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STEM-Based Learning Process Analysis of Students' Science Process Skills

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Abstract: The STEM-based learning process spurs the creativity of students in knowledge, skills and others. Students' science process skills are very supportive in improving the quality of education to solve problems in everyday life. This study aims to determine the suitability of the learning process by pre-service teachers with the learning planning stages, students' science process skills and the correlation between the learning process and science process skills. This research is quantitative and qualitative through descriptive research. The results showed that the value of the results of observations on the learning process by the pre-service teacher was in the good category. The value of students' science process skills is in the sufficient category. There is a correlation between the STEM-based learning process and students' science process skills, which means that the STEM-based learning process affects students' science process skills even though it is small. The conclusion in this study is that the STEM-based learning process on science process skills has a positive relationship to the quality of student learning.

Keywords: Creativity; Ecology; Science process skills; Pre-service teacher; STEM-based learning process

Introduction

The learning process as a teaching and learning activity that involves teachers and students. The learning process applied determines the success of learning or the acquisition of students' knowledge (Maasrukhin et al., 2019) in the form of efforts to attract students' attention in learning. Variations in learning methods can be adjusted to the abilities and material being taught. The development of the times accompanied by developments in various fields, is expected to integrate various developments in the learning process. One approach that can be applied in this era is the STEM approach. The STEM approach is science, technology, engineering and mathematics integrated to develop products, processes and systems that benefit human life. This learning makes students not only understand the material but are required to think about finding solutions to problems (Davidi et al., 2021).

The STEM approach supports student creativity by integrating knowledge, skills and abilities in solving problems (Haryadi et al., 2020). The application of the STEM-based learning process involves students directly in independent learning activities in an effort to improve human thought processes from various more advanced fields (Rosana et al., 2021). Some students use the STEM-based learning process as their best experience and want the activity time to be extended as proof that students are interested in the learning process (Özkul et al., 2020).

STEM education has differences that are adjusted to the ability to think cognitively at each level of education. STEM education with the hope of forming human resources who have high expertise according to their fields and can provide new innovations. New innovations are forms of integration of knowledge, skills, value in science, technology, engineering, and mathematics (Setiawan et al., 2020).

The distinctive feature of STEM-based learning is the existence of an Engineering Design Process (EDP) activity pattern that is used to integrate science, mathematics and technology. EDP is a decision-making process, usually repeated, in which basic science, mathematics and engineering concepts are applied to develop optimal solutions to achieve stated goals (Mangold et al., 2013).

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An explanation of the EDP (Engineering Design Process) Pattern or the process of designing a work or machine in the STEM approach is as follows:

Table 1. Engineering Design Process (Giyanto. et al., 2020).

EDP Pattern Name	Explanation
Define the problem	Formulation of the problem
Plan solutions	Solution plan
Make a model	Create and develop models
Test the model	Using models
Reflect and redesign	Communicate, reflect, evaluate, redesign

The learning process involves students and educators forming interactions as a process of acquiring knowledge and knowledge as well as the attitudes and beliefs of students. This is the important role of educators in the learning process. Education helps so that the process of acquiring knowledge and knowledge, material mastery and the formation of attitudes and trust in students is realized (Suardi, 2018). Activities in the learning process are designed by teachers as educators who must be able to find loopholes so that learning is carried out more effectively. Plans designed to encourage the use of techniques that can develop cognitive behavior and construction theory of teaching solutions and problems (Susanto, 2016).

Efforts given by the teacher to develop the abilities of students such as science process skills. The pre-service teacher will try harder to deal with difficulties in the learning process by direct experience or seeking information from various parties to solve problems, even adapting to increasingly advanced times (Kim et al., 2015). Science process skills are an approach based on the assumption that science develops and forms through a scientific process. The process of learning science is developed in students as a meaningful experience by demanding physical and mental intellectual involvement (Priyani et al., 2020). The development of science process skills is used to help students gain an understanding of material that is long-term memory so that it is expected to be able to solve all forms of life's problems (Haryadi et al., 2020).

