SPEKTRA: Jurnal Kajian Pendidikan Sains
Vol. 11, No. 1, 2025, pp. 49-61
ISSN: 2548-642X, DOI: 10.32699/spektra.v11i1.7812

IMPROVEMENT OF STUDENTS' SCIENCE PROCESS SKILLS IN SCAFFOLDING-BASED PROBLEM-BASED LEARNING ON THE MATERIAL OF TRAVELLING WAVES AND STATIONARY WAVES

Zahra Nadifa Elahi[1], Saeful Karim[1], Duden Saepuzaman[1]
[1]Physics Education Study Program, Faculty of Mathematics and Natural Sciences Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

Article Info

Article history:
Received 03/08/2024
Accepted 29/04/2025
Published 03/05/2025

Keywords:
Problem-Based Learning
Scaffolding
Science Process Skills
Travel and Stationary Waves

ABSTRACT

The study examines how scaffolded problem-based learning might improve students' science process abilities, particularly regarding the traveling and stationary wave material. Using a quantitative method, the study included 35 students in class XI IPA from a public high school in Sukabumi city, where purposive sampling was used to determine. The science process skill assessment instrument was utilized to administer the pretest and posttest during the data gathering phase. The data was analyzed using the N-Gain test. The study's results demonstrated that the pretest and posttest scores differed significantly after treatment, showing that students' science process abilities have improved, as seen by the normalized N-Gain value, which was included in the moderate category. The improvement in the indicators' science process skills of observing, communicating, and concluding is categorized as moderate. While the increase for indicators of classifying, measuring, and predicting is categorized as high.

Corresponding Author:
Zahra Nadifa Elahi
Physics Education Study Program, Faculty of Mathematics and Natural Sciences Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
Email: zahranadifae@gmail.com

1. INTRODUCTION

The *Merdeka* Curriculum, launched by the Indonesian government in 2022, presents a major transformation in physics learning in Indonesia. Students may cultivate their critical thinking abilities, creativity, and teamwork via the curriculum. Learning outcomes in physics learning are divided into two main categories, namely physics understanding, which aims to build a deep understanding of various physics phenomena, and process skills, which aim to provide the development of essential science skills needed to conduct scientific investigations (Anggreaena et al., 2022). These categories are designed to ensure that students not only grasp theoretical concepts but also apply them in practical scenarios. By integrating hands-on experiments and collaborative projects, the curriculum seeks to engage students and foster a passion for scientific inquiry. Learning outcomes in physics understanding and process skills must be given to students as a whole, because both are very important for students to achieve the teaching targets that have been set.

But in fact, the implementation of teaching in schools shows that during the physics learning process, teachers focus more on teaching physics understanding than on science skills. These issues may stem from several factors, such as, namely, the availability of inadequate tools, as well as the availability of limited or even nonexistent laboratories, causing teachers to have difficulty in preparing lessons that can train science skills. When learning only focuses on the learning outcomes of physics understanding aspects, it will cause students' dependence on teacher explanations as the main learning source, whereas in science learning, students must conduct independent exploration and look for other learning sources from diverse learning activities. This can avoid inhibiting the development of feelings of curiosity and interest in learning in students.

Science process skills are crucial for stimulating curiosity, fostering responsibility, encouraging independent learning, helping learners to carry out research, and improving various other process skills (Janah et al., 2018). In this context, “process” refers to the interconnectedness of all teaching elements or factors that work together to achieve a common goal. This goal reflects an indication of student success in dealing with problems in everyday life. According to (Kastawaningtyas & Martini 2018), science process skills facilitate students to actively participate in obtaining information so that students can better understand and implement the insights that have been obtained.

Through observations, the researcher found that in physics learning, students' process skills can still be said to be in the insufficient category because during the teaching stage, they rarely practice science process skills. This is one of the obstacles that prevent students from understanding physics by the objectives of the Merdeka curriculum. In addition to observations, the researcher also conducted a trial of the student science process skills test research instrument. The trial was conducted on 67 students with 20 multiple-choice questions with traveling wave and stationary wave material, each item worth 1 point. The results of the trial obtained an average of 12 out of 20 perfect points. These results indicate that students are not yet skilled in applying science process skills in learning.

Basic and integrated science process skills are two types of science process skills (Juhji & Nuangchalerm 2020). There are six aspects to basic science process skills based on (Rezba et al. 2002), namely analyzing, classifying, communicating, assessing, estimating, and giving conclusions. These six aspects can be practiced during learning by the teacher. Meanwhile, integrated science process skills, according to (Chabalengula et al. 2012), consist of five aspects, including controlling variables, providing operational definitions, providing hypothesis formulation, providing model formulation, and interpreting data and conducting trials. Both science process skills are very applicable and suitable for secondary school science courses (Jack, 2013). In particular, the development of integrated science process skills will start with fundamental science process skills (Darmaji et al., 2018).

