Development of subject-specific pedagogy based on guided inquiry about Newton's law to improve senior high school students' scientific literacy ability

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Abstract. Newton's law is the foundation law in physics and has many applications in everyday life. This study aims to create a subject-specific pedagogy based on guided inquiry about Newton's law to improve students' scientific literacy. The product was developed through four-D method i.e. define, design, develop, dissemination. The sample included 20 grade XI IPA students of high school 1 Kerinci were involved as subjects on a limited tryout and 64 students on field tryout which separated into two groups as experimental and control class that selected by the random sampling technique. Data are collected through product assessment sheet and test of scientific literacy. Data analysis technique using t-test at 0.05 significance level. Findings show that (1) based on expert judgment, the product i.e. subject-specific pedagogy based on guided inquiry about Newon's law was appropriate and feasible to be implemented in the classroom; (2) The product was effective to increase the scientific literacy of the students for there were differences between experiment and control class in gain-value of scientific literacy ($p=0.011$).

1. Introduction
The learning in the 21st century is intended to develop the competencies that learners need to adapt, not feel depressed, and overcome life in the 21st century [1]. One of the competencies that must be possessed by learners in the 21st century is the scientific literacy [2][3][4]. The survey result from PISA 2015 (Program for International Student Assessment) Indonesian students' achievement for science, reading, and math was at rank 62 from 69 countries [3]. This is because there is no scientific phenomenon that presented by teacher in learning and there is no application of learning based on the scientific investigation (inquiry) so that students tend to passive [5]. The lessons that the teacher presented contained only lectures and written, directly into the mathematical form, not revealing misconceptions, not correcting assignments, inappropriate analogy models, demonstration model is narrow and does not emphasize aspects Pedagogical Content Knowledge (PCK). Lack of Scientific literacy skills on the students caused less ability of students to solve the high order thinking skills question and applicative question[7].

Improvement the scientific literacy skills require learning model in accordance with the development of students' abilities, one of learning models that are considered to improve the scientific literacy skills is Inquiry [8][9][10][11]. The inquiry is a student-centered learning which involve students in the investigation, so that inquiry learning is a scientific process. [12][13][14]. Inquiry Learning is divided into four levels; confirmation Inquiry, structured inquiry, guided inquiry, open
Implementation of inquiry model for teaching in the learning process can be seen in table 1.

| Level Inquiry          | Question   | Method   | Solution |
|------------------------|------------|----------|----------|
| Confirmation inquiry   | Given      | Given    | Given    |
| Structured Inquiry     | Given      | Given    | Open     |
| Guided Inquiry         | Given      | Open     | Open     |
| Open Inquiry           | Open       | Open     | Open     |

Guided Inquiry is a model for teaching that agrees with the level of high school students' thinking development [15]. The appropriateness of guided inquiry model to the student can be seen from the characteristics of the teacher while identifying the problem and conveying many questions that refer to the procedure [17]. This research uses guided inquiry model to increase the ability of scientific literacy on high school students.

Guided inquiry learning must consider the aspects of Pedagogical Content Knowledge (PCK) [18][19][20]. PCK is the knowledge that goes beyond the subject matter knowledge to the dimensions of subject matter knowledge for teaching [21]. Knowledge of PCK as a product is called Subject Specific Pedagogy (SSP) which is the way of teachers thinking in form of learning products [22]. SSP as a product includes two basic components lesson plan and student worksheet. The development of SSP in this study focuses on the subject of physics since physics is one of science learning that is possible to improve the scientific literacy skills, especially on Newton's Law subject matter, because this subject matter enables the students to engage in science and science-related issues that include scientific processes, scientific attitudes and the application of science in everyday life. [7][23]. Newton's Law is also a material that has many applications in everyday life making it possible to develop the ability of scientific literacy on the student. Newton's Law is also a suitable subject matter for developing students' understanding because this material has an abstract concept so that many learners do not understand speed, acceleration and how objects can move [24][25].

