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Improving Observation, Experiment Planning, and Communication Skills Based on the STEM Approach

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Abstract: Physics learning needs to emphasize science process skills (KPS) in students. In fact, from the results of a case study conducted at SMAN 2 Banda Aceh, it was found that the LKPD used by teachers was still conventional and there were no aspects of KPS. The purpose of this study was to determine the results of the application of physics LKPD based on the STEM approach in improving the KPS of high school students. This study used a quantitative approach of experimental type Non-Equivalent Control Group Design. The samples used in this study were X4 and X6 class students totaling seventy people taken by purposive sampling. The instrument in this study was the KPS test. Data analysis of this study used the average test, N-gain test and t-test. The results showed the average value of the experimental class KPS N-gain of 0.70 was in the high category and the control class N-gain of 0.63 was in the medium category. Based on the results of the t-test, it can be concluded that there are differences in the improvement of students' KPS in physics learning taught with the STEM approach and those taught using the direct learning model.

Keywords: Science process skills; STEM Approach; Worksheet

Introduction

Science process skills are skills needed to obtain, develop, and apply science concepts, principles, laws, and theories, both in the form of mental skills, physical (manual) skills, and social skills (Zamista, 2016). Science Process Skills are very important for every learner to be equipped to use the scientific method in developing science to gain new knowledge or share their knowledge. In the learning process, mastering science process skills allows learners to acquire the skills expected to solve problems in everyday life (Ningsi et al., 2020). An educational breakthrough in achieving effective learning is the STEM approach. STEM has been recognised around the world as a hot-topic publication, which is very important to be applied in education (Jho et al., 2016; Li et al., 2020; Zizka et al., 2021). Science, technology, engineering, and mathematics (STEM) education has gained a lot of attention, as the problems that we face globally are multidisciplinary and call for an integrated approach in management (Wang, 2012).

Learning with the STEM approach aims to make it easier for students to understand the concept of material, apply the material in everyday life, and be able to explore the potential that exists in themselves (A. T. I. Sari et al., 2018). The integration of STEM emphasises students to be active in learning. Physics learning needs to emphasise science process skills in students. As part of science, physics also has three characteristics, namely as a process, product, and procedure. Physics as a process means that physics has a process to gain knowledge related to nature and science. During the learning process, science process skills are not only used as the basis of the scientific method but also learn about

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the characteristics of knowledge (Hikmah et al., 2021). Science process skills aim to make students more active in understanding and mastering a series of learning activities such as observing, classifying, interpreting, predicting, hypothesising, planning research experiments, and communicating (Prasasti, 2018).

The results of preliminary observations and interviews with physics teachers conducted at SMAN 2 Banda Aceh, it is known that SMAN 2 Banda Aceh implements an independent curriculum, the implementation of practicum that takes place is still verification because it only proves concepts that have been previously learned which results in low science process skills of students. Based on the data from the case study, it is known that the science process skills of students are obtained with an average percentage of 48.4%. The low science process skills are because students still do not recognise the practicum tools used and some students do not read the worksheet provided by the teacher so that they still have difficulty in conducting experiments and interpreting data. The solution that will be done is to apply physics worksheet based on the STEM approach.

Some previous studies related to research, namely research conducted by Mukaromah et al. (2022) showed that STEM learning can be an alternative in honing science process skills in the 21st century era. Sari et al. (2022) showed that STEM learning proved to be efficient and effective in developing students' science process skills. Djafar et al. (2022) showed that the development of learning tools for project-based learning models with a STEM approach is effective for improving students' science process skills. Then research conducted by Kareem et al. (2022) shows that the application of the STEM approach has a major impact on increasing the use of technology and 21st century skills and teachers must be trained to help learners integrate lessons with concepts in the real world. In addition, previous research conducted by Ilah et al. (2020) showed that the application of the STEM approach in teaching must be maximised considering that the 21st century is dominated by the rapid development of technology and knowledge.

Measurement material is the initial material for grade X students in studying physics, therefore it is necessary to have interesting and systematic teaching materials so that students feel interested and enjoy studying physics. In this regard, a way is needed to motivate students to learn, especially in mastering the concept of measurement with active students directly to construct their knowledge. Based on these problems, teachers need to make innovations in the teaching and learning process. Innovation in the teaching and learning process for a more effective and efficient learning process, learning by using worksheet can be used as one of the learning reference options in physics subjects to optimise students' science process skills (Intan, 2023).

