



Development of Newton Gravity Student Worksheets on Problem-Based Learning Model to Improve Students' Scientific Argumentation Skills

Dhila Linggar Lentika, *Setyo Admoko

Physics Education Department, Faculty of Mathematics and Science Education, State University of Surabaya.

Corresponding Author e-mail : setyoadmoko@unesa.ac.id

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Abstract

The purpose of this study was to evaluate the validity, practicability, and efficiency of student worksheets for improving students' scientific argumentation skills on the topic of Newton's Law of Gravity. This study was conducted using the 4-D method, which consists of four stages of research: define, design, develop, and disseminate. It is restricted to the development stage in this study. The validity of the student worksheets was analysed based on aspects of content feasibility, guidelines, questions, scientific argumentation skills, and the Problem Based Learning model achieved an overall percentage of 93.75 %, 100 %, and 95.83 % respectively. 100 %, 100 %, 100 %. The practical aspect of student worksheets is analyzed based on the students' feedback in terms of the student worksheets component, Problem Based Learning model, enthusiasm, Newton's Law of Gravity topic, and scientific argumentation, with an average of 86 %, 82 %, 91.5 %, 88.5 %, and 88 % with robust criteria, respectively. The effectiveness of the student worksheets was determined using the outcomes of the scientific argumentation test's pretest and posttest, and they met the criteria for being very effective. The given test received an average n-gain score of 0.7342 in the interpretation category. Based on the research findings of the data analysis for validity, practicability, and effectiveness, it is possible to conclude that the student worksheets developed are feasible and effective in improving students' argumentation skills. Student worksheets based on a similar Problem Based Learning model could be designed to improve students' argumentation skills on other physics topics.

Keywords: Newton's Gravity, Scientific Argumentation Skills, Student Worksheets

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INTRODUCTION

PISA (Program for International Student Assessment) reviewed science abilities in implementing teaching process into real-life problems in 2018, revealing that Indonesia was ranked 71st out of 79 countries, with an overall grade of 396 for science subjects (OECD, 2019). Generally speaking, the OECD's (Organization for Economic Cooperation and Development) average standard rating for science subjects is 489. According to the PISA outcome, Indonesia is a country with total score lower than the OECD average. Capability of participating in scientific activities and communicating in a scientifically appropriate manner Communication skills with scientific arguments are one of the most important contributions in science. However, they are still infrequently used in science education.(Osborne, 2010).

PISA measures students' ability in three areas: (1) identifying scientific problems and questions being able to find solutions scientifically based, (2) explaining or research hypotheses using appropriate scientific knowledge, and (3) using scientific evidence to determine conclusions and communicate and characterize the assumptions, evidence, and reasons behind the conclusions drawn. (OECD, 2015). Argumentation is essential in teaching

process, according to these scientific competencies. This is why argumentation is essential to teach students to think critically, develop knowledge, and communicate effectively both verbal and non - verbal.

Scientific argumentation skills have an essential role in science, which is less applied in science programs and activities in the laboratory (Kurniasari & Setyarsih, 2017). Another point is that students are hardly practiced to argue scientifically in schools with no student-centered system because teaching is focused on the teacher, which represses students' ability to discuss. Argumentation skill plays a major role in training students in developing their thinking skills so that students' knowledge could also strengthen (Devy et al., 2020). Other research from (Niki Bagus S et al., 2020) mentioned that the utilization of the Toulmin Argument Pattern (TAP) in understanding physics leads to an increase in scientific argumentation ability and understanding of students' concepts when combined with other support in the form of scientific argumentation-based exercises

Scientific argumentation helps students improve their conceptual understanding and ability to express their thoughts using scientific evidence. Students with low concept mastery have poor argumentation skills, and conversely (Noviyani et al., 2017). According to (Erduran et al., 2004) *Toulmin Argument Pattern* (TAP) is a way to analyse arguments. According to Toulmin (2003), argumentation consists of six components: claim, grounds, warrant, backing, qualifier, and rebuttal. As defined in his book "The Uses of Argument," Toulmin's argument can be represented in the following illustration.