The application of STEM-based learning has increased science process skills in students' knowledge (Bhakti et al., 2020; Farach et al., 2021; Khamngoen et al., 2021; Özkul et al., 2020). STEM learning that directly involves students has a positive impact so that the work they get can be utilized by many people (Rosana et al., 2021). The STEM approach is integrated to develop products, processes and systems that benefit the lives of students (Yulia, 2021).

From the several studies above, this research is aimed at examining how the STEM-based learning process in ecological material as well as environmental change and preservation carried out by the pre-service teacher affects the science process skills possessed by students at State Senior High School 11 Banda Aceh. The selection of this material is at the State Senior High School level because the material is more detailed or in-depth. This study examines the STEM-based learning process that is applied to the material by the pre-service teacher which category it belongs to in science process skills. The completeness of the learning process applied by the pre-service teacher in terms of his preparation for teaching the results in science process skills. The purpose of this study was to determine the suitability of the learning process by the pre-service teacher with the learning planning stages, students' science process skills and the correlation between the learning process and science process skills through the application of STEM learning to ecological material as well as environmental change and preservation.

Method

The method used in this research is quantitative and qualitative using a descriptive approach. Descriptive method is a research method in the form of data collection to test hypotheses related to current conditions and events. Report the state of the object or subject under study in accordance with what it is. The purpose of the descriptive method is to systematically describe the facts and characteristics of the object or subject being studied appropriately (Darmawan, 2013). This research is a descriptive analysis of activity (activity analysis) aims to determine the science process skills of students with the STEM-based learning process.

Table 2. Science Process Skills Test Instrument

Aspects and Sub-aspects of Indicators
Basic skills
Observe
Recording data/information
Follow orders/instructions
Take measurements
Implement procedures/techniques/use of equipment
Process skills
Make predictions
Make inferences
Selecting procedures
Investigative skills
Designing an investigation
Carry out investigations
Report the results of the investigation

This research was conducted at State Senior High School 11 Banda Aceh with a sample of 58 class X students. Determination of the sample is determined by using a purposive sampling technique. The research sample was determined based on the abilities possessed by students regarding the material and based on interviews with teachers, it was obtained that sample information had more abilities than the others. The

research instrument used was a test sheet containing essay questions, an observation sheet containing statements according to the Subali indicator for observing students' science process skills. Another instrument, a checklist sheet containing indicators developed by Ambarawati (2016) for observing the learning process carried out by pre-service teachers.

The data collection technique in this study was from video documentation for the learning process and students' science process skills used were divided into two stages, namely the preparatory stage with research instruments and other research tools to record videos and the implementation stage, namely observation from videos that have been recorded. Data analysis techniques in descriptive research are quantitative data. Analysis of research data aims to test the truth of what is proposed in the research. The learning process uses the formula proposed by Cohen to measure the level of agreement between raters (inter rater reliability) because there are two observers. Cohen's Kappa coefficient is shown in equation 1 (Fuadi. et al., 2015).

$$K = \frac{\sum fo - \sum fe}{N - \sum fe} \quad (1)$$

Table 3. Kappa Interpretation (Napitupulu, 2014)

Kappa Index	Agreement
< 0.40	Bad
0.40 – 0.60	Fair
0.60 – 0.75	Good
> 0.75	Excellent

Science process skills were analyzed quantitatively by using descriptive statistics to obtain the average score, the lowest score, and the highest score. The data that has been obtained is then analyzed descriptively (Sa'diyyah et al., 2016). The results obtained are interpreted using the following criteria:

Table 4. Categorization of Science Process Skills Scores (Arifin, 2016; Sudjana, 2008)

Average value	Criteria
A (Very good)	≥ Mean + 1.5 SD
B (Good)	Mean + 0.5 SD ≤ X < Mean + 1.5 SD
C (Enough)	Mean – 0.5 SD ≤ X < Mean + 0.5 SD
D (Less)	Mean – 1.5 SD ≤ X < Mean – 0.5 SD
E (Very less)	≤ Mean + 1.5 SD

