Biology and Physics at the Faculty of Tarbiyah and Teaching, Universitas Islam Negeri Ar-Raniry in Banda Aceh, Indonesia. The results suggest that both open-ended and guided inquiry modules are effective in enhancing students' mastery of SPS. Overall, inquiry-based learning is found to be more effective than conventional teaching methods for improving mastery of SPS among students.

Additionally, the study indicates that the inquiry-based modules have a similar positive impact on both male and female student teachers, leading to an increase in their SPS mastery. However, it is important to note that the study included a higher proportion of female student teachers—averaging 68.14%—compared to 21.86% male student teachers in guided inquiry and conventional classes. Thus, the results may not fully represent the experiences of each group comparably.

Moreover, the focus of this study does not delve into how teacher educators, differentiated by gender, teach student teachers to master SPS.

Therefore, further research is warranted to explore this aspect more thoroughly.

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ENHANCING PRE-SERVICE TEACHERS' SCIENCE PROCESS SKILLS THROUGH OPEN-ENDED AND GUIDED INQUIRY-BASED LEARNING

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Abstract

This study investigates the effectiveness of open-ended and guided inquiry-based learning modules in enhancing Science Process Skills (SPS) among pre-service science teachers in Indonesia. The study responds to the limited research on SPS development under the implementation of the Independent Curriculum. A quasi-experimental non-equivalent pretest-posttest control group design was employed involving 204 pre-service teachers enrolled in Environmental Education courses, distributed across open-ended inquiry, guided inquiry, and conventional learning groups. Data were analyzed using two-way ANOVA and factorial MANOVA (3×2), considering gender and study program (Biology and Physics) as moderating variables. The results reveal statistically significant improvements in SPS for both inquiry-based groups compared to the conventional group ($p < 0.001$). Gender-based differences were also observed: female participants outperformed males in the guided inquiry group, while males performed better in the open-ended group. No significant differences were found between study programs. The findings underscore the potential of inquiry-based learning modules to foster key scientific competencies and suggest that gender-responsive strategies may further optimize SPS outcomes. This study contributes to international discussions on competency-based science teacher education and offers practical insights for curriculum design in national and global contexts.

Keywords: *Science Process Skills, Pre-service Science Teachers, Open-ended Inquiry, Guided Inquiry*

A. Introduction

Science process skills (SPSs) are crucial for developing science concept knowledge and scientific attitude at all levels of education. However, a large number of studies have evidenced that students continue to have low SPS and little training (Al-Rabaani, 2014; Athiyyah et al., 2020; Nicol et al., 2023), and less encouragement for the tools and practical resources (Nuangchalerm & Prachagool, 2010).

To train students with SPS, it is relevant to use 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). Scientific Inquiry can stimulate thinking skills and increase interest and motivation to learn science because it is a 'hands-on' and 'minds-on' activity (Margunayasa et al., 2019; NRC, 2000; Perla et al., 2023) and also can increase a positive and scientific attitude (Hafizan et al., 2012; Thuneberg et al., 2017).

There are four reasons why SPS is relevant for training science students. *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) and also understand the knowledge acquired (Bati et al., 2010). *Second*, students better understand complex and abstract concepts 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 (Rustaman, 2008). Therefore, educators' good understanding of SPS will enable them to use it in the classroom.

Since teachers' SPSs are crucial, it is also important to train prospective pre-service teachers on these skills. Students must also be taught to conduct scientific research and develop a better understanding of the concepts under study (Jannah, 2020), solve problems (Hafizan et al., 2012), and create higher mental processes such as critical and creative thinking skills and decision-making skills (Adnyana & Citrawathi, 2017). Teachers

with good knowledge of science concepts can usually master SPS well too (Radford et al., 1992).