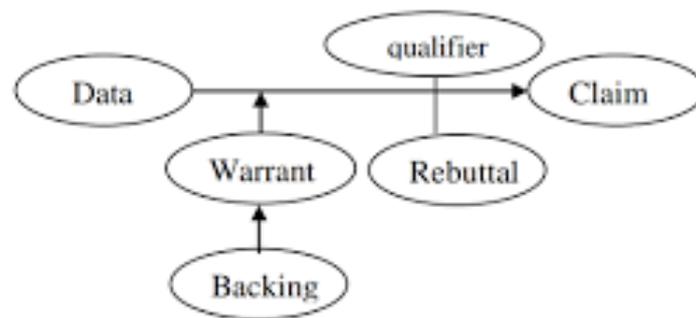


Figure 1. Toulmin's Argument Pattern (Toulmin, 1958)

According to Toulmin's argument scheme that argumentation has several scientific indicators which include claim (opinion), evidence supporting facts (evidence), warrant (justification), explaining the relationship between data and claim, and rebuttal (making a rebuttal) (Osborne, 2010). Research result (Erduran et al., 2004) shows that Toulmin's argumentation pattern is very suitable to be used by researchers to identify arguments and measure the level of argumentation. The assessment technique used to determine the argumentation ability of students is based on the final assessment and given the appropriate level of mastery in **Table 1** below.

Table 1. Level of argumentation of Toulmin pattern (TAP)

| Level | Characteristics of Argument |
|-------|--|
| 5 | The broad arguments are more than a rebuttal. |
| 4 | Arguments with a claim with a identifiable rebuttal. This argument may also have multiple claims and counter-claims, but they are not required to exist. |
| 3 | Arguments with a series of claims or counter-claims with data, warrants, or backing are sometimes accompanied by weak rebuttals. |
| 2 | Arguments consist of claims with good data, warrants or backing, but do not contain any disclaimers. |
| 1 | Simple arguments in the form of claim and counterclaim or claim vs claim. |

(Erduran et al., 2004)

Results of research (Syerliana et al., 2018) by conducting an argumentation test using the *Toulmin Argument Pattern* (TAP) which consists of several argument components, it shows that the scientific argumentation ability of students is still low. This is a basic finding about appropriate and innovative learning models that can improve students' understanding of students' scientific argumentation skills. The student worksheets used by students today do not present problems to find a concept independently and this condition encourages the development of student worksheets that are more effective and easy to use and more systematic presentation (Falah, 2017). According to (Barlenti et al., 2017) the development of student worksheets can support the process of learning activities in class and interesting student worksheets can help students independently and in groups to be active in class.

Based on a review, the researchers conducted a study to define the validity, practicability, and efficacy of the Problem Based Learning worksheet in improving students' scientific argumentation skills on Newton's Law of Gravity. This research will analyze how students' scientific argumentation skills improved after using student worksheets designed for physics learning.

METHOD

The type of research used is the Research and Development (R&D) research model which aims to develop student worksheets. This research was developed using the 4-D method, namely the study found by (Thiagarajan, Semmel S.S., 1974) which includes four stages of research: define, design, develop, and disseminate. In this research, it is limited to 3 stages: define, design, and develop as well as on Newton's Law of Gravity sub-material to improve the students their scientific argumentation skills. The following are the stages of research on developing student worksheets using modified 4-D stages on Newton's Law of Gravity:

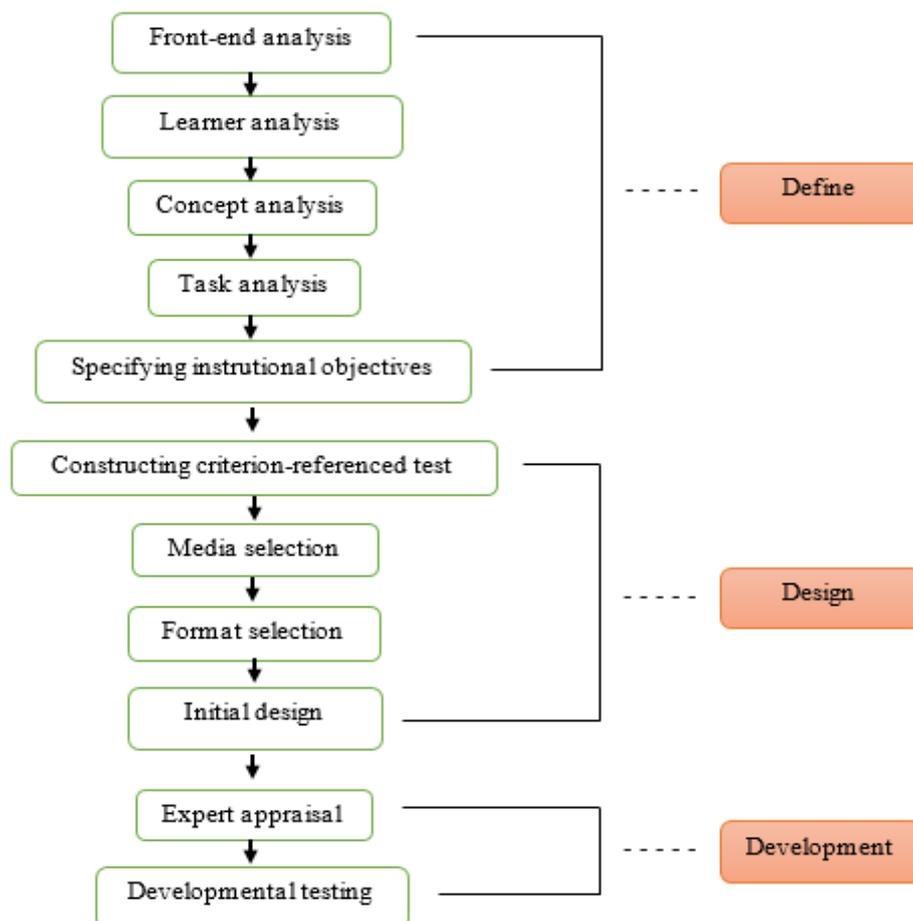


Figure 2. Modification of 4-D Stages

This research focuses on developing physics worksheets based on essential competencies 3.8 and 4.8 to improve students' scientific argumentation skills. The validity, practicability, and effectiveness of developing these student worksheets are evaluated. The validation results and trial data were used to generate the research data obtained from developing these student worksheets. Validation sheets, response questionnaires, pre-test question sheets, and post-test scientific argumentation skills were used in this study. The trial phase was taken out in the even semester of the 2021/2022 academic year in class X MIPA SMAN 2 Madiun. Twenty-five students participated in the study. The research was carried out in May 2022..

The data from the validation results are used to evaluate the validity of the student worksheets. The validation results were derived from physics lecturers and were descriptively quantitatively analyzed, containing the percentage of assessment indicators. This evaluation is based on a Likert scale in **Table 2** below.

Table 2. Likert Skala Scale

| Scale Value | Evaluation |
|-------------|------------|
| 1 | Very bad |
| 2 | Bad |
| 3 | Currently |
| 4 | Well |
| 5 | Very good |

(Riduwan, 2008)

The resulting data is calculated the percentage with the following formula:

$$(\%) \text{ validity} = \frac{\text{total score}}{\text{criteria score}} \times 100\%$$

Criteria score = max score x \sum rated aspect x \sum respondent

The results of the percentage calculation are then interpreted in the criteria of **Table 3** below.