The utilization of active and learner-centered learning models and strategies is one of the initiatives taken by educators to enhance the quality of learning, such as practicums, discussions, and problem-solving. This needs to be considered because there are several problems when learning takes place, one of which is the lack of motivation of students in learning physics. Based on these problems, it encourages educators to have more creativity to arrange lively teaching and simultaneously encourage the growth of student skills. Among the solutions that can be sought, the application of problem-based learning can help address these issues (Spriani et al., 2019). The issues that are presented during learning activities in the problem-based learning (PBL) paradigm are genuine or authentic situations that are relevant to the everyday lives of the students. These presented problems become the basis of the learning process, which can then foster a deeper understanding and connection between theoretical concepts and their practical application.

In the syntax of the PBL learning teaching model, it can facilitate comprehensive, authentic assessment due to the nature of problem discovery and problem solving inherent in it (Indrianawati & Wahjudi, 2014). The PBL teaching stages, based on (Handayana, 2017), consist of orienting students to the problem, organizing students to carry out learning, directing individual or group research, creating and presenting work, and concluding with a review and analysis of the phases involved in solving a problem. This stage has benefits for students; among others, it can foster students' creative potential and help them build their critical thinking abilities and habits to direct the investigation of problems that have been carried out. In the application of problem-based learning into a paradigm of cooperative learning, creating a constructive learning environment and mutual respect is an absolute thing. This is because students in one class have different backgrounds, criteria, and abilities. The appropriate approach is required to accomplish the same learning objectives after instruction, to be combined with the learning model to be applied (Shoit et al., 2023). The strategy that can be combined to support the success of the applied learning is scaffolding.

The scaffolding learning strategy is a teaching method that emphasizes collaborative interaction between teachers and students. The aim is to provide targeted support and guidance to students who struggle throughout their learning phases (Badriyah et al., 2017). The scaffolding technique is based on Vygotsky's hypothesis of the zone of proximal development. The zone of proximal development (ZPD) is the division of tasks that can be completed by a learner without guidance from more knowledgeable people, such as educators or peers (Amiruddin et al., 2018). The purpose of assisting is not to limit learners' freedom in completing tasks but to guide them towards a more detailed understanding of difficult theories (Rahmatiah et al., 2017). According to (Kusmaryono 2021), the provision of scaffolding assistance can vary, including support, advice, warnings, instructions, and provision of keywords. In the early stages of learning, assistance in the form of scaffolding is given to students, and then as the teaching and learning process progresses, the amount of help is progressively decreased until students can do their assignments on their own.

In research conducted by (Nasir et al. 2023), students' science process skills may be trained using the PBL learning paradigm as more science process skills tests are being acquired for every benchmark and cycle that is used. Furthermore, in (Shoit et al. 2023), which discusses the use of the PBL model combined with scaffolding strategies, count values are higher than the t-table results, indicating that the PBL learning model with scaffolding strategies is effective in teaching and learning activities. Concerning the previous discussion, it is expected that the stages of teaching in schools can be aligned with the developmental needs of students and skills that can support the success of learning objectives. From this description, it is necessary to combine learning models with learning strategies. In the following study, the PBL learning model combined with teaching strategies in the form of scaffolding is used to examine if science process skills have increased in students in teaching physics with the material of traveling waves and stationary waves. When measuring science process abilities, research often focuses on one of the learning models or learning techniques. In this study, researchers combined both of these things, namely learning with a problem-based learning model assisted by scaffolding learning strategies. As revealed by (Agrota

Shoit 2023), to achieve the same learning objectives at the end of teaching, the right strategy needs to be combined with the learning model to be applied.

2. METHOD

The following study uses quantitative techniques. Quantitative study techniques are a variety of clearly structured and well-planned study activities from the beginning, beginning with the establishment of study goals, selection of study subjects, determination of study objects, data sampling, and determination of data sources, to the determination of research methodologies (starting with data collection and ending with data analysis) (Ghozali, 2021). Meanwhile, this study also used a quasi-experimental research design: a one-group pretest-posttest design as presented in Table 1 below.

Table 1. One-Group Pretest-Posttest Design

Pretest	**Treatment**	**Posttest**
O_1	X	O_2

Where, o1 is pretest results before treatment, o2 is posttest results after treatment, x is treatment through the application of learning phases using the scaffolding-based problem-based learning model

One of the senior high schools carried out the following study. The population in the following study included every student in grade XI at a Sukabumi City high school, while the sample in the following study was limited to one grade XI class in the high school, consisting of 35 students. The sample was selected by purposive sampling, which was based on the recommendation of the relevant subject teacher and refers to the class schedule that will receive the material to be studied.