The improvement of scientific literacy ability measured in this research includes 4 aspects are; the role of science, scientific behavior and understanding the natural phenomena, validating the source and applying the results of the investigation, mathematical ability [3][26][27]. The complete aspect of scientific literacy skills is followed Table 2.

| Aspect of Scientific Literacy       | Indicator                                                                 |
|-------------------------------------|---------------------------------------------------------------------------|
| Role of Science                     | 1. Identify the question that can be answered through the scientific method |
|                                     | 2. Understand the nature of scientific endeavor                           |
|                                     | 3. Understand about generic phenomena                                     |
| Scientific behavior and understanding the natural phenomena | 1. Describe the nature phenomena                                            |
|                                     | 2. Identify variable of the experiment                                    |
|                                     | 3. Data Collected and obtained with observation and experiment             |
|                                     | 4. Given the critical question about design experiment                    |
| Validating the source and applying the results of the investigation | 1. Evaluate conclusions based on the result of the experiment               |
|                                     | 2. Understand the role of science to make a conclusion                     |
|                                     | 3. Evaluate the source validity                                            |
|                                     | 4. Apply scientific conclusions in daily life                             |
| Mathematical Ability                | 1. Using mathematics in science                                           |
|                                     | 2. Create table and graph representation                                  |
|                                     | 3. Understand how to read table and graph representation                 |
The development of SSP in this study was adjusted with guided inquiry model to improve the scientific literacy skills of the student. The development of the SSP is designed based on curriculum analysis, the student needs analysis, and Newton’s Law concept analysis. The purpose of the SSP development is:

- To produce subject-specific pedagogy (SSP) based on Guided Inquiry model that appropriate with the students’ needs.
- To know the effect of guided inquiry model of subject-specific pedagogy (SSP) to increase scientific literacy skills on the student.

2. Method

This study is research and development (R&D) with 4D Model consisted of 4 Stages (Define, Design, Develop, Disseminate) [28]. The product developed is SSP consists of lesson plan and student worksheet, while the instrument is a test of scientific literacy ability. Stage Define is to determine products development guidelines through subject matter analysis, competency analysis, task analysis, and instrument analysis. The Design stage is to determine the initial design of the SSP based on the guidelines, while the develop stage to gain the final product through expert judgment, limited tryout, and field tryout. There are 3 expert lectures, 2 physics teachers, and 2 peer instruction to judge the feasibility of the SSP and the content validity of the scientific literacy test. Visibility of the SSP is determine based on the average score of each expert judgement and qualitatively classified based on criteria on Table 3.

| Table 3. Data Conversion Criteria of Validity |
|---------------------------------------------|
| Interval                                    |
| $X > \bar{X} + 1.8SBi$                      |
| $\bar{X} + 0.6SBi < X \leq \bar{X} + 1.8SBi$ |
| $\bar{X} - 0.6SBi < X \leq \bar{X} + 0.6SBi$ |
| $\bar{X} - 1.8SBi < X \leq \bar{X} + 0.6SBi$ |
| $X \leq \bar{X} - 1.8SBi$                   |
| Criteria                                    |
| Very Good                                   |
| Good                                        |
| Enough                                      |
| Less Good                                   |
| Very Less                                   |

Where $\bar{X}$ = mean score = 1/2 (maximum score + minimum score)

$SBi$ = standard deviation = 1/6 (maximum score - minimum score)

$X$ = score achieved

The limited tryout to determine the readability of the SSP and the empirical validity of scientific literacy test, while the field tryout to determine the effectiveness of the SSP to increase the scientific literacy of the students. Subjects in this field tryout were 60 students of SMA Negeri 4 Kerinci. In this stage, the students are divided into two class i.e. experiment class and control class. The experimental class is given learning by using the developed SSP and the control class using the learning conventional SSP used by the teacher. The field tryout design use the quasi-experiment method with pretest-posttest control group design as shown in table 4. The experimental class was given learning by the SSP Product and the control using the learning tools used by the teacher. The field testing design used the quasi-experiment method with pre-post test control design.

| Table 4. Quasi Experiment Design in Field Tryout |
|-----------------------------------------------|
| Group             | Pretest | Treatment | Posttest |
| Eksperiment       | $t_1$   | $X_1$     | $t_2$    |
| Control           | $t_1$   | $X_2$     | $t_2$    |
With:
\[ t_1 = \text{pre-test} \]
\[ X_1 = \text{treatment with Guided Inquiry Model of Subject Specific Pedagogy (SSP)} \]
\[ X_2 = \text{treatment with Conventional Model of Subject Specific Pedagogy (SSP)} \]
\[ t_2 = \text{post-test} \]

In the Disseminate Stage, the product is distributed in several schools such as SMA Negeri 1 Kerinci, SMA Negeri 4 Kota Jambi, and SMA Negeri 4 Kerinci.