Table 3. Interpretation of Validation Criteria

| Percentage (%) | criteria |
|----------------|-------------|
| 0-20 | Invalid |
| 21-40 | Not valid |
| 41-60 | Quite valid |
| 61-80 | Valid |
| 81-100 | Very valid |

(Riduwan, 2008)

Student worksheets can be declared valid and tested in learning if they meet the criteria for the percentage result of $\geq 61\%$ (Riduwan, 2008).

The effectiveness of the student worksheets is assessed from the increase in the learning outcomes of students' scientific argumentation skills. The data comes from the data from the pre-test and post-test which were analyzed descriptively quantitatively using n-gain score analysis.

The resulting scientific argumentation test score data is then analyzed using n-gain score analysis $\langle g \rangle$ according to the following equation:

$$\langle g \rangle = \frac{\% \langle G \rangle}{\% \langle G_{\max} \rangle} = \frac{(\% \langle S_f \rangle - \% \langle S_i \rangle)}{(100\% - \% \langle S_i \rangle)}$$

Keterangan:

$\langle g \rangle$ = gain score

$\% \langle S_f \rangle$ = post-test score percentage

$\% \langle S_i \rangle$ = pre-test score percentage

The resulting percentage results are then interpreted with the criteria in **Table 4** below.

Table 4. N-Gain Score Interpretation Criteria

| Score $\langle g \rangle$ | Interpretation |
|------------------------------------|----------------|
| $\langle g \rangle \geq 0,7$ | Tall |
| $0,7 > \langle g \rangle \geq 0,3$ | Currently |
| $\langle g \rangle < 0,3$ | Low |

(Hake, 1998)

Based on these criteria, student worksheets is said to be effective if the results of the student's scientific argumentation skills test get an n-gain score 0,4 (Hake, 1998).

The practicality of the student worksheets is assessed from the data from the student response questionnaires. The results of the response questionnaire are used to see students' responses when learning using student worksheets which are being developed to improve scientific argumentation skills. The form of the student response questionnaire was made using a checklist.

The formula for calculating the percentage of students' responses to the questionnaire answers is:

$$(\%) \text{ response} = \frac{\text{total score obtained}}{\text{criteria score}} \times 100\%$$

The calculation percentage results are interpreted into categories in **Table 5** below.

Table 5. Interpretation of Student Response Categories

| Percentage (%) | Category |
|----------------|-------------|
| 0-20 | Very weak |
| 21-40 | Weak |
| 41-60 | Enough |
| 61-80 | Strong |
| 81-100 | Very strong |

(Riduwan, 2008)

Based on these categories, student worksheets can be said to be practical if the students' responses $\geq 61\%$ (Riduwan, 2008).

RESULTS AND DISCUSSION

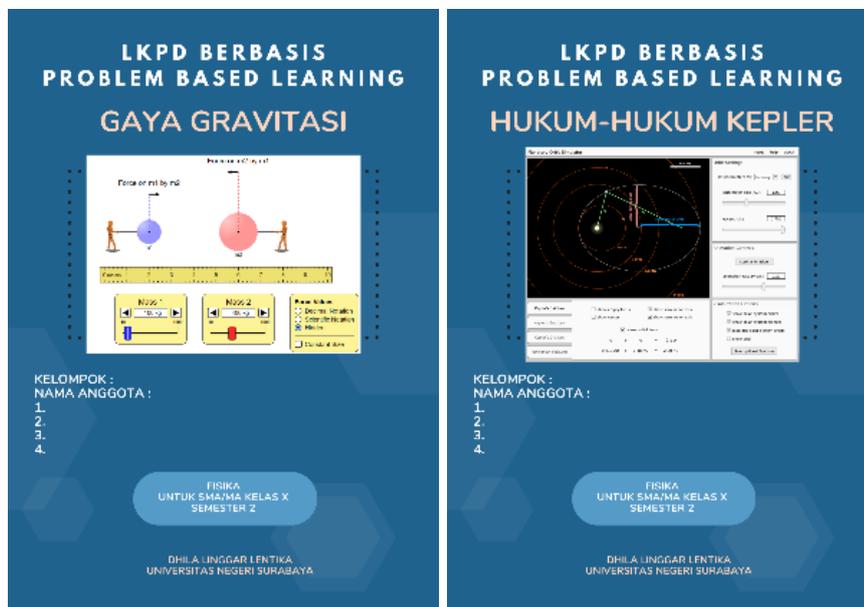
The results of this study are student worksheets validation, pre-test and post-test scores of scientific argumentation skills tests, and student response data to student worksheets. This student worksheets was developed using the 4D method which consists of the following stages.