The correlation between the stem-based learning process and students' science process skills uses the calculation of the Product Moment Method correlation coefficient analysis, also known as the Pearson formula. To see the level of closeness of the correlation, Guilford's interpretation of the magnitude of the significant correlation is used as follows:

Table 5. Correlation Closeness Level

Coefficient Intervals	Closeness Level
< 0.19	A little; almost no connection
0.20 – 0.39	Low correlation; relationship is sure but small
0.40 – 0.69	Moderate correlation; substantial relationship
0.70 – 0.89	High correlation; strong relationship
0.90 – 1.00	Very high correlation; very reliable relationship
≥ 0.30	A practically significant relationship

Result and Discussion

The learning process applied by prospective teachers to ecological material as well as environmental change and preservation in class XIA at Senior High School 11 Banda Aceh amounted to 58 for these two materials. Pre-service teachers are constrained by time in the field, they have to minimize the activities listed in the lesson plans due to the pandemic, where the learning process lasts for 30 minutes. As far as the observers observed in this study, prospective teachers have worked optimally by sorting out the main activities that will be applied to students so that the material is conveyed correctly and in accordance with the syntax previously designed in the lesson plan. The learning process applied in class uses a STEM-based approach. The learning process activities obtained data by observing the video of the learning process by two observers. The two observers assessed according to the indicators of the learning process. Each indicator is observed whether or not there are activities carried out by prospective teachers. The number of items observed was 62. Data obtained from each observer were analyzed using the Kappa Cohen formula for inter-rater reliability analysis. The results of the reliability test between raters can be seen in the following table:

Table 6. Inter Rater Reability Learning Process on Ecology Material and Environmental Change and Preservation

Material	N	Value	Asymp. Std. Error	Approx. Sig	Category
Ecology	62	0.708	0.111	0.000	(Good)
Environmental change and preservation	62	0.727	0.102	0.000	(Good)

Based on the table, it shows that the results of the inter rater reliability test on ecological material amounted to 0.708 and on environmental change and preservation material amounted to 0.727 belonging to the good category. The number of standard errors or Asymp. std. The smaller the error, the better the test results. The probability value obtained concluded that the agreement between the two observers was stated to

be good. Furthermore, the suitability analysis data of the learning process is presented in the table below:

Table 7. Appropriate Value of Learning Process

Assessment Aspects	Observer 1	Observer 2	Average	Category
Lesson Opening Skills	68.8	62.5	65.6	Enough
Skills to explain (carrying out core activities)	100	100	100	Good
Questioning skills	78.6	100	89.3	Good
Strengthening skills	25.0	25.0	25.0	Very less
Variation skills	73.3	63.3	68.3	Enough
Skills close the lesson	81.3	62.5	71.9	Enough
Lesson plan	100	100	100	Good

Based on the following table shows that the learning process is observed with seven aspects with different values. The values obtained are classified from very poor to good categories. In the aspect of opening lesson skills, the pre-service teacher is included in the sufficient category in attracting attention, motivation, reference, and material association. The ability of the pre-service teacher looks like an experienced teacher in teaching style, use of media, varied interaction patterns and so on. However, the ability of the pre-service teacher in expressing conflicting ideas, as well as the connection between the previous material and the material to be studied is not treated in class. In the aspect of explaining skills (carrying out core activities), the pre-service teacher looks good in mastering methods, materials, and mastering competencies. The use of methods involving student activity, exploration, collaboration, accurate material, material development, and responses to suitability/not competence.

The aspect of questioning skills, the ability of the pre-service teacher looks good to stimulate students to ask questions and vice versa, and opportunities to answer for students, transfer of turns and others. The aspect of holding reinforcement, the pre-service teacher looks very lacking. The pre-service teacher only participates in the learning process as usual without strong reinforcement. Meanwhile, reinforcement must be clear to the intended student, reinforcement is given immediately after the expected student behavior or response appears, and the type or type of reinforcement used should vary and not be treated in the learning process. Other actors are also affected by the short time (pandemic period) which also affects the learning process with the many activities carried out.