However, previous SPS studies on pre-service teachers in Indonesia, the United States, Malaysia, and Turkey show unsatisfactory results and fall in the lower category (Adlim et al., 2020; Chabalengula et al., 2012; Eryilmaz & Kara, 2016; Susilawati et al., 2019). Several factors influence SPS for pre-service teachers in several countries. These factors include differences in study programs (Rustaman, 2008) and gender (Al-Rabaani, 2014; Lincoln et al., 2004; Özgelen, 2012; Rumalolas et al., 2021; Rustaman, 2008). Therefore, professional educators must develop SPS.

Teachers should possess a strong understanding and must exhibit competence in SPS to enable to effectively teach the skills (Nicol et al., 2023). Professional educators should also have conceptual knowledge (Vergara et al., 2021), scientific skills and attitudes (Jannah, 2020; NRC, 2000) and good pedagogical skills (Astalini et al., 2023; García-Vandewalle García et al., 2023) because they must plan and implement different learning strategies for science learning, different learning methodologies, and models.

To produce good, memorable learning and improve SPS for pre-service teachers, inquiry is suitable to apply (Astalini et al., 2023) as they need to apply it when teaching. The effectiveness of inquiry-based science learning, especially guided inquiry for pre-service teachers, can increase self-confidence, develop various skills, and develop understanding of content knowledge and scientific knowledge among pre-service teachers (Lamminpää et al., 2023; Stamer et al., 2021).

Although guided inquiry can lead to good science learning, the implementation of learning using inquiry is still a problem for educators in Indonesia (Rustaman, 2008). Previous studies show that SPS develop when students do activities given by the teacher, such as an experiment (Evriani et al., 2017), and the quality of teacher learning has not changed much after they have attended various workshops and training. Only those who have frequently attended workshops and conferences related to their areas of expertise improve their knowledge of the concepts they teach (Al Mamun & Lawrie, 2023; Sudirman et al., 2023; Uludağ & Semra Erkan, 2023). It was also found that many teachers were not very creative and lack of knowledge in developing independent learning (Pamenang et al., 2020; Peretz et al., 2023), as most teach conventionally as they were taught at university (Mohajer et al., 2023; Peretz et al., 2023).

This study intends to assist lecturers in teaching Environmental Education courses and to solve environmental problems in everyday life

through inquiry-based learning by developing an Inquiry-Based Science Learning Module (IBSLM). IBSLM is a learning module consisting of information that can facilitate lecturers in developing SPS in the learning of environmental knowledge of student teachers. IBSLM consists of five sections: 1) Learning plan; 2) learning objectives; 3) hands-on activities; 4) learning materials; and 5) assessment. The IBSLM developed in this module consists of an open-ended inquiry module and a guided inquiry module. The former is that student teachers carry out experiments freely, and these experiments are fully controlled by pre-service teachers, whereas in the latter, the activities are guided by the lecturers.

B. Method

1. Research Design and Sample

The study employed a quasi-experimental non-equivalent pretest-posttest control group design (Creswell 2012). The quasi-experimental design aimed to identify the differences between the results of the control group and the treatment group. It used a 3x2x2 factorial. The first independent variable is the learning model using the guided inquiry module, the open-ended inquiry module, and conventional learning. The second independent variable is study programs (Biology and Physics), and the third variable is gender (male and female). The design of this study is shown in Table 1 below:

Table 1. Research design

Class	Pretest	Treatment	Post-test
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

Table 1 shows that the three groups received a pretest at the initial meeting. Fourteen SPS questions were given in the form of objective questions, where pre-service teachers chose the correct answers based on their initial knowledge of environmental learning about the basic concepts of environmental knowledge and their problems. Next, the treatment was carried out in two experimental classes and one control class based on the study programs (Biology and Physics). In experimental class I, environmental learning was conducted using the open inquiry module,

whereas in experimental class II, Environmental learning was conducted using the guided inquiry module. Both modules are science learning modules that integrate the five steps of inquiry-based science learning (NRC, 2000).

The sample used in this study, as can be seen in Table 2, was 204 pre-service teachers studying at the Faculty of Education and Teacher Training, Universitas Islam Negeri Ar-Raniry Banda Aceh. The sampling method was random group assignment (Lavrakas et al., 2019).