Define Stage (Defining)

The define stage contains student analysis, needs, competencies and concept analysis. The analysis carried out at this stage found that scientific argumentation skills were still not applied to science material and activities in the laboratory (Kurniasari & Setyarsih, 2017). The other factor is that students are hardly trained to argue scientifically in schools that don't use student-centered method, so that learning is focussed on the teacher, which can inhibit students' ability to argue. Whereas there are several concepts in Newton's Law of Gravity content, misconceptions might well emerge if students' understanding is still not measured. As a result, students require adequate learning media for the learning process, including student worksheets on Newton's Law of Gravity to practice students' scientific argumentation competence.

Design Phase (Design)

This design stage leads to the creation of the first draft of the student worksheets. The resulting student worksheets can help students learn the material by conducting experiments that are adapted to the *Problem Based Learning* syntax (Andriyatin et al., 2019). The student worksheets developed for this study took the form of two student worksheets, each containing one subchapter of the Newton's Law of Gravity topic.



(a)

(b)

Figure 3. Student worksheets cover display (a) Student worksheets cover 1 (b) Student worksheets cover 2

Seeing as group discussion learning was used in this research, the student worksheets cover encompasses the title of the content, school and class levels, and group members' names. This student worksheets starts with a problem that requires students to gather information and draw up a claim (argument stage: claim) and problem formulation. Then, using an online experiment from an online application whereby the link has been prepared and is listed in the student worksheets, students are asked to prove the claim that has been cultivated through a lab session. Students are instructed to retrieve solid data in the table of observations and statements of observations (argument stage: data), analyze it, and relate it to the claims being made (argument stage: warrant). Following that, students seek data to back up their claims in publications or teaching materials that have been provided (argument stage: backing). Following that, students communicate the outcomes of their discussions with their groups, and other groups can refute statements that are false about the claims presented (argument stage: rebuttal). The diagram below depicts the stages of argumentation in the student worksheets.