The aspect of skills in carrying out variations, the ability of the pre-service teacher is quite good in interacting with students, using media, and teaching methods that attract students. However, the use of sound, concentration of student attention, teacher-student patterns are not carried out in the learning process. In the aspect of closing skills, the pre-service teacher is quite good at evaluating, assessing and reflecting on students. And the lesson plan aspect is very good in fulfilling all the indicators listed. The STEM approach with the Engineering Design Process (EDP) pattern is suitable to be applied to ecological material as well as environmental change and preservation so that learning is more effective and varied. Every activity carried out by students seems to enjoy learning biology (Rustaman, 2021). STEM-EDP learning increases the effectiveness of a set of products and learning outcomes. The teacher directs students in groups in each activity so that learning objectives are achieved (Nurtanto et al., 2020).

The learning process applied gives the impression of a flexible process for students. The pre-service teacher has designed the best possible way to solve life's problems in the material being taught by finding solutions (Widowati et al., 2021). This was done in research on ecological material with the existence of 3D miniatures which were assembled by students with simple tools and materials and material for environmental change and preservation by making simple filter tools and comparison tools for pollution causes. The solutions provided can be assembled by students with simple tools and materials.

The STEM-based learning process that is applied, the teacher or pre-service teacher who teaches has an important role so that learning is more effective and efficient. Pre-service teachers in STEM-based learning as a field that is growing and integrating various knowledge must have the ability because they will become educators for the next generation with developments in various fields. Even the pre-service teachers who were given STEM education themselves saw an increase in their knowledge (Akaygun et al., 2016). Pre-service teachers experience difficulties in finding problems in the material-related environment, finding ideas, developing materials, products and others. This is an influence for students in the interest and curiosity of students (Calis, 2020). The learning process in this study was observed with videos recorded while the learning took place in the room to be assessed according to the indicators of the learning process.

Science process skills as an important part of the learning process so that it can take place effectively and efficiently. The pre-service teacher implements a STEM-based learning process with appropriate and adequate steps. The learning process is designed with the hope that students will obtain ecological material as well as environmental change and preservation properly and correctly. The realization of effective learning for students can be seen from the final results obtained by students. Each activity in learning also strongly supports the final results that can be observed, one of which is the science process skills possessed by students.

Measurement of science process skills in this study used 35 indicators whose data were collected through observation and 8 indicators through tests. The average yield value on science process skills observed during the learning process can be seen in the following table:

Table 8. Average Value of Science Process Skills in Ecology Materials and Environmental Change and Preservation

Aspect	Average Score of Science Process Skills	Category
Basic Skills	71.60	Enough
Processing Skills	80.27	Good
Investigating Skills	74.60	Enough

Based on the table, it shows that each average value obtained in each aspect, namely aspects of basic skills, aspects of processing skills, and aspects of investigative skills. The basic skills aspect obtained an average score of 71.60 in the sufficient category, the process skills aspect obtained an average score of 80.27 in the good category and the investigative skill aspect obtained a value of 74.60 in the sufficient category. The highest score is in the aspect of processing skills because students are active in the learning process as direct observation which will become their experience.

Data analysis of the average value obtained from students' science process skills during the STEM-based learning process is applied. Aspects of basic skills obtained from science process skills in this study can be seen in Figure 1.

Based on the Figure 1, it shows that there are 20 indicators of the aspects of basic skills observed. Of the 20 indicators that obtained scores, seven indicators were in the good category, eight indicators were in the sufficient category, four indicators were in the poor category and one indicator was in the very poor category. This aspect looks at the ability of students to identify, compile, complete, assemble and others. The highest score was obtained by the indicator demonstrating fine motor control in various ways (arranging/completing charts/cutting/assembling/ shaping/assembling) with a score of 81.61 in the good category. Then, the indicator demonstrates gross motor control in various ways (eg running a machine/motorcycle) with a value of 81.04 in the good category. Learners arise curiosity about ongoing learning with a variety of equipment and practical materials. The lowest score was also seen in the indicator carrying out the screening technique with a value of 68.97, this was because the screening was carried out outside the room, only group representatives observed the screening process and this was the lowest score in students' science process skills which were obtained in the very poor category.