Table 2. Number of pre-service teachers according to study program

Program studies	The number of pre-service teachers in the class			Total
	Experiment I (Open-ended inquiry)	Experiment II (Guided Inquiry)	Control (Conventional)	
Biology	35	33	36	104
Physics	33	34	33	100
Total	68	67	69	204

Table 2 shows that a total of 204 pre-service teachers from two study programs, namely Biology and Physics, participated in this study. Of the 204 respondents who were involved in this study, 104 pre-service teachers (50.98%) were from the Biology study program, and 100 (49.02%) from the Physics study program. They were again divided into three different learning model classes: 68 (33.33%) were in the open-ended inquiry class (Experimental class I), 67 (32.84%) were in the guided inquiry class (Experimental class II), and 69 (33.82%) were in the conventional class (control class).

By gender, the respondents were 139 females (68.14%) and 65 males (31.86%). The open-ended inquiry class of the Biology study program involved a total of 35 pre-service teachers, 10 males and 25 females. For the Physics study program were 33, 13 males and 20 females. The class that received guided inquiry in the Biology study program consisted of 33 pre-service teachers, comprising 11 males and 22 females. The Physics study program involved 34, 11 males and 23 females. The conventional class of the Biology study program involved 36, 10 males and 26 females. The Physics study program involved 33 pre-service teachers, 10 males and 23 females.

The instrument used fourteen multiple-choice questions that refer to the six constructs of SPS, namely observe, hypothesis, design experiment, experiment, apply the concept, and communicate. The questions given in these six constructs are in the form of questions that enhance SPS related to environmental concepts that occur in daily life. The questions of each construct are developed based on the independent curriculum.

Furthermore, validity and reliability are two important things in the data collection procedure. To determine these two things, it is analyzed using Kuder Richardson 20 (KR 20). The validity of these six constructs is 0.80, while the results of reliability are depicted 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		
KR 20				0.079		

The results of the KR-20 analysis show 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 communicating. Even though this ability is crucial one it must be mastered by the teacher. Meanwhile, the mean value indicates that the overall interpretation of scientific process ability is well oriented, with a mean value of around 6.06. while Kuder Richardson 20 (KR 20) value shows $0.079 > 0.05$. This means that the instruments used in research are relatively constant or reliable.

All data obtained from pretest and posttest research instruments were analyzed using SPSS 22. The statistics used in the analysis of this study are descriptive statistics and inferential statistics. For descriptive analysis, it is used to thoroughly describe the research subject, such as

class, gender, and study program of the respondents. The statistics used are frequency, percentage, mean, and standard deviation. Inferential analysis was used to analyze the relationship between three independent variables and three dependent variables. The first independent variable is the class (open-ended inquiry module, guided inquiry module, and conventional learning). The second independent variable is gender (male and female). The third variable is the study program (Biology and Physics). To determine the effectiveness of using the inquiry module in improving SPS, involved two-way ANOVA and a 3x2 Factorial MANOVA were involved. The two-way ANOVA test is used to determine differences in SPS based on class, gender, and study program. The MANOVA test was used to analyze the hypothesis of the independent variable that produces the same mean vector for the dependent variable, and used the Box's M test ($p > 0.05$). Meanwhile, the MANOVA Factorial 3x2 test was used to analyze the impact of class and study programs on the six constructs of SPS.

Therefore, this study hypothesizes that:

- H01: The use of open-ended and guided inquiry modules in learning has a significant effect on pre-service teachers' SPS based on the study program
- Ha1: The use of open-ended and guided inquiry modules in learning has no significant effect on pre-service teachers' SPS based on the study program
- H02: The use of open-ended and guided inquiry modules in learning has a significant effect on pre-service teachers' SPS based on gender
- Ha2: The use of open-ended and guided inquiry modules in learning has no significant effect on pre-service teachers' SPS based on gender
- H03: The use of open-ended and guided inquiry modules in learning has a significant effect on the six constructs of SPS pre-service teachers based on gender and study program
- Ha3: The use of open-ended and guided inquiry modules in learning has no significant effect on the six constructs of SPS pre-service teachers based on gender and study program

C. Result and Discussion

1. Results

This study aims to investigate the effects of using open-ended and guided inquiry modules on the SPS of the pre-service teachers

undertaking Environmental Education courses based on class, gender, and study program, and the pre-service teachers' SPS learning conventionally.