Pretest and posttest assessments were used as methods to collect data in the following study. The initial assessment, or pretest, was conducted to evaluate students' basic abilities in applying science process skills, while the final assessment, or posttest, had the purpose of measuring students' achievements in mastering these science process skills. Students were given a test consisting of multiple-choice questions with indications about fundamental science process skills to determine whether or not their science process skills had improved following treatment. Data analysis in the following study used quantitative analysis. Quantitative data were obtained from the pretest and posttest scores. Pretest and posttest data were analyzed using N-Gain testing according to the science process skills benchmarks tested on students with the calculations and categories below (Hake, 2002).

$$N - Gain = \frac{posttest\ result - pretest\ result}{maximum\ result - pretest\ result} x100\% \tag{1}$$

Table 2**.** N-Gain Value Categories

N-Gain Value	**Category**
g < 0,3	Low
0.7 > g ≥ 0.3	Moderate
g ≥ 0.7	High

(Azita Seyed Fadaei, 2019)

3. RESULTS AND DISCUSSION

The skills test instrument used is the result of an instrument trial conducted before the research and through several tests, including a content validity test, a construct validity test, and a reliability test. The content validity test involved 4 validators to assess 5 aspects of content validity for each item on the test instrument. By using Aiken's V formula to calculate the content validity coefficient, it was found that out of 20 items, there were 3 invalid items, so only 17 items were suitable for use in research. Then the construct validity test is measured through Ministep Rasch software by reviewing the outfit mean square (MNSQ), outfit Z-standard (ZSTD), and point measure correlation (Pt Measure Corr) values with criteria as shown in Table 3.

Table 3. MNSQ, ZSTD, and Pt Measure Corr Outfit Criteria

Criteria	**Value Received**
MNSQ	0.5 < MNSQ < 1.5
ZSTD	-2.0 < ZSTD < +2.0
Pt Measure Corr.	0.40 < Pt Measure Corr.< 0.85

```
     SUMMARY OF 67 MEASURED Person
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT     MEASURE   S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN       9.0       17.0        .15     .70       .88   -.03   1.23    .26 |
|  SEM        .6         .0        .21     .02       .05    .12    .19    .15 |
| P.SD       4.6         .2       1.72     .18       .37    .97   1.55   1.21 |
| S.SD       4.6         .2       1.74     .18       .37    .98   1.57   1.22 |
| MAX.      15.0       17.0       2.78    1.04      1.98   2.59   9.90   6.18 |
| MIN.       1.0       16.0      -3.22     .53       .24  -1.21    .09   -.99 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .74 TRUE SD    1.56  SEPARATION  2.09  Person RELIABILITY  .81 |
|MODEL RMSE    .72 TRUE SD    1.57  SEPARATION  2.16  Person RELIABILITY  .82 |
| S.E. OF Person MEAN = .21                                                   |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .99 (approximate due to missing data)
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .87  SEM = 1.62 (approximate due
STANDARDIZED (50 ITEM) RELIABILITY = .93

     SUMMARY OF 17 MEASURED Item
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT        OUTFIT    |
|          SCORE      COUNT     MEASURE   S.E.      MNSQ   ZSTD   MNSQ   ZSTD |
|-----------------------------------------------------------------------------|
| MEAN      35.5       66.8        .00     .34      1.01   -.17   1.57   -.19 |
|  SEM       2.9         .1        .36     .02       .07    .38    .54    .37 |
| P.SD      11.7         .5       1.44     .07       .28   1.54   2.17   1.47 |
| S.SD      12.1         .5       1.49     .08       .29   1.59   2.23   1.52 |
| MAX.      47.0       67.0       4.36     .62      1.76   2.77   9.01   3.02 |
| MIN.       3.0       65.0      -1.24     .31       .56  -3.26    .41  -2.41 |
|-----------------------------------------------------------------------------|
| REAL RMSE    .37 TRUE SD    1.39  SEPARATION  3.74  Item   RELIABILITY  .93 |
|MODEL RMSE    .35 TRUE SD    1.40  SEPARATION  4.03  Item   RELIABILITY  .94 |
| S.E. OF Item MEAN = .36                                                     |
-------------------------------------------------------------------------------
Item RAW SCORE-TO-MEASURE CORRELATION = -.99 (approximate due to missing data)
Global statistics: please see Table 44.
UMEAN=.0000 USCALE=1.0000
MISSING RESPONSES:    .3%  (APPROXIMATE)
```