The application of physics worksheet based on the STEM approach was applied in the experimental class and in the control class which used discovery learning used by the teacher. The purpose of the study was to determine the improvement of the ability to observe, plan experiments and communicate through worksheet based on the STEM approach. The hypothesis in this study is that there is an increase in the ability to observe, plan experiments and communicate students who are taught using physics worksheet based on the STEM approach.

Method

The approach used in this research is Non-Equivalent Control Group Design. This study used two classes, namely the experimental class and the control class. The experimental class is the class that gets treatment by applying the STEM approach-based worksheet using the Engineering Design Process (EDP) step, while the control class is the comparison class using only the discovery learning model. The experimental class and control class in this study were given a pretest and also a posttest to see any differences in the science process skills of the two classes. The Non-Equivalent Control Group Design design in this study can be seen in Table 1.

Table 1. Nonequivalent Control Group Research Design

Class experiment	$\mathbf{O_1}$	$\mathbf{X_1}$	$\mathbf{O_2}$
Class control	O_1	X_2	O_2

The population in this study were all students of class X SMAN 2 Banda Aceh consisting of 7 (seven) classes totalling 265 students. The sample in this study amounted to 70 students. The researcher determined the sample class using purposive sampling, where sample members were selected specifically based on the research objectives. The instruments used to measure science process skills are multiple choice questions and observation sheets. The parameters in this study are measuring science process skills using three indicators, namely observation, planning experiments and communicating.

The implementation of the research used several techniques including: Teaching Modules, worksheet and test instruments. Stages of data analysis, namely, analysis of validation sheets using the calculation of the Aikens index and Inter-Rater Agreement (IRA). Based on the results of the assessment conducted by experts,

the results of the feasibility of worksheet through the calculation of the Aikens index are 0.96 which indicates that the worksheet is valid and through the Inter-Rater Agreement (IRA) which is 0.56 which shows the reliabilty of worksheet is at a fairly good level not by chance. The validity and reliability data of the worksheet are shown in Table 2 below.

Table 2. Data on Validity and Reliability of Worksheet

Category	Aiken Index	Validity Standards	Inter Rater Agreement (IRA)	Validity Standards
Worksheet	0.96	Valid	0.556	(Good agreement beyond chance)

Result and Discussion

Assessment The next data analysis is the analysis of science process skills using the N-Gain test, normality test (Shapiro Wilk test) and independent sample t-test. Normality test criteria if the Sig value. > 0.05 is declared normal, homogeneity test to determine the level of similarity of variance between the experimental group and the control group. To do this homogeneity test using the SPSS programme. Homogeneity test criteria if the Sig value. > 0.05 is declared homogeneous, n-gain test using the Meltzer formula, and independent sample t-test, which is a comparative test or different test to determine whether there is a significant difference in mean or average between 2 groups. To conduct this test using the SPSS programme. The criteria if ($p < 0.05$) then there is a difference in the science process skills of students.

Based on the results of the implementation of learning that integrates worksheet based on the STEM approach and discovery learning is assessed based on indicators of science process skills, including pretest and posttest scores on measurement material. The pretest-posttest data obtained were then analysed to determine the improvement of observation, planning experiments and communicating through worksheet based on the STEM approach. The average N-Gain value of each indicator can be seen in the following **F**igure 1.

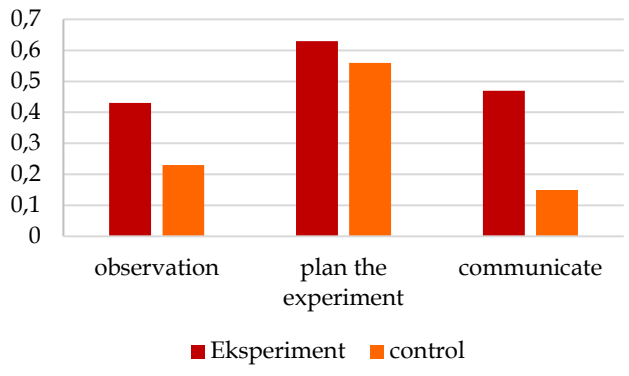

Figure 1. Average n-gain per indicator of science process skills

Figure 1 shows that the three aspects have increased after the application of physics worksheet based on the STEM approach. This can be seen from the N-Gain results of students. This is done to find out more clearly the difference in the value of students' improvement in each indicator.