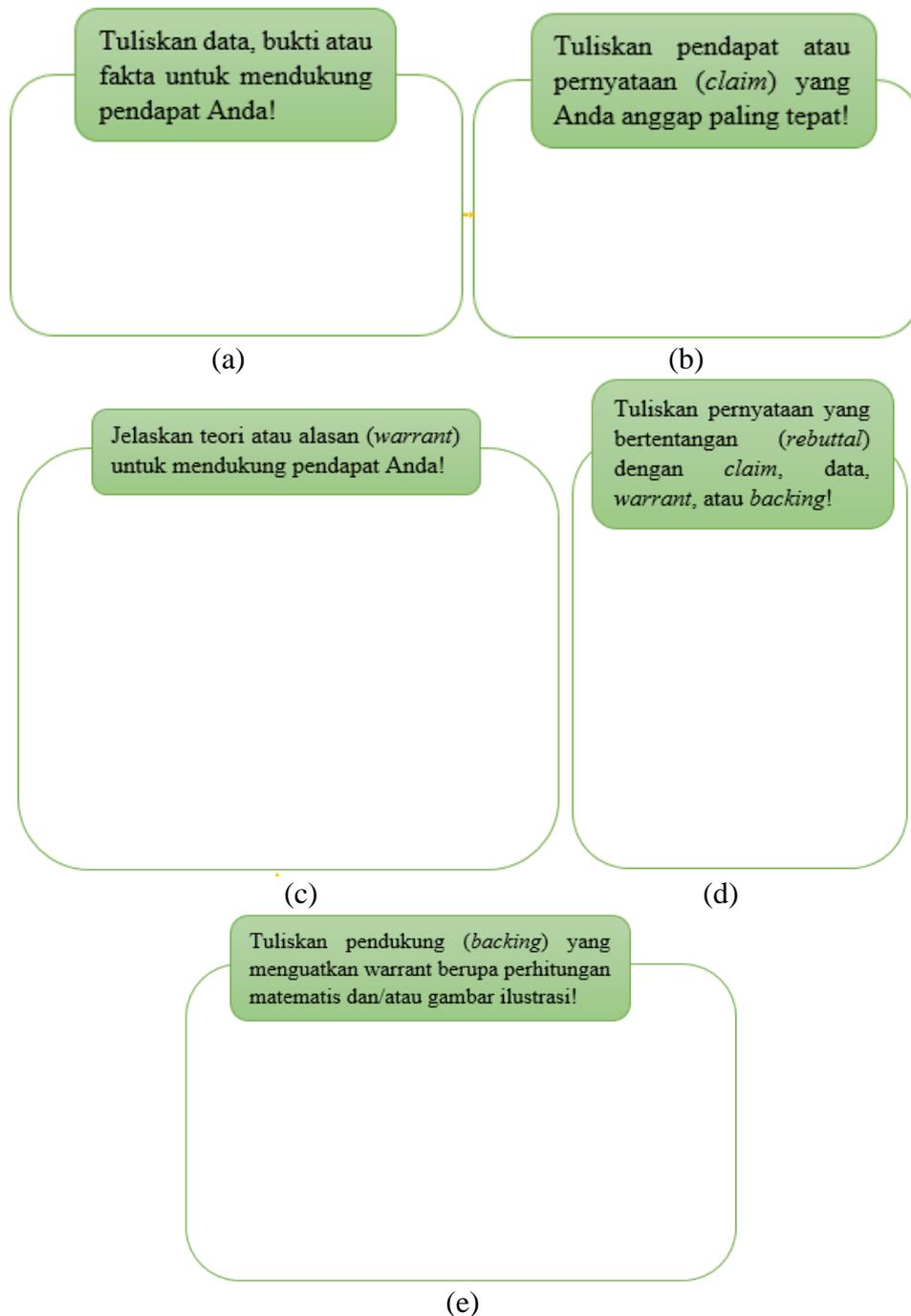


Figure 4. Display of argumentation stages in student worksheets (a) claim stage (b) data stage (c) warrant stage (d) backing stage (e) rebuttal stage

Development Stage (Development)

This stage of development entails revision, validation, testing, and data analysis. The student worksheets that have been revised through a validation process are the end result of this stage (Hasanah et al., 2017). The validation results of the student worksheets will be quantitatively analyzed to obtain recommendations for improvement the student worksheets. At this stage, conclusions will be drawn about the feasibility of the developed student worksheets, which will be evaluated in terms of validity, practicability, and effectiveness.

Student Worksheets Validity

This validation of student worksheets was being interpreted through the validation of several aspects assessed by the validator lecturer. Furthermore, the validation process for student worksheets takes the form of experts providing suggestions and comments on student

worksheets developed by researchers. There are several errors in writing or explicit problems in offering advice, and a revision process has been completed. The validation of student worksheets was being performed using a validation sheet instrument, which is then analyzed and the average percentage is calculated **Table 6** below.