Figure 1. Fit Data Analysis Results

The Figure 1 above contains data analysis information that measures 67 respondents and 17 items. Based on the results of the analysis above, it is known that the outfit mean squared (outfit MNSQ) value for the item is obtained at 1.57, so it can be said that this value is classified as not fit because the value is in the range 0.5 < MNSQ < 1.5. This can be interpreted as there being an inconsistency between the answers to the test instrument and the level of difficulty of the items. Meanwhile, for the outfit Z Standardized (outfit ZSTD) for items, a value of -0.19 is obtained, which is also classified as a fit value because the value is in the range -2.0 < ZSTD < +2.0. Because there is a value that does not fit, therefore a more detailed analysis is needed to find out which items do not fit to measure the science process skills of students on the material of traveling waves and stationary waves. Reliability tests were carried out using Ministep Rasch with the Summary Statistics menu, which can present several reliability values, including person reliability, item reliability, and Cronbach's alpha. The interpretation of the three values can be expressed as in Table 4.

Table 4. Interpretation of Item and Person Reliability and Cronbach's Alpha

Summary Statistic	Index Value	Interpretation
Item and Person Reliability	r > 0.94	Excellent
	0.90 < r < 0.94	Very Good
	0.80 < r < 0.90	Good
	0.67 < r < 0.80	Fair
	r ≤ 0.67	Low
Cronbach's Alpha (KR-20)	KR – 20 ≥ 0.80	Very High
	0.70 ≤ KR – 20 < 0.80	High
	0.60 ≤ KR – 20 < 0.70	Good
	0.50 ≤ KR – 20 < 0.60	Medium
	KR – 20 < 0.50	Low

The results of data analysis using Rasch analysis with Ministep Rasch software on the in statistics output menu obtained the results as found in Table 5.

Table 5. Reliability Test Analysis Results

	Reliability	Alpha Cronbach
Person	0.81	0.87
Item	0.93	

The value of the consistency of students' answers (person reliability) has a value of 0.81, which is included in the good category, and the quality of the instrument items (item reliability) gets a value of 0.93, so that it is included in the very good category. Then, the Cronbach's alpha in this science process skills test instrument has a value of 0.87, which is included in the very high category. Based on the reliability analysis that has been presented, it can be concluded that this test instrument can be trusted to measure science process skills consistently and can be said to be good for representing science process skills in students.

Based on various trials that have been carried out, there is one item that is not feasible, so the feasible test instrument to use is only 16 items. The decision to take the items to be used in the study was to use only 12 items, where the composition of each indicator of science process skills was measured using two items used for pretest and posttest. The research was conducted for two meetings with the division of material, at the first meeting discussing traveling waves and at the second meeting discussing stationary waves. Students are required to fill out a pretest sheet at the beginning of the first meeting, then fill out a posttest sheet when the second meeting is over. After the data collection was complete, the researcher analyzed the N-gain from the pretest and posttest results of the students. The N-Gain may be used to determine how well the students are doing in science process skills, calculation based on the results of the pretest and posttest that students received with the maximum score that can be achieved being 12. The following has the aim of finding the outcomes of employing the scaffolding-based PBL model to enhance students' scientific process skills. The table below describes the N-Gain recapitulation of the pretest and posttest data.

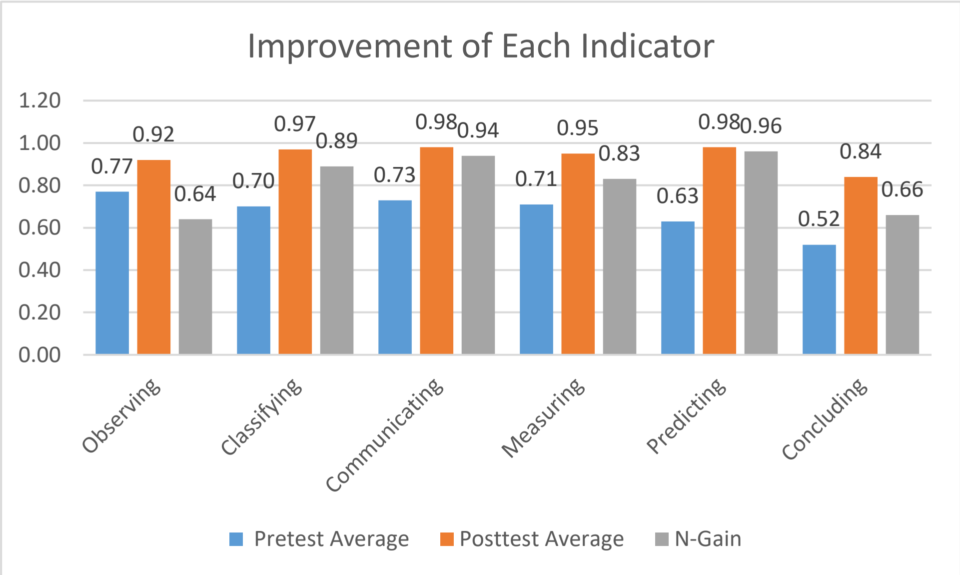

Figure 2. Graph of the Improvement of Science Process Skills for Each Indicator

The indicators of science process skills used in this study are indicators of science process skills according to Rezba, which consist of observing, classifying, communicating, assessing, predicting, and concluding. The results of the normalized gain for the science process skills test are shown in Figure 2, showing an increase in each indicator of students' science process skills after implementing learning using the PBL model based on scaffolding on the material of traveling waves and stationary waves for class XI high school students.