The N-Gain value of science process skills as in Figure 1 is known from three aspects, namely aspects of observation, planning experiments, and hypothesising obtained by students on each indicator can be described as follows:

Observation

In the first aspect, namely observation, where students are expected to observe and then understand the knowledge of a phenomenon based on their knowledge. In this process, teachers guide the students to question the main problem they have faced and provide the opportunity for students to find solutions to the problem on their own (Sari et al., 2022). During the learning process the teacher has accustomed students to make observations of the problems obtained. So that students are accustomed to making observations of problems and have understood what is meant by observation. Observation activities aim to train accuracy and thoroughness in thinking. Observation provides an important foundation for cognitive development and students' understanding of the surrounding environment (Prasasti, 2018). The average obtained by the experimental class in the observation aspect is 0.43 which is a moderate category. While that obtained in the control class is 0.23 which is a low category. In this aspect, using the five senses in making careful and structured observations. The Observation step, which during research uses the environment as a laboratory, is related to the indicator of knowledge about science which causes students to be skilled in the scientific method (Yuliani et al., 2016).

Based on the values obtained, it can be concluded that the observation aspect of the experimental class is higher than the control class. This is because the experimental class was given treatment when making observations on the worksheet through the application of the STEM approach. This is in line with Utami et al. (2022) that with the use of worksheet based on the STEM approach students can observe the problems around them and the teacher as a facilitator. Through the stages

of STEM learning, students are given the opportunity to experience firsthand how scientists discover concepts. Students can able to solve real-world problems as they do using systematic thinking and analytical thinking skills of real engineers in STEM activities (Cayvaz et al., 2020). Therefore, in order to solve these problems, students must use the interdisciplinary approach of knowledge and skills of different disciplines by its nature (Wang, 2012). Starting from the observation of the problems found by learners before planning the experiment then questions arise. From these questions, hypotheses or temporary answers arise that need to be proven by experimentation. Where STEM-based learning aims for students to better understand the material concepts, apply them in daily life, and uncover their potential (A. T. I. Sari et al., 2018).

Planning the Experiment

Furthermore, the aspect of planning experiments, in this aspect students are expected to be able to compile detailed experimental steps, determine manipulation variables, response variables and control variables, and design valid data collection methods. In this aspect, the experimental class obtained a higher n-gain value of 0.63 and the control class obtained an average n-gain of 0.56. Both classes are accustomed to identifying response variables, control variables, manipulation variables and defining variables operationally. It's just that in the experimental class the worksheet was designed by applying the STEM approach, while the control class was designed without applying the STEM approach. Students can carry out experiments by changing variables and recording the results of scientific work interactively, encouraging active participation in high-level thinking and problem solving and facilitating learning of abstract concepts (Christine, 2016). STEM approach implementation can be improved by planning technology-learning activities (such as hands-on activities) that incorporate engineering design so that students can obtain comprehensive crossdisciplinary experience (Brophy et al., 2008).

During the learning process, the experimental class was more enthusiastic about working on the worksheet than the control class. As Syahirah et al. (2020) said that STEM emphasises learning in the engineering aspect as a form of STEM integration, where in this aspect it can hone students' abilities in engineering and practice in real life. Collaboration and teamwork in planning experiments makes physics learning in the classroom more fun and interesting, thereby increasing student engagement in the classroom (Duran et al., 2011). The implementation of STEM in learning encourages learners to design, develop, utilize technology, sharpen their cognitive and affective skills, and apply their knowledge (Fiteriani et al., 2021). Somwaeng (2021) says that practicing science, math and technology skills and bringing knowledge to design work or make work in finding needs or solving problems related to everyday life is proven to develop children's flexible thinking ability.