In general, the differences in SPS mastery of the pre-service teachers based on the study programs can be seen in tables 4, 5, and 6.

Table 4. Mean and standard deviation of pretest and posttest SPS

Kelas	Study Program	N	Pretest		Posttest	
			Mean	Standard Deviation	Mean	Standard Deviation
Open-ended inquiry	Biology	35	44.49	22.123	69.59	14.426
	Physics	33	40.69	19.842	69.91	14.807
	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

The analysis of open-ended inquiry scores shows that the pretest average for Biology and Physics study programs is around 42.64%, while the posttest score is around 69.74%. This shows a significant increase when using a learning model using a guided inquiry module. In guided inquiry, the average score on the pretest is around 40.51% while the posttest is around 72.92%. while in conventional inquiry, the average pretest shows 46.68%, and the posttest ranges from 41.30%. This can be seen in Table 5 below:

Table 5. Two-way ANOVA analysis of differences in SPS mastery

	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			

The ANOVA test results show that the SPS of Physics and Biology pre-service teachers have significant differences. This can be seen from the significance value between study programs and classes that have sig. values ranging from $0.894 > 0.05$. can be seen in Table 6.

Table 6. Scheffe's post-hoc examination of the differences in SPS mastery of pre-service teachers 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

The analysis using two-way ANOVA and Scheffe's Post Hoc test, as shown in tables 4, 5, and 6, shows that there is no significant difference in mastery of SPS between the pre-service teachers who used open inquiry and those who used guided inquiry. Hence, pre-service teachers who use open-ended inquiry have the same mastery of SPS as those in the guided inquiry class.

Mastery of SPS can be influenced by several aspects, such as the learning model provided, gender, and several other factors. Table 7 shows the differences in average scores between male and female pre-service teachers in mastering SPS.

Table 7. The results of the pretest and posttest of SPS mastery of pre-service teachers between classes by gender

Class	Gender	N	Pretest		Posttest	
			Mean	Standard Deviation	Mean	Standard Deviation
Open-ended inquiry	Male	23	35.09	17.879	72.05	15.215

Guided Inquiry	Female	45	46.50	21.569	68.57	14.154
	Total	68	42.64	20.978	69.74	14.503
	Male	22	41.55	14.727	70.77	13.208
Conventional	Female	45	40.00	17.914	73.96	13.718
	Total	67	40.51	16.837	72.92	13.536
	Male	20	46.42	11.703	49.64	13.409
	Female	49	46.79	14.139	37.90	14.883
	Total	69	46.68	13.394	41.30	15.342

The analysis shows that open-ended inquiry, male pre-service teachers had higher SPS than females. Meanwhile, for the guided inquiry, the SPSs of female pre-service teachers were higher than those of males. The difference is statistically significant, as shown in Table 8.

Table 8. Two-way ANOVA analysis of differences in SPS mastery based on gender

	Type III Sum of Squares	Df	Mean Power Two	F	Sig.
Class	576.287	2	288.143	72.946	0.001*
Gender	13.922	1	13.922	3.524	0.06
Class*Gender	31.727	2	15.863	4.016	0.02*
Standard Error	782.114	198	3.950		
Total	16601.000	204			

The significant value of the difference in pre-service teachers' SPSs between groups based on class*gender was with a value of $F = 4.016$ and a significant value (p) = 0.02 ($p < 0.05$). This suggests that, based on gender, there is a significant difference in pre-service teachers' SPSs between the open-ended inquiry and the guided inquiry. There is also an interaction between class and gender on SPSs. The interactions that occur are as shown in Figure 1.