The figure above also shows that the improvement of students' science process skills per indicator shows that there are differences in the category of improvement in each indicator. The observation indicator falls into the medium category because the N-Gain value is 0.64, which is included in the medium category. Observing indicators are measured using test instruments number 1 and 2. Item number 1 presents a wave graph, so students can be expected to identify the number of waves on the graph. Furthermore, in item number 2, the indicators of the questions given to students are in the form of presenting images of waves propagating at a certain position, and then students are expected to determine the location of the phase difference mentioned in the item.

The increase in observing benchmarks is that students are expected to be able to use their senses or tools to carry out the learning process about things and events (Gizaw & Sota, 2023). Observing indicators is trained to students in the syntax of directing students to the problem. Students' observation skills are trained with the help of media such as demonstrations and videos of phenomena (Ardiyati et al., 2019). One example of an activity during the research conducted to train this indicator is that students observe a video of waves in seawater, and then students are asked to suggest what information can be obtained from the video. After the research process, it was found that there were still errors and a lack of students' skills in finding out or identifying information using their five senses. Apart from the fact that there are still some learners who are not yet skilled, overall this observation indicator has increased (Nasir et al., 2023).

On the indicator of classifying students' science process skills, measured using items 3 and 4, an N-Gain result of 0.89 was obtained, which falls into the high category. The test question indicator number 3 in this classification indicator presents several statements regarding the types of stationary waves so that students can identify which statements are correct regarding stationary waves. Next, in item number 4, a table of characteristics of traveling waves and stationary waves is presented, and students are expected to distinguish the differences between traveling waves and stationary waves through the answer choices provided in that item.

In this classification indicator, students are expected to develop the skills of sorting, classifying, and organizing objects based on similarities or differences (Biswal Biswajit Behera, 2023). This classifying indicator is trained in the syntax of combining ideas through guided group discussions by researchers. An example of an activity carried out to train this indicator is that students discuss what the characteristics of traveling waves and stationary waves are. (Maison et al. 2019) also conducted similar research and reported that learners can classify according to order or practical size. This proves that learners can distinguish between what needs to be measured and what needs to be weighed. In the process, some students are wrong in answering the items of the classification indicator. This is because when guided group discussions are taking place, some students are not focused, so it is difficult to distinguish or classify something.

Then, the improvement in the communication indicator was valued at 0.94 and fell into the moderate category. Test items number 5 and 6 are used as measurement tools to evaluate the scientific process skills of the communication indicator. In item number 5, the form of the question indicator that measures communication skills is presented with a graph of Melde's experiment results, which correlates the tension of the string with the wave propagation speed, allowing students to interpret the correlation graph between string tension and wave propagation speed. The next question indicator, specifically in question number 6, presents a question about the relationship between two quantities in a wave, and then students can adjust the correct form of the relationship graph between the two quantities mentioned in that question.

In this indicator, it is required of students to be able to use words or symbols to explain events, objects, and activities in this communication indicator (Biswal Biswajit Behera, 2023). This communication indicator is trained in the syntax of developing and presenting work. This communication indicator includes obligations that can be easily implemented by learners because of the freedom they have to express their opinions (Lestari & Oktaviani, 2023). In practice, not all students can master this communication skill, especially in understanding the relationship between simulations and experiments that students do (Ardiyati et al., 2019) and in interpreting graphs. This happens because there are learners who do not understand the definition of directly proportional and inversely proportional. In addition, variables that are not represented in the graph act as additional distractions for learners.

In addition, the measurement indicators have improved to a high level marked by an N-Gain score of 0.83. The value was obtained based on the analysis of students' answers to test items numbers 7 and 8. The form of the problem presented to measure this indicator in question number 7 is presented with a display of the Melde experiment simulator, and then students can measure the wavelength shown in the picture in question. Meanwhile, in test item number 8, the Melde experiment simulator display is presented, and then students can determine the wavelength, followed by calculating the speed of wave propagation using the variables that students have calculated.