Communicate

The last aspect is communicating, learners are expected to be able to communicate their ideas both with their peers and with teachers or other audiences to convey the results of the learning process they have gone through. Communication is the basic principle of a learning process, when someone has a very high understanding of knowledge but he cannot communicate what is in his mind or he cannot convey his ideas both orally and in writing, then it will hinder his process in learning and facing the challenges that come with the demands of the 21st century (Haryanti et al., 2018). During the learning process by applying physics worksheet based on the STEM approach, students are able to apply their knowledge to solve complex problems and develop STEM competencies (Setiawan et al., 2020). And worksheet based on the STEM approach can train students in applying their knowledge to make designs as a form of problem solving related to the environment and technology (Permanasari, 2016).

Then the data in this study was also tested for normality. The calculation results are obtained as follows.

Table. 3 Normality Test

	Levene's Test for Equality of Variances		
	Statistics	Df	Say
Pretest Experimental Class	0.964	35	0.299
Pretest Control Class	0.942	35	0.067
Posttest Experimental Class	0.945	35	0.082
Posttest Control Class	0.960	35	0.221

Based on the output of table 3 produced in the control class pretest, a normality significance value of 0.067 was obtained, with a normality significance value of 0.221 for the posttest, while for the experimental class pretest the normality significance value was 0.299 and for the posttest it was 0.082, where From the significance value it can be concluded that the data is all normally distributed, this is because all the data obtained has a sig value >0.05. This is in line with research conducted by (Mukaromah, 2022) showing that STEM learning can be an alternative in honing science process skills in the 21st century era.

Next, a hypothesis test was carried out using the independent sample t-test to obtain the following data.

Based on Table 4, it can be seen that the t value$_{count}$ *pre-test* amounting to 0.969 with a significance of 0.336 > 0.05 so that H_0 accepted, this shows that in the pretest there was no difference in science process skills in the experimental class and the control class. This is also supported by the mean value of the experimental class, which is 36.7, which is close to/not much different from the control class, which is 34.6. While t_{count} *post-test* amounting to 2.211 with a significance of 0.030 < 0.05 so that H_0 rejected, this shows that there is a difference in the increase in students' science process skills in the experimental class taught using the STEM approach and the control class taught using the STEM model.*discovery learning*. This is also supported by the mean value of the experimental class, which is 81.2, which is greater than the control class, which is 76.3. This is in line with research (Sari, 2020) which shows that STEM learning has proven to be efficient and effective in developing students' science process skills.

Table 4. Hypothesis Testing

	Experiment	Control	Mean difference	t-test	*Say. (2-tailed)	Decision
Pretest	36.7	34.6	2.14286	0.969	0.336	H_0 accepted
Posttest	81.2	76.3	5.00000	2.211	0.030	H_0 rejected

Furthermore, the observation sheet was used to determine the difference in the science process skills of students during the learning process in the experimental class using worksheet based on the STEM approach and the control class using the usual worksheet used by the teacher. The science process skills of students were observed with an indicator observation sheet. The results of the observation of science process skills obtained can be seen in Table 5 below.

Table 5. Observation Results of Students' Science Process Skills

Class	Meeting	Percentage (%)	Category
Experiment	I	55.3125	Enough
	II	77.8125	Tall
	Average	66.5625	Tall
Control	I	51.875	Enough
	II	60.3125	Enough
	Average	56.0947	Enough

Based on Table 5 above, it can be seen that the average observation results of students' science process skills in the experimental class obtained a high category and the control class obtained a medium category. The average observation results in the experimental class were higher than the control class. This is because the experimental class applied worksheet based on the STEM approach, during the learning process students were more actively involved than the control class which applied the usual worksheet used by the teacher. This is in line with the research of Djafar et al. (2022) which states that there are differences in the science process skills of students using worksheets that are applied to learning based on the STEM approach with students who are taught using worksheets without the application of the STEM approach. Based on the results of observations by observing the activities and behaviour of students during the learning process that adheres to the indicators of science process skills, the results obtained can support the improvement of science process skills as measured by science process skills test questions.

Based on the description above, it can be said that worksheet based on the STEM approach can improve students' science process skills. The activities on the worksheet can encourage students to be able to identify and define control variables, response variables, and manipulation variables so that students will be skilled in conducting experiments that can train their science process skills. So that the advantages of this worksheet can activate students in learning, help students develop concepts, train students to find and develop process skills, make it easier for students to use it and the effectiveness of learning time. Science process skills are skills that can be linked to STEM as shown in Figure 2 below.