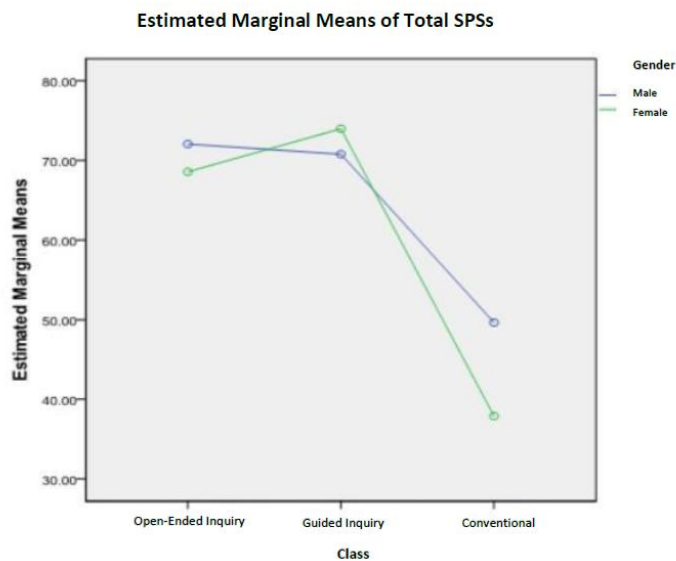


Figure 1. Interaction between groups and gender of pre-service teachers on SPSs

Table 8 and Figure 1 show that there is a significant interaction between groups and gender in SPSs. The interaction that occurred between the group and the gender of pre-service teachers on SPSs, where female pre-service teachers in the guided inquiry had higher SPS than males. Meanwhile, in the open-ended inquiry and conventional classes, male pre-service teachers have higher SPS than females. This suggests that there is a significant interaction between groups and gender in pre-service teachers' SPSs.

Pillai's Trace is used for one class of dependent variables (pretest or post-test only of SPSs). Pillai's Trace test results in the Multivariate Test Table show that overall, there is a significant relationship between open-ended inquiry, guided inquiry and conventional class [$F(12,388) = 13.23$, sig 0.000 $p < 0.05$] to the SPSs construct of 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 in observing skills,

hypothesizing skills, experiment designing skills, conducting experiments skills, concept application skills and communication skills.

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

The analysis as depicted in Table 8 shows the significance value of Lavene's test for the skill construct observes the sig value. = 0.000, $p < 0.05$. Meanwhile, 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), $p > 0.05$.

Table 10. Mean and standard deviation of the SPS construct of pre-service teachers based on study programs and classes

SPS Construction	Study Program	Class	N	Mean	Standard Deviation
Observe	Biology	Open-ended inquiry	35	85.71	25.928
		Guided Inquiry	33	90.90	23.233
		Conventional	36	61.11	38.005
		Total	104	78.84	32.450
	Physics	Open-ended inquiry	33	89.39	24.230
		Guided Inquiry	34	92.64	21.785
		Conventional	33	59.09	38.435
		Total	100	80.50	32.485
	Hypothesis	Open-ended inquiry	35	77.14	30.541
		Guided Inquiry	33	78.78	28.035
		Conventional	36	44.44	28.729
		Total	104	66.34	33.006
		Total			

Design Experiments	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			
	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			
Carry Out Experiments	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			
	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			
Application of The Concept	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			
	Biology	Open-ended	35	46.66	27.057
		inquiry	33	50.50	31.316
		Guided Inquiry	36	24.99	23.059
		Conventional	104	40.38	29.257
		Total			
Communicate	Physics	Open-ended	33	45.45	27.410
		inquiry	34	47.05	32.945
		Guided Inquiry	33	23.23	22.798
		Conventional	100	38.66	29.860
		Total			
	Biology	Open-ended	35	78.09	22.784
		inquiry	33	75.75	22.473
		Guided Inquiry	36	49.07	24.543
		Conventional	104	67.30	26.675
		Total			