In the implementation, students are asked to compare unknown quantities using instruments with predetermined units (Gizaw & Sota, 2023). This measuring indicator is trained in the syntax of guiding individual and group investigations. Science process skills related to this measuring indicator are easier to master due to exposure and practice from an early age or from the beginning of school, where teachers involve them in activities such as measuring the dimensions of objects or counting objects (Farida et al., 2023). When practicing this measuring indicator, there were arguments (differences of opinion) between group members when carrying out the measurement process using a ruler and when weighing weights using a four-arm balance. Even after the research, some learners still showed a lack of accuracy in their measurement techniques. This indicates that some students have not yet developed proficiency in using measuring instruments, so they need guidance and support.

Questions number 9 and 10, which are used to measure the prediction indicator, also show that students' science process skills have improved and are currently in the high category with an N-Gain value of 0.96. In the list of problems tested is problem item number 9, with the question indication being the presentation of a table of stationary wave experiment results. From this table, it is expected that students can predict the tension of the string for different string masses and lengths based on the patterns already known from the listed table. The next question item, question number 10, is given a question indicator in the form of presenting a table of stationary wave experiment results; then students can predict the speed of wave propagation with different period values based on patterns that are already known from the table listed.

In the implementation of this study, students are asked to give estimates about something based on patterns that are already known (Ayu Sri Rahayu, 2019). This predictive indicator is trained in the syntax of combining ideas. In the implementation of the study, this predictive indicator was also trained during the Melde experiment data collection. Learners carry out the Melde experiment using different loads and then write it down in the table of experimental results. Then, learners realize that there is a relationship between the weight of the load used and the waveform that occurs. As a study conducted by (Darmaji et al. 2018) found, this prediction indicator is the most prominent skill. After the research was conducted, it was found that some students made mistakes in answering items with predicting indicators. This could happen because some students did not realize that a pattern was formed in the data in the question.

The last indicator is concluding with an N-Gain score of 0.66, which falls into the moderate category. This indicator was tested through items number 11 and 12 on the test instrument. The form of presentation of the problem used to measure this concluding skill in question number 11 is presented with several pictures of the results of stationary wave experiments using different frequency sources to produce different waveforms, and then students are expected to draw the right conclusion. Meanwhile, the next question item that measures this inferring indicator is number 12, which has a question indicator in the form of presenting a table of stationary wave experiment results; then students can conclude the information in the table as a description of the relationship between the variables listed in the table in the question item.

In this benchmark, students are asked to form ideas to explain the observations that have been made. This concluding indicator is trained in the syntax of examining and assessing the phases involved in issue solution. In the process, it was still found that some students were not yet skilled in practicing skills with inferring indicators. For example, when students provide conclusions on the outcomes of trials that have been conducted, it is found that some students are mistaken in making conclusions, such as mistakenly mentioning the magnitude or the sign of the relationship between two quantities. Similar things are also found in research conducted by (Ardiyati et al. 2019), namely, on the conclusion indicator, some students have failed to draw inferences that may be applied to explain comparable occurrences. These difficulties can come from students' difficulties in understanding or processing the information they have obtained or the actions they have taken.

Despite the obstacles or shortcomings encountered during the research process, the use of the scaffolding-based problem-based learning (PBL) approach in the classroom resulted in a noticeable overall improvement in students' science process skills. Research by (Nasir et al. 2023), which is consistent with the findings of this study, highlights the positive impact of teaching using the PBL model on science process skills. By introducing students to problems related to the topic being discussed, this approach stimulates students' curiosity and encourages them to delve deeper into the subject matter, which in turn fosters the development of important science process skills. As during the research process, students tend to ask more questions to the researcher and actively engage in discussions during group work. Furthermore, (Gunawan et al. 2023) in their research revealed that the application of the PBL model is a superior approach to enhancing students' science process skills, as conventional teaching methods are often inadequate for improving these skills. In the conducted research, the selection of indicators for science process skills was considered based on their application in the classroom, so that the learning aimed at improving these science process skills can be optimally implemented. This idea is further supported by the findings of (Hardiyanti et al. 2017), which demonstrate the efficiency of the PBL model in developing students' science process skills. A similar finding was also reported by the researchers, as there were differences in the test results of students using different learning models.

Meanwhile, (Spriani et al. 2019), in their research, found that the integration of scaffolding in the modified PBL model serves as a powerful tool to enhance students' learning motivation. By providing scaffolding, learners are encouraged to engage in the learning process, which in turn enhances their ability to understand complex concepts more easily. Scaffolding provided by the researcher includes giving examples, instructions, keywords, and suggestions. These types of assistance are provided to students through both one-to-one scaffolding and peer scaffolding. Meanwhile, (Gusmardin et al. 2019) showed that students' science process skills significantly improved after the application of scaffolding in physics lessons, where students actively participated in problem-solving through scaffolding instructions. Similarly, (Hardiyanti et al. 2017) revealed that learning with developing classification and prediction indicators shows that the problem-based learning model is successful in developing science process skills. This is in line with the research findings, namely that there is an improvement in the classification and prediction indicators.