3. Result and Discussion

It has been mention that the purpose of this study is to produce guided Inquiry Model of SSP that is appropriate with students needs and feasible to be used in learning based on expert validation and can improve the ability of scientific literacy of high school students on Newton’s Law material.

3.1. Problem One: Feasibility of developed SSP

The developed Newton’s Law SSP consists of the lesson plan and student worksheet. Expert judgment results are analyzed based on the criteria contained in Table 3. Aspects that validated on the lesson plan are the formulation of indicators, content, learning step, assessment of learning outcomes and language. The aspects reviewed on the student worksheet are the content, tasks, images, and language. The result of validation of lesson plan from seven experts was shown in figure 1.

![Figure 1. Result of Expert](image1.png)

From figure 1 it can be concluded that all aspects reviewed has scores more than 4.2 and categorized as very good. Some of the improvements suggested by the validator include clarifying the syntax of learning and adapting the learning proposed toward aspects of scientific literacy. The result of expert judgment on student worksheet was shown in figure 2.

![Figure 2. Result of Expert Judgment on Students Worksheet](image2.png)
From figure 2 it can be concluded that all aspects reviewed has scores more than 4.2 and categorized as very good. Some of the improvements suggested by experts is to customize the investigation problem with experiment. After the student worksheet is categorized feasible by the expert then a limited trial done with 20 students as subject to get the Student’s readability level using the questionnaire. The result of readability level test in SMA Negeri 1 Kerinci is categorized very good, this indicates that the student worksheet produced is ready to be used in field tryout to improve the scientific literacy ability.

3.2. Problem Two: The Effectiveness of the Developed SSP to Improve Scientific Literacy

The propose of the testing field determines the effectiveness of SSP products to improve students’ scientific literacy skills. The implementation of the SSP product was conducted four times on Newton's law matter by taken samples of 64 students from SMA Negeri 4 Kerinci. Instruments used for pretest and posttest are 20 items of multiple choice that have been declared as valid and reliable. Descriptive pretest and posttest of scientific literacy skills on the student showed in table 5.

| Table 5. Descriptive Analysis of Scientific Literacy skills on the students |
|---------------------------------------------------------------|
| **Aspect of Scientific Literacy Skills** | **Experiment Class** | **Control Class** |
| | **Pre test** | **Post test** | **Pre test** | **Post Test** |
| Role of Science | 52 | 74 | 34 | 62 |
| Scientific behavior and understanding the natural phenomena | 37 | 79 | 39 | 71 |
| Validating the source and applying the results of the investigation | 34 | 83 | 46 | 73 |
| Mathematical Ability | 36 | 69 | 40 | 68 |
| **Maximum Score** | 59 | 91 | 56 | 84 |
| **Minimum Score** | 25 | 63 | 25 | 41 |
| **Standart. Dev** | 10.32 | 9.03 | 10.52 | 8.24 |
| **Score Average** | 40 | 76 | 40 | 68 |

Based on the pretest result the average score obtained is 40 in both classes. It indicates that the student's initial ability is the same level. After a different treatment using the SSP developed in the experimental class and conventional SSP on the control class, there is a different ability of Scientific literacy ability, the result of the post-test shows that the students in the experimental class have a higher average than the students in the control class.

To know the difference between of the scientific literacy ability improvement on the student is used Independent Sample t-test, Normality and Homogeneity test is needed. Normality test is to see whether the ability of the student in normal distribution and homogeneity test is to ensure the scores distribution of experiment class and control class in scientific literacy ability has the same variance Normality test results is shown in table 6 and Homogeneity test results is shown in table 7.

| Table 6. Result of Normality Test |
|----------------------------------|
| **Aspect of Scientific Literacy Skills** | **Eksperiment Class** |
| | **Statistic** | **df** | **Sig.** |
| Experiment Class | .936 | 32 | 0.061 |
| Control Class | .963 | 32 | 0.336 |