Physics	Open-ended	33	77.77	21.516
	inquiry	34	75.49	20.611
	Guided Inquiry	33	46.46	23.482
	Conventional	100	66.66	25.950
	Total			

The results of the analysis of the *mean* and standard deviation of the SPS construct show that the average value in the ability to observe between Biology and Physics pre-service teachers is higher for Physics pre-service teachers (80.50). In terms of hypothesizing ability, Physics pre-service teachers obtained higher scores (60.50), Physics pre-service teachers had higher ability to design experiments (61.00), Biology pre-service teachers had higher concept application ability (40.38), and Biology pre-service teachers had higher communication skills (67.30).

Table 11. MANOVA analysis of differences in SPS constructs for pre-service teachers based on study program and class

Category	Leaning variable	Type III Sum of Squares	Df	Mean Squared	F	Sig.
Study Program	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					
	Carry Out	9.578	1	9.578	.012	.912
	Experiments					
	Application of The Concept	233.759	1	233.759	.306	.581
Class	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	34267.114	2	17133.557	21.726	.000
	Experiments					
Study	Application of The Concept	24994.602	2	12497.301	16.346	.000
	Communicate	38580.510	2	19290.255	37.676	.000
Study	Observe	287.457	2	143.729	.165	.848

<i>Title of Papers (Filled Out by the Editor)</i>						
<i>Author Name (Filled Out by the Editor)</i>						
	Hypothesis	67.461	2	33.731	.040	.961
	Design	30.089	2	15.045	.015	.985
	Experiments					
	Carry Out	94.665	2	47.333	.060	.942
	Experiments					
	Application of The	45.577	2	22.789	.030	.971
	Concept					
	Communicate	61.235	2	30.617	.060	.942

2. Discussion

The two-way ANOVA test analysis indicates that there was a significant difference in SPS mastery of pre-service teachers between open-ended inquiry, guided inquiry, and conventional group based on gender. This means that female pre-service teachers in the guided inquiry had higher SPS than males. Meanwhile, in the open-ended inquiry groups, male pre-service teachers have higher SPSs than females. This means that the use of guided inquiry-based science learning modules has an impact on female whereas open-ended inquiry impact on male pre-service teachers on SPS mastery. The results are contrary to those of some previous studies (Al-Rabaani, 2014; Astalini et al., 2023; Nicol et al., 2023), but consistent with those of other previous studies (Evriani et al., 2017; Kurniawan & Fadloli, 2016) showing that the SPS of female pre-service teachers is higher than that of males.

An analysis of the two-way ANOVA test shows that there is no significant difference in SPS mastery of pre-service teachers based on study programs. This means that the science lessons received by Biology and Physics pre-service teachers are both effective. The effectiveness of this learning is because each topic of pre-service teachers' learning requires them to think critically and actively to develop SPS. This is in line with the results of the studies by Krathwohl (2002) and Marzano et al. (2009). It was also found that students who have gone through an active learning process can demonstrate complex thinking skills such as effective communication, cooperation, and collaboration, and the ability to process information properly and effectively (Knezek et al., 2023; Krathwohl, 2002).

The process of mastering active thinking skill strategies is also needed in assisting professional teachers in developing teaching and learning strategies (Sudirman et al., 2023). There is no difference in the

SPS of pre-service teachers for both Biology and Physics study programs because the lecturers had attended seminars and workshops related to innovative learning that improve their SPS. The results of this study are different from those of previous studies by Jannah (2020) and Rustaman (2008) in that the SPSs of prospective Biology and Physics pre-service teachers had significant differences.