4. CONCLUSION

Based on the analysis of research data that shows significant progress in students' science process skills after the implementation of the treatment, as evidenced by the overall normalized N-Gain scores falling into the moderate category, it can be concluded that there are significant practical implications for the education sector. For teachers, this research recommends the adoption of a problem-based learning model with scaffolding as an effective approach, especially in topics such as waves. Teachers are also encouraged to pay special attention to the development of all indicators of science process skills, including those showing moderate improvement, such as observing, communicating, and concluding, as well as utilizing N-Gain as a measure of student learning progress. In addition, collaboration and sharing of best practices among teachers in the implementation of this model are highly recommended. These efforts will not only enhance the teaching and learning experience but also foster a more engaging and effective educational environment for students. Ultimately, prioritizing these strategies could lead to significant improvements in student outcomes and a deeper understanding of scientific concepts. Thus, the findings of this research underscore the importance of the scaffolding-based problem-based learning approach as a promising strategy to comprehensively enhance students' science process skills, which requires attention and support at both the teaching practice and educational policy levels.

REFERENCES

Amiruddin, M., Prastowo, S. B., & Prihandono, T. (2018). Analisis Pengaruh Strategi Scaffolding Konseptual dalam Model Pembelajaran Terhadap Hasil Belajar Fisika SMA. *Seminar Nasional Pendidikan Fisika*, *3*, 39–45.

Anggreaena, Ginanto, Felicia, Andiarti, Herutami, Alhapip, Iswoyo, hartini, M. (2022). *Panduan Pembelajaran dan Asesmen*. Badan Standar, Kurikulum, Dan Asesmen Pendidikan Kementerian Pendidikan, Kebudayaan, Riset, Dan Teknologi Republik Indonesia.

Ardiyati, T. K., Wilujeng, I., Kuswanto, H., & Jumadi. (2019). The Effect of Scaffolding Approach Assisted by PhET Simulation on the Achievement of Science Process Skills in Physics. *Journal of Physics: Conference Series*, *1233*(1). https://doi.org/10.1088/1742-6596/1233/1/012035

Ayu Sri Rahayu. (2019). *Pengembangan Lks Ipa Berbasis Keterampilan Proses Sains Untuk Siswa Kelas V Sd Pada Materi Zat Tunggal Dan Campuran*.

Azita Seyed Fadaei. (2019). Comparing Two Results: Hake Gain and Dellow Gain, to Analyze FCI Data in Active Learning Process. *US-China Education Review A*, *9*(1). https://doi.org/10.17265/2161-623x/2019.01.003

Badriyah, L., As'ari, A. R., & Susanto, H. (2017). Analisis Kesalahan dan Scaffolding Siswa Berkemampuan Rendah Dalam Menyelesaikan Operasi Tambah dan Kurang Bilangan Bulat. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, *2*(1), 50–57.

Biswal Biswajit Behera, S. (2023). Enhancing Science Process Skills through Inquiry - Based Learning: A Comprehensive Literature Review and Analysis. *International Journal of Science and Research (IJSR)*, *12*(8), 1583–1589. https://doi.org/10.21275/sr23817121415

Chabalengula, V. M., Mumba, F., & Mbewe, S. (2012). How pre-service teachers' understand and perform science process skills. *Eurasia Journal of Mathematics, Science and Technology Education*, *8*(3), 167–176. https://doi.org/10.12973/eurasia.2012.832a

Darmaji, D., Kurniawan, D. A., Suryani, A., & Lestari, A. (2018). An Identification of Physics Pre-Service Teachers' Science Process Skills Through Science Process Skills-Based Practicum Guidebook. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *7*(2), 239–245. https://doi.org/10.24042/jipfalbiruni.v7i2.2690

Farida, L., Suryajaya, S., & Suyidno, S. (2023). Profile of Basic and Integrated Science Process Skills in Science Learning at Madrasah Ibtidaiyah Negeri. *SEJ (Science Education Journal)*, *7*(2), 99–109. https://doi.org/10.21070/sej.v7i2.1644

Ghozali, I. (2021). *Metode Penelitian Kuantitatif untuk Bisnis dan Ekonomi*.

Gizaw, G. G., & Sota, S. S. (2023). Improving Science Process Skills of Students: A Review of Literature. *Science Education International*, *34*(3), 216–224. https://doi.org/10.33828/sei.v34.i3.5

Gunawan, R., Hasan, M., Kasmawati, K., & AS, J. (2023). Penerapan Model Problem Based Learning dalam Meningkatkan Kemampuan Berpikir Kritis Peserta Didik. *LaGeografia*, *22*(1), 12. https://doi.org/10.35580/lageografia.v22i1.52195

Gusmardin, Y., Bektiarso, S., Wicaksono, I., Studi, P., & Fisika, P. (2019). Pengaruh Model Pembelajaran Guided Inquiry Disertai Scaffolding Prompting Questioning Terhadap Keterampilan Proses Sains Siswa Pada Materi Gerak Lurus di SMA. *Jurnal Pendidikan Fisika*, *8*(2), 93–100.