Table 6. Student Worksheets Validation Results

| Rated aspect | Average percentage (%) | Criteria |
|-------------------------------------|------------------------|------------|
| Material eligibility | 93.75 % | Very valid |
| Instructions for working | 100 % | Very valid |
| Question | 95.83 % | Very valid |
| Scientific Argumentation Skills | 100 % | Very valid |
| <i>Problem Based Learning Model</i> | 100 % | Very valid |

Based on Table 6, it can be seen that all aspects of validity assessed from the developed student worksheets are in very valid criteria, which indicates that the student worksheets can be used in the learning process. This study follows other studies that state that the worksheet through the Toulmin Argument Pattern (TAP) approach is excellent and feasible for learning activities (Devy et al., 2020).

On the validity aspect of the feasibility of the material obtained a value of 93.75% which means that the student worksheets can be said to be very valid or feasible to use. This shows that the material in the student worksheets has conformity with the indicators and learning objectives, the phenomena given are under the concept of the material. Based on research (Rachmanita Murniati dan Gusti Made Sanjaya, 2013) Validation of the developed worksheet with the appropriate category has met the feasibility component topic. And demonstrates the suitability of portraying a topic with learning indicators in online media and worksheets display. This could also help students understand the topic, and the lesson in the worksheet is suitable for use as a classroom activity. In the validity aspect of the work instructions, the score is 100%, which means it is in the very valid category and is feasible to use. Standard procedures are written in simple sentences, image guidelines illustrate the contents, and teaching and learning is implemented systematically in the correct sequence.

In the validity aspect of the question, it gets a value of 95.84% which means it is in the very valid or feasible category to be used. This shows that the questions in the student worksheets are under the learning objectives, using sentences that are easy to understand and related to the problems to be solved in the student worksheets.

In the validity aspect of scientific argumentation skills, the score is 100%, meaning that student worksheets can be said to be very valid or feasible. This shows that the student worksheets has been in line with scientific argumentation skills. Student worksheets based on the Toulmin Argumentation Pattern that is appropriately applied can be used as a guide in training and analyzing students' scientific argumentation skills by presenting information that can improve students' thinking. According to the opinion of (Lazarou, 2009) that the application of a good Toulmin Argument Pattern (TAP) can be used as a reference to analyze the level of argumentation skills and can be a positive discovery that can improve students' argumentation skills.

In the validity aspect of the Problem Based Learning model, the score is 100%, which means it is in the very valid or appropriate category to use. This shows that the Problem Based Learning model can be in line with the student worksheets which contains elements of scientific argumentation and can train students with the combination.

Student Worksheets practicality

The practicality of the student worksheets is assessed from the student response questionnaire. The response questionnaire consists of questions using the checklist method and there are 4 answer choices, namely strongly agree, agree, disagree and strongly disagree. The following are the percentages and results of student responses.

Table 7. Student Response Questionnaire Results

| Rated aspect | Average percentage (%) | Criteria |
|-------------------------------------|-------------------------------|-----------------|
| Student Worksheet | 86 % | Very strong |
| <i>Problem Based Learning Model</i> | 82 % | Very strong |
| Motivation | 91.5 % | Very strong |
| Newton's Law of Gravity Material | 88.5 % | Very strong |
| Scientific Argument | 88 % | Very strong |

The student worksheets aspect met very strong criteria based on the questionnaire response data. This demonstrates that students comprehend learning through the use of student worksheets. Learning with student worksheets is exciting and engaging for students. The aspect of the Problem Based Learning model gained very strong criteria based on data collected. This demonstrates that students could take part in learning activities when using the Problem Based Learning model.

The motivation aspect received very strong criteria based on the questionnaire response data. This indicates that students are motivated to learn and participate debate during the learning process. Student worksheets that have been developed could evoke students' enthusiasm for learning as well as attract students' interest because the appearance is consistent with the material and could entice students for using them throughout learning (Putri & Mitarlis, 2015).

Based on the questionnaire data, the material aspect of Newton's Law of Gravity received very strong criteria. This identifies that students can understand the material. Students can explain concepts and phenomena related to the material. According to research (Putri & Mitarlis, 2015) the developed student worksheets can make it easier for students to understand material that contains facts and concepts.