The results of the inference analysis using the 3 x 2 factorial MANOVA test 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 the *mean* of the scores pre-service teachers who used guided inquiry in Biology and Physics study programs is higher than that of the open-ended inquiry class and the conventional class pre-service teachers. As for the skill constructs of carrying out experiments and communication skills, their means of the scores of pre-service teachers' classes using open-ended inquiry in the Biology and Physics study program is higher than that of students of the guided inquiry class and the conventional class. The results show that in both Biology and Physics study programs, pre-service teachers who use open-ended inquiry have high observing skills, hypothesis skills, experimental design skills, and concept application skills compared to those using guided inquiry and open-ended inquiry. All the skills fall into high-level skills (Krathwohl, 2002), which include the activities 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, and creating (Marzano et al., 2009).

In this study, each hands-on activity in the guided inquiry-based learning, the pre-service teachers in both study programs have observation skills, hypothesis skills, experimental design skills, and good concept application skills. For hands-on activities designed to train teachers to observe, they carried out observations using various media based on the concepts being learned, such as real objects, models or pictures, or graphs. In addition to observing skill aspects, the pre-service teachers hypothesizing skills, experiment designing skills and concept applying skills were also investigated through activities designed at the hands on activity. In the guided inquiry class in the Biology and Physics Study Program, the skill of creating hypotheses that the pre-service teachers have is not a good result. This is shown when pre-service teachers were asked to create hypotheses before the experiment was carried out. The ability of pre-service teachers in generating hypotheses is

their ability to guess or estimate from a research problem, or the ability to make a hypothesis to connect two variables, or make assumptions or conjectures (Margunayasa et al., 2019).

The skills of pre-service teachers in planning investigations and applying the concepts in this study have improved. Pre-service teachers in the guided inquiry classes in Biology and Physics study programs have the skills to prepare learning tools and materials before learning begins based on the concepts to be learned. The skills needed in designing experiments such as determining the tools and materials to be used, the objects to be investigated, the factors or variables considered, the criteria for success, the methods and work steps, and how to record and process data to draw conclusions (Lestari & Diana, 2018). At the time of designing and experimentation, the teacher should direct the experiment under study, and during the experiment carried out and the teacher should act as a facilitator.

The skills of doing experiments and communication in the open-ended inquiry class of the Biology and Physics Study Program are higher than those of the guided inquiry class and the conventional class. The results of this study indicate that the activities of doing and communicating procedures and results of investigations at each meeting of pre-service teachers are good, as they were seen as very active in classroom discussions. The activeness of pre-service teachers in using this skill can be seen when each class finishes presenting the results of their group work, and other groups respond to the groups presenting the investigations through questions and answers.

However, some groups were not active in using this skill. This indicates that the inactivity of pre-service teachers in conducting question-and-answer sessions 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 can encourage students' ability to communicate effectively, practically, and flexibly (Lusidawaty et al., 2020; Siantuba et al., 2023). A learning experience that is geared towards increasing scientific literacy (Wenning, 2010).

Inquiry learning should develop students' SPS. According to scholars (Jannah, 2020; NRC, 2000; Susilawati et al., 2019), 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), it 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 teachers' SPSs. Inquiry-based learning encourages to improvement of science process abilities (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; 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 to raise questions and form hypotheses based on existing ideas. *Second*, provide opportunities for discussion in class. All participants in the class are allowed 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 pre-service teachers' worksheets was designed to train them to have SPS. SPS develops hands-on and teacher worksheets activities such as observing skills, hypothesizing skills, experiment designing skills, conducting experiments skills, applying concept skills, and communication skills. Therefore, to improve SPSs, pre-service teachers' learning is done by inquiry or discovery. This is intended so that pre-service teachers can develop high-level mental processes, such as critical thinking and making decisions (Nicol et al., 2023).

Learning through discovery is not just science learning, but a way of using science to teach students to think (Hafizan et al., 2012; Noris, Saputro, 2021; Sunday et al., 2022). Through SPSs such as observing, hypothesizing, designing experiments, carrying out experiments, applying concepts, and communication, this study provides opportunities for pre-service teachers 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 pre-service teachers to the knowledge they have just learned. Activities and exercises provided through hands-on and pre-service teachers' worksheets can relate the knowledge possessed by pre-service teachers to the knowledge learned.