Hake, R. (2002). Lessons from the physics education reform effort. *Ecology and Society*, *5*(2). https://doi.org/10.5751/es-00286-050228

Handayana, J. (2017). *Model dan Metode Pembelajaran Kreatif dan Berkarya.*

Hardiyanti, P. C., Wardani, S., & Nurhayati, S. (2017). Keefektifan model problem based learning untuk meningkatkan kps siswa. *Jurnal Inovasi Pendidikan Kimia*, *11*(1), 1862–1671.

Indrianawati, I., & Wahjudi, E. (2014). Studi Komparasi Hasil Belajar Siswa Menggunakan Model PBL dan Model Pembelajaran Kooperatif Tipe STAD. *Jurnal Pendidikan Akuntansi (JPAK)*, 1–11. https://ejurnal.teknokrat.ac.id/index.php/jurnalmathema/article/view/652

Jack, G. U. (2013). *The Influence of Identified Student and School Variables on Students ' Science Process Skills Acquisition*. *4*(5), 16–23.

Janah, M. C., Widodo, A. T., & Kasmui. (2018). Pengaruh Model Problem Based Learning Terhadap Hasil Belajar Dan Keterampilan Proses Sains. *Jurnal Inovasi Pendidikan Kimia*, *12*(1), 2097–2107.

Juhji, J., & Nuangchalerm, P. (2020). Interaction between scientific attitudes and science process skills toward technological pedagogical content knowledge. *Journal for the Education of Gifted Young Scientists*, *8*(1), 1–16. https://doi.org/10.17478/jegys.600979.XX

Kastawaningtyas, A., & Martini, M. (2018). Peningkatan Keterampilan Proses Sains Siswa Melalui Model Experiential Learning Pada Materi Pencemaran Lingkungan. *Jurnal Penelitian Pendidikan IPA*, *2*(2), 45. https://doi.org/10.26740/jppipa.v2n2.p45-52

Kusmaryono, I. (2021). Strategi Scaffolding Pada Pembelajaran Learning / Development. *Prosiding Seminar Nasional Pendidikan Sultan Agung 2 (Sendiksa 2)*, *2*(2), 26–37.

Lestari, T., & Oktaviani, V. (2023). Analysis science process skills of grade viii students on digestive system material. *Biosfer*, *16*(2), 380–389. https://doi.org/10.21009/biosferjpb.31731

Maison, M., Darmaji, D., Kurniawan, D. A., Astalini, A., Dewi, U. P., & Kartina, L. (2019). Analysis of science process skills in physics education students. *Jurnal Penelitian Dan Evaluasi Pendidikan*, *23*(2), 197–205. https://doi.org/10.21831/pep.v23i2.28123

Nasir, M., Fahruddin, F., Haljannah, M., & Nehru, N. (2023). Implementasi Model Pembelajaran Problem Based Learning untuk Meningkatkan Keterampilan Proses Sains Siswa SMAN 5 Kota Bima. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, *6*(1), 289–296. https://doi.org/10.54371/jiip.v6i1.1370.

Rahmatiah, R., Koes H., S., & Kusairi, S. (2017). Pengaruh Scaffolding Konseptual dalam Pembelajaran Group Investigation Terhadap Prestasi Belajar Fisika Siswa SMA dengan Pengetahuan Awal Berbeda. *Jurnal Pendidikan Fisika Dan Teknologi*, *2*(2), 45–54. https://doi.org/10.29303/jpft.v2i2.288

Rezba, R. J., Sprague, C., & Fiel, R. L. (2002). Learning and Assessing Science Process Skills 4th Edition. In *Hunt Publishing Company*.

Shoit, A., Rasiman, R., Harun, L., & Harianja, M. (2023). Kemampuan Pemecahan Masalah Siswa SMA pada Pembelajaran Problem-Based Learning Pendekatan Culturally Responsive Teaching dengan Strategi Scaffolding. *Jurnal Theorems*, *8*(1), 126–139.

Spriani, H. G., Ain, N., & Pratiwi, H. Y. (2019). Pengaruh Model Pembelajaran Problem Based Learning Melalui Metode Scaffolding Dan Motivasi Belajar Terhadap Pemahaman Konsep Fisika. *RAINSTEK : Jurnal Terapan Sains & Teknologi*, *1*(2), 29–40. https://doi.org/10.21067/jtst.v1i2.3437.