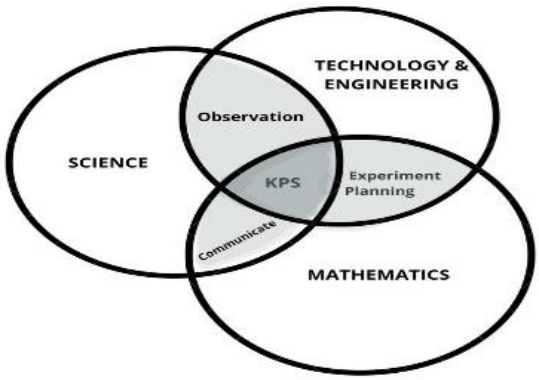

Figure 2. Relationship between STEM integrated approach and science process skills

Figure 2 shows that the STEM approach has an effect on science process skills seen from the indicators that are interconnected with STEM disciplines. The STEM approach focuses on applying mathematics, science and engineering knowledge, designing and carrying out experiments, analyzing and interpreting

data, and communicating with teams from various disciplines (Sanders, 2009). Each indicator of science process skills has increased after the application of worksheet based on the STEM approach. Based on the research results obtained, worksheet based on the STEM approach can be used as a tool for educators to improve students' science process skills. As the results of research conducted by Sarı et al. (2020) which states that STEM learning is proven to be efficient and effective in developing students' science process skills. So that with the existence of worksheet based on the STEM approach, it can help students more easily understand or find a concept by being directly involved in the discovery of the concept. As with the worksheet, students are more required to play an active role in constructing their knowledge, so that students know more about the usefulness or function of the experiment.

Science process skills are supported by learning outcomes. Students' learning outcomes were assessed using pretest-posttest questions on measurement material. The learning outcomes of students obtained that there was an increase in the experimental class and control class in all indicators of competency achievement after the use of worksheet based on the STEM approach on measurement material. N-gain in the experimental class was obtained 0.70 with a high category and N-gain in the control class was obtained 0.68 with a medium category. It can be seen that the increase in learning outcomes in the experimental class is greater than the control class. In line with research conducted by Sukma (2018) that the STEM learning approach can affect the improvement of student learning outcomes.

Based on the description above, it can be said that the worksheet based on the STEM approach can improve the science process skills and learning outcomes of students because it is in accordance with the theory that STEM learning is an approach that encourages students to actively participate in learning activities that emphasise the relationship between knowledge and collaboration skills in the STEM science field to solve problems through experimental investigations to find a correct concept. The activities in the worksheet encourage students to be able to identify and define control variables, response variables, and manipulation variables so that students will be skilled in conducting experiments that can train their science process skills.

So that the advantages of this worksheet can activate students in learning, help students develop concepts, train students to find and develop process skills, make it easier for students to use it and effectiveness in learning. During the learning process when applying worksheet in the experimental class, it was seen that students were more enthusiastic in using worksheet than the control class. This is because the worksheet in the experimental class applied learning using the STEM approach, while the worksheet in the control class used the usual worksheet used by the teacher, namely students only followed the steps in the worksheet. By applying a STEM approach in the learning process, you can instill science process skills, such as problem solving by carrying out the initial steps of observation, team work, and finally concluding/communicating (Howard-Brown et al., 2012; Hutton, 1990). The STEM approach is important in bringing students to a level that can compete at the global level (Brainer, 2012). Sirajudin et al. (2021) said that learning activities using the STEM approach directly provide student experience to be able to combine each aspect at once. Learning stages that integrate these four aspects facilitate students' understanding of learning materials.

Conclusion

Based on the results of the research that has been done, it shows that the implementation of worksheet based on the STEM approach can improve observation, planning experiments and communicating with students. It can also be seen during the learning process that students are actively involved in fulfilling these three aspects and students learn to cooperate well and have good communication with their friends, help each other between group members, and play an active role in each group so that the problems contained in the learning process can be solved properly. Worksheet based on the STEM approach used needs to be redesigned and studied further so that it can be applied with various types of material, especially in physics subjects and applied continuously and continuously.

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