SPS is the essence of science educators, and students must understand. This relates to the limitations of science as a process, that science is not just facts. It is the ability to use basic knowledge to predict or explain various natural phenomena. Therefore, the emphasis on the need for SPS for pre-service teachers must be improved to enhance their ability to teach. Thus, learning that emphasizes the active process of science can change teacher behavior in teaching science.

The findings of this study also hold broader implications beyond the Indonesian context, particularly in addressing global challenges in science teacher education. Inquiry-based science learning, as demonstrated in both the open-ended and guided inquiry modules, aligns with international educational goals that emphasize the development of critical thinking, scientific literacy, and inquiry competence among pre-service teachers (NRC, 2000; Nicol et al., 2023). These skills are considered essential by global institutions such as UNESCO and the OECD to meet the targets of Sustainable Development Goal 4, which advocates for inclusive and quality education for all. Moreover, the study responds to a recurring issue reported internationally—namely, the persistent gap in SPS among pre-service teachers despite exposure to formal coursework (Chabalengula et al., 2012; Eryilmaz & Kara, 2016). By offering evidence of how structured inquiry modules can improve SPS, this research contributes valuable insights that can inform teacher education policies and instructional design not only in developing countries but also in diverse educational systems striving for competency-based learning outcomes.

D. Conclusion

The study was carried out to determine the pre-service teachers' mastery of SPS by class, gender, and study program, who were taught using open-ended and inquiry modules, and taught conventionally. After analyzing and discussing the findings, it can be concluded that SPS, including observation, hypothesis, design experiment, and the application

of the concepts, among pre-service teachers enrolled in two programs: Physics and Biology, as well as to analyze differences by gender. The findings indicate a significant difference in SPS mastery based on gender, but not between the study programs.

Pre-service teachers who used an inquiry module demonstrated an improvement in SPS mastery for those studying Biology and Physics at the Faculty of Tarbiyah and Teaching, Universitas Islam Negeri Ar-Raniry in Banda Aceh, Indonesia. The results suggest that both open-ended and guided inquiry modules are effective in enhancing Pre-service teachers' mastery of SPS. Overall, inquiry-based learning is found to be more effective than conventional teaching methods for improving mastery of SPS among Pre-service teachers.

Additionally, the study indicates that the inquiry-based modules have a similar positive impact on both male and female student teachers, leading to an increase in their SPS mastery. However, it is important to note that the study included a higher proportion of female student teachers, averaging 68.14%, compared to 21.86% male student teachers in guided inquiry and conventional classes. Thus, the results may not fully represent the experiences of each group comparably.

Moreover, the focus of this study does not delve into how teacher educators, differentiated by gender, teach Pre-service teachers to master SPS. Therefore, further research is warranted to explore this aspect more thoroughly.

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Rab, 23 Apr 2025 pukul 23.30

Article ID: 1174

Dear Authors/Contributors,

Congratulations! We are pleased to inform you that we have reached a decision regarding your manuscript titled "**Enhancing Pre-Service Teachers' Science Process Skills Through Open-Ended and Guided Inquiry-Based Learning**".

Our decision is to: Your Article is Accepted.

After going through a rigorous review process and considering feedback from reviewers, our editorial team is confident that your contribution will add important insights to the field you are studying. Your article has demonstrated high research quality and is in line with the focus and scope of this journal.

The study highlights a highly relevant issue in the context of teacher education, particularly under the implementation of the Kurikulum Merdeka in Indonesia. The quasi-experimental design employed is appropriate and well-executed. The statistical analyses, including ANOVA and MANOVA, are correctly applied and support the findings effectively. The results are clearly presented, and the discussion meaningfully connects the findings with existing literature, showing a good grasp of current trends in science education and inquiry-based learning. The manuscript is well-structured, and the references used are current and relevant, which strengthens the theoretical foundation of the study. The conclusion appropriately summarizes the key findings and implications, with a brief but insightful note on the gender dynamics and further research directions.

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