The scientific argumentation aspect earned very strong parameters based on the questionnaire response data. This indicates that students understand the components of scientific argumentation (claim, data, warrant, backing, and rebuttal), which could contribute to making the content understandable, and the developed worksheets could also support students in arguing.

Research described above, it is clear that the student worksheets have met the practicality criteria through each aspect and are included in the very strong response criteria, indicating that this student worksheet could be confirmed practical for use in the educational process. This can enhance learning outcomes with the results of good student feedback to the provided student worksheets, in which it can establish and help encourage students in learning, and could be more effective to use.

Student Worksheets Effectiveness

The effectiveness of the student worksheets as measured by the students' scientific argumentation skills test pretest and posttest scores. The level of students' mastery of the content on Newton's Law of Gravity and the growth of their scientific argumentation skills could be measured using this test. This test was given online, via WhatsApp groups, and had completed simultaneously by students at their homes.

Student worksheets are said to be effective if the results of the students' scientific argumentation skills test yield an n-gain score of 0,4 (Hake, 1998). The scientific argumentation skills test consists of various essay questions, each of which incorporates an argumentation stage. The questions in the lesson plan have been adapted to the Competency Achievement Indicators (GPA). In **Table 8** below are the results of the n-gain scores obtained from 25 students who took part in the trial.

Table 8. Test Calculation Results

| Test Type | Average Pre-test Score | Average Post-test Score | N-Gain score | Interpretation |
|--------------------------------------|------------------------|-------------------------|--------------|----------------|
| Scientific argumentation skills test | 6.40 | 74.80 | 0.7342 | tall |

According to Table 8, the n-gain score for the students' scientific argumentation skills test was 0.7342, with a high explanation classification. The student worksheets are seen to be very effective based on the n-gain values obtained because the n-gain test score obtained was 0. As there is an increment in learning outcomes and students' scientific argumentation skills when using the developed student worksheets, this student worksheets is very effectively used to train students' scientific argumentation skills. Students used worksheets created during the learning process, and when a limited trial was conducted, students were appropriately guided in the use of worksheets, allowing students to cultivate their understanding of scientific argumentation skills. This is consistent with Toulmin's claim that using the Toulmin Argumentation Pattern (TAP) can achieve higher students' conceptual mastery and scientific argumentation skills (Toulmin, 2003). This research supports other studies that prove training students' scientific argumentation skills could maximize concept mastery, learning quality, and reasoning abilities (Viyanti et al., 2016).

CONCLUSION

Based on the discussion of the research data, it can be concluded that the student worksheets developed is feasible to use with the following details. The validity of the student worksheets is assessed based on the aspects of material feasibility, work instructions, questions, scientific argumentation skills, and Problem Based Learning models get an average percentage of 93.75%, 100%, 95.83%, 100%, and 100% respectively with very good criteria, valid and feasible to use. The practicality of the student worksheets is assessed based on the student's response in terms of the student worksheets aspect, Problem Based Learning model, motivation, Newton's Law of Gravity material, and scientific argumentation, obtaining an average percentage of 86%, 82%, 91.5%, 88.5%, respectively. and 88% with very strong criteria. The effectiveness of the student worksheets was determined using the results of the scientific argumentation test's pretest and posttest, and they met the criteria for being very effective. The given test has a high interpretation category and an average n-gain score of 0.7342. Based on the findings of the data analysis for validity, practicability, and effectiveness, it is possible to conclude that the student worksheets developed are feasible and effective in improving students' argumentation skills. Student worksheets based on a similar Problem Based Learning model can be created to improve students' argumentation skills on other physics materials.

RECOMMENDATION

Following the completion of this research, the researcher experienced challenges with students who did not understand the primary objective of creating these student worksheets. As a result, additional research is expected to provide more detailed steps as well as other components.

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