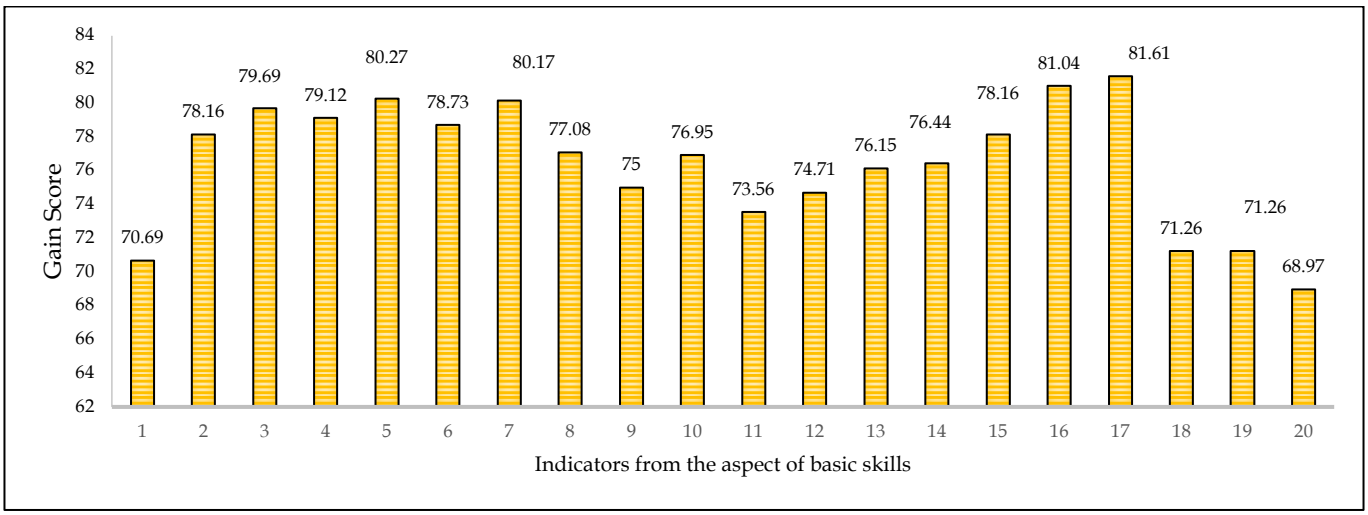

Figure 1. Average indicators on basic skills aspect

Good category indicators, namely indicator 3 identifying objects of observation based on their descriptions, indicator 4 identifying objects of observation to be matched with certain references (color/shape/level), indicator 5 identifying similarities/differences between objects of observation, indicator 6 identifying potentially risky situations when working in school/laboratory with what is in everyday life, and indicator 7 records simple information from observations by presenting it in various forms.

The sufficient category indicator, namely indicator 2 identifies the type of data that can be collected in making observations in accordance with the sensory apparatus used, indicator 8 makes a summary of the observations, indicator 9 draws a simple form of the results of observations, indicator 10 compiles information in tabular form complete with table titles, indicator 12 completes an observation procedure (with/without tools) according to commands given verbally, indicator 13 completes an observation

procedure, indicator 14 provides measuring units/devices to carry out measurements and indicator 15 roughly estimates relative weight, volume, and time interval short term of observation.

Poor category indicators, namely indicator 1 identifying the type of data that can be collected in conducting observations with or without measuring instruments, indicator 11 completing an observation procedure (with/without tools) after the teacher demonstrates it, indicator 18 identifying laboratory equipment commonly used in observations and indicator 19 separate solid or liquid materials by using a certain way. The category indicator is very lacking, namely carrying out screening techniques because in this observation it is only done by group representatives who observe directly outside the classroom. Even though the information obtained from these observations was conveyed in group discussions.