Test result of normality using Shapiro-Wilk test shows scores 0.061 for experiment class and 0.336 for control class. All of them more than 0.05 it means scientific literacy ability of experiment class and control class has a normal distribution.
The result of homogenity test using Levene Statistic find out the significance 0.956>0.05 as shown in table 7, it means that scores distribution of of experiment class and control class in scientific literacy ability has the same variance. After the data is declared normal and homogenous then the Independent Sample t-test is done. the Independent Sample t-test results can be seen in table 8.

| Variable                 | t     | Sig |
|--------------------------|-------|-----|
| Scientific Literacy Skills | 3.178 | 0.011 |

The result analysis data with Independent Sample t-test using 0.05 significance level show that there is a difference between the ability of science literacy on the experimental class and the control class of this matter shown with significance 0.011 < 0.05 this means that there are differences scientific literacy skills on the students in experiment and control class. With this result, the developed Guided inquiry of SSP can be used to improve literacy skills on the student. But there are some remedial for the students because there are still learners who get a score below 75 on the aspect of Mathematical Ability because students have lack ability to read graphs and tables, besides the students also difficulties on the questions that ask students to explain the variables in the experiment.

3.3. Research Findings
Guided inquiry learning was appropriate and could be used in physics learning especially in improving students' thinking ability and involvement of learners in Science [29]. Learning used guided inquiry model that was assisted by a supportive learning tool could improve students' scientific literacy skills because this model provided opportunities for the student to engage in the scientific process. [9]. The developed physics SSP was appropriate to the guided inquiry instructional steps, so the developed SSP could optimize the application of guided inquiry learning in the classroom [22].

Development of science literacy ability could be seen in syntax guided inquiry among others as follows; Issues posed in guided inquiry could be questions that involve students identifying problems, designing experimental steps to resolve problems. In syntax 2 and 3 guided inquiry, students were expected to be able to investigate and collect data, so that it will invite students to conduct scientific investigations. At the last stage of guided inquiry is the conclusion, at this stage, the student were instructed to explain the problem solving given by the teacher used the scientific evidence from the data collection result, then be communicated or discussed in class. So the overall model of inquiry has been related to aspects of science literacy so as to give a positive effect on the increase of scientific literacy on the student [8][9][10][11]. Syntax guided inquiry relationship with aspects of science literacy can be seen in figure 3.
Learning with guided inquiry models requires students to do the experiment. Especially on Newton's Law Subject, students were directed to learn this subject matter directly by observing, observing, investigating, and analyzing the environment around them [13] [14]. So by applying Guided Inquiry-based learning supported by SSP developed, it could improve the Literacy of Science Student [26] [27]. However, there are some important notes in this study that must be considered to apply Guided Inquiry Model of Subject Specific Pedagogy (SSP) is the time teachers use to explain the material to the students was too long thus reducing the time to experiment. Students who did not have an initial knowledge of Newton's Law material would certainly have a problem to make experiments Newton's Law that would affect the learning process. To optimize the learning time can use blended learning based learning [30], the next research can be developed Guided Inquiry Model of Subject Specific Pedagogy (SSP) based on blended learning where teachers can provide early knowledge to learners online and can optimize learning in class by doing experiment.

4. Conclusion
The This study is research and development (R&D) with 4D Model, the aim of this study is to produce Subject-Specific Pedagogy Based on Guided Inquiry to increase the ability of students' scientific literacy, the developed component is the lesson plan and student worksheet. The development of SSP is based on the results of expert validation and implementation of SSP in SMA Negeri 1 Kerinci with 64 student. The evaluation of the Subject-Specific Pedagogy by physics teacher, lecturers and peer with categorized very good, it can be concluded that Guided Inquiry Model of Subject Specific Pedagogy (SSP) was suitable for learning. The results of analysis variance is 0.011 using t-test at 0.05 significance level. It can be concluded that Guided Inquiry-based learning using SSP physics could improve students' scientific literacy skills.

The result of the development Subject-Specific Pedagogy Based on Guided Inquiry is expected to be further developed for other subject matter of the physics. Subject-Specific Pedagogy consisting of the lesson plan and student worksheet is a complementary component that should be used simultaneously in learning to develop students' scientific literacy skills. The next research can be developed Guided Inquiry Model of Subject Specific Pedagogy (SSP) based on blended learning where teachers can provide early knowledge to learners online and can optimize learning in class by doing experiment.
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