In the aspect of basic skills, students are seen to be actively working in accordance with the teacher's directions, observing all activities carried out in the classroom. Although, there are some students who look no less indifferent as if they have no curiosity in themselves, overall students participate in the STEM-based learning process. Student worksheet assignments, individual assignments, and the process of assembling tools, following work procedures carried out by students. Everything cannot be separated from the direction and supervision of the pre-service teacher. Aspects of process skills obtained from science process skills in this study can be seen in Figure 2.

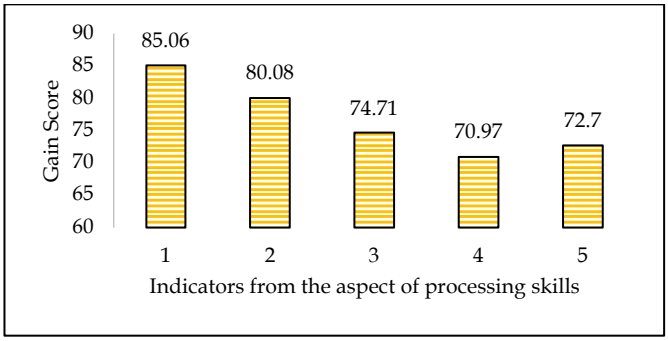

Figure 2. Average indicators on the aspect of processing skills

Based on the figure, it shows that in the aspects of process skills, there are five indicators observed. This aspect has one indicator belonging to the category of very good, good, and sufficient. While the other two indicators belong to the less category. The value obtained from the indicator predicts changes in the condition of the object 85.06 which is the highest value of the other indicators. The indicator category is very good. The lowest score is obtained from the indicator of anticipating risks and adopting appropriate precautions and procedures in carrying out each laboratory experiment/practical investigation with a value of 70.97 in the less category, because students look like they are not indifferent to doing it.

Very good category indicators, namely indicator 1 predicts changes in the condition of the object of observation. The good category indicator, namely indicator 2, makes reasonable generalizations based on the observations. The sufficient category indicator, namely indicator 3, combines observations and information provided to formulate hypotheses on observations. Poor category indicators, namely indicator 4 anticipates risks and adopts appropriate precautions and procedures in carrying out each laboratory experiment/practical investigation and indicator 5 identifies an appropriate procedure (observation/ enumeration/measurement/sampling/separation/crushing/heating/use of indicators chemistry) or choose the right equipment/apparatus in accordance with the practical problems faced.

Students in predicting changes in the condition of the object have shown their ability to be very good. Making generalizations that make sense based on the results of observations seen in the task is good, and the combination of observations and information provided to formulate hypotheses seen from the data is sufficient. However, when students anticipate risks and adopt appropriate precautions and procedures in carrying out each laboratory experiment/practical investigation on observation and identify an appropriate procedure (observation/enumeration/measurement/sampling/separation/crushing/heating/use of indicators chemistry) or choosing the right equipment/apparatus in accordance with the practical problems encountered in the observation is still lacking without the direction of a pre-service teacher.

Aspects of investigative skills obtained from science process skills in this study can be seen in Figure 3. Based on the Figure 3, it shows that there are 10 observed aspects of investigative skills with two indicators including very good category, one good category indicator, three sufficient category indicators and four poor category indicators. The highest score on the indicator presents a discussion of the results of an investigation/research with a value of 85.63 in the very good category. Students are seen doing the results of the investigation/research they have done. In fact, students were seen helping each other in completing the Student Worksheet assignments. Students know the benefits, background, learning they do, seen in the conclusions drawn at the end of learning. The lowest value of the indicator determines the independent variable as a treatment factor in investigations/research with a value of 71.55 in the less category, seen in the tasks it completes.

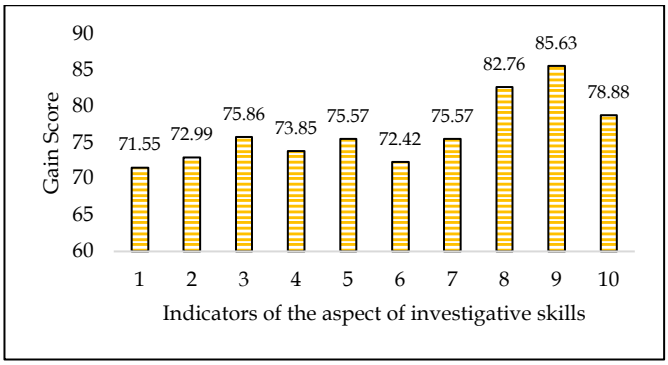

Figure 3. Average indicators on the aspect of investigating skills

Very good category indicators, namely indicator 8 presents the conclusions of the data from the investigation/research and indicator 9 presents a discussion of the results of the investigation/research. The good category indicator, namely indicator 10, determines the truth of the results of the investigation/research. Indicators in the sufficient category, namely indicator 3, explain the background of the importance of carrying out an investigation/research, indicator 5 defines the benefits of an investigation/research and indicator 7 determines the research hypothesis in an investigation/research. Poor category indicators, namely indicator 1 determines independent variables as treatment factors in investigations/research, indicator 2 identifies the relationship between independent variables and dependent variables in an investigation/research, indicator 4 formulates the objectives of the investigation/research and indicator 6 designs suppressive/disturbing variable control (suppressed variable) so that it becomes a control variable in an experiment.

Students in presenting conclusions on the results of investigation/observational research, discussing the results of investigation/observational research and establishing the truth of the results of investigation/observational research are good and very good as can be seen from the tasks and activities they carry out in the learning process. The ability of students to present the background of the importance of carrying out an investigation/observational research, formulate the benefits of an observational investigation/research and establish research hypotheses in an investigation/research is quite adequate. Students in determining independent variables as treatment factors in observational investigations/research, identifying the relationship between independent variables and dependent variables in an investigation/research, formulating investigative/research objectives and formulating the benefits of an investigation/research are still relatively lacking.

Effective learning can be supported by several factors such as science process skills. Science process skills as measured by observing the process and the final learning outcomes of students. Science process skills improve students' academic achievement. Students who have all indicators of science process skills give a positive response to learning because they feel more understanding, increase motivation and interest in learning. Science process skills can build other factors in students in the learning process such as motivation and interest in learning (Bhakti et al., 2020).

Science process skills with STEM-based learning processes show a relationship between the two. The use of the STEM approach in learning can be applied to improve students' science process skills (Farach et al., 2021). The science process skills indicator consists of 3 aspects, namely aspects of basic skills, aspects of process skills, and aspects of investigative skills. The observations made showed the enthusiasm of students to participate in assembling and listening to each activity in the learning process. This learning is expected for all students to work actively and accompanied by direct material concepts. The learning process designed by the pre-service teacher provides experience for students (Bhakti et al., 2020). Students are also free to express themselves in the classroom. This can be seen from the data obtained, the STEM-based learning process implemented by the pre-service teacher is good and in accordance with the indicators of the learning process. The science process skills obtained from students with observations obtained good results and the final results in the written test obtained from students' answers showed that 57 students obtained good results and one student obtained a poor score.

The hypothesis in this study is the relationship between the learning process and students' science process skills in ecolo material as well as environmental change and preservation at State Senior High School 11 Banda Aceh. Test the data using the Product Moment Method correlation coefficient analysis or what is known as the Pearson formula. Following are the results obtained from the Pearson formula test which can be seen in the following table:

Table 9. Hasil Uji Korelasi Product Moment Method

N	Sig. 2 Talied	Pearson Correlation	Category
58	0.029	0.288	Low correlation; positive but small relationship

Based on the table it shows that the relationship between the STEM-based learning process and students' science process skills obtained a value of 0.288 which is included in the low correlation category; positive but small relationship. From these results it was concluded that there was a correlation between the STEM-based

learning process and the science process skills of students at State Senior High School 11 Banda Aceh.

Conclusion

From the results of the study it can be concluded that, first, the suitability of the learning process by the pre-service teacher with the learning planning stages is included in the good category according to the indicators of the learning process. Second, students' science process skills in ecological material as well as environmental change and preservation obtained values belonging to the sufficient category. Third, there is a relationship between the learning process and science process skills through the application of STEM learning to ecological material as well as environmental change and preservation.

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