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Article

Development of E-Worksheets Based on Inquiry Using Spectrophotometer Practicum Tools to Train Science Process Skills in Light Waves Materials

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ABSTRACT
This study aims to develop an inquiry-based e-Worksheet (Electronic Student Worksheets) that is valid, practical, and effective in enhancing science process skills in the topic of light waves with the assistance of Liveworksheet. The research development design used is Design Development Research (DDR), which consists of four stages: analysis, design, development, and evaluation. The results of the product validity test obtained an average percentage score of 90.12%, categorized as very valid. The results of the small-scale test, in terms of readability, achieved an average percentage of 85.2%. In the large-scale test, the practicality test, specifically the student response test, received a score of 82.75%, while the teacher perception test obtained a score of 90%. All average scores from both the small-scale and large-scale tests fall into the very practical category. Secondly, the effectiveness test results from the Paired Sample T-Test showed an average of 0.000, indicating that science process skills were well-trained and showed a significant improvement, with an N-Gain score of 0.63 after the implementation of the inquiry-based e- Worksheet. This means that the inquiry-based e- Worksheet, utilizing spectrophotometer lab equipment to train science process skills in light wave topics, is effectively used in the learning process with a moderate category.

INTRODUCTION

Education in the 21st century has become increasingly important to ensure students possess skills in learning and innovation, utilization of technology and information media, and the ability to work and survive by leveraging life skills (Wrahatnolo & Munoto, 2018). 21st-century learning requires students to have various skills. One of the skills that can be developed to prepare 21st-century students is science process skills (Bahri et al., 2017). Students are expected to understand concepts and have process skills in implementing them, making science process skills one of the crucial abilities students must possess, especially in physics or science subjects (Sulastri et al., 2021).

Science process skills are necessary for students to study the world of science and technology in more detail. Students are required to understand concepts and possess process skills in implementing them, making science process skills one of the important aspects that students must have, especially in physics or science lessons (Sulastri et al., 2021). Students are able to learn science meaningfully through the exploration of science process skills based on a constructivist approach. The constructivist view of learning encourages students to use active techniques (experiments or real-world problem-solving) to create more knowledge. (Sugrah, 2019). Through direct activities such as science experiments, students use different senses by touching, feeling, moving, observing, listening, and sometimes smelling and experimenting in an interactive way. Students are required to incorporate information they have gathered from observations that can be shared with others. Equipped with good communication skills, students will be able to describe natural phenomena in learning (Turiman et al., 2012).

The science process skills of 10th-grade students in Sukabumi City Public High Schools are still in the low category (Wahyuni et al., 2020). One of the difficult topics to understand in physics learning is light waves. Students' difficulties mostly lie in concept comprehension because it requires higher-order thinking, involves too many formulas, and includes too many calculation problems, making it hard for students to grasp the material well (Rizki, 2023). Science process skills can be trained and developed through practical activities. Practical activities require students to conduct observations, experiments, and test concepts they have learned, both inside and outside the laboratory. With experimental activities, students are able to find and find answers to the problems they face and can be trained to think scientifically so as to improve learning outcomes (Rohana et al., 2022).

One way to train students' science process skills is through learning activities using inquiry-based practicum (Hidayati et al., 2021). Inquiry-based learning is a teaching strategy that aims to develop students' skills in facing problems they might encounter by using methods employed by scientists through research, investigation, analysis, and inquiry in the classroom (Sen & Vekli, 2016). Inquiry involves higher-level mental processes, such as formulating problems, designing experiments, conducting experiments, collecting and analyzing data, drawing conclusions, having an objective attitude, honesty, curiosity, openness, and so on (Syahgiah et al., 2023).

Based on a preliminary study conducted with five high school teachers in Lampung regarding the teaching of light wave material in schools, it was found that the Student Worksheets (LKPD) used by teachers did not employ teaching aids and only consisted of a collection of problems. Teachers only explained the material through books and internet media. They used lecture and demonstration methods to deliver light wave material. The difficulties experienced by teachers in teaching light wave material include limited practicum equipment and lack of learning resources, resulting in a suboptimal learning process.

A preliminary study conducted with students regarding the learning of light wave material in schools revealed that students find it difficult to understand light wave material, the delivery of material by teachers is hard to comprehend, and it is challenging to understand example problems. According to students, factors causing difficulties in classroom learning include the absence of practicum implementation, too many formulations or formulas, limited learning media, and lack of learning resources. In this era of technological developments, most students are more interested in teaching materials that utilize other media such as computers/laptops, even smartphones compared to teaching materials in the form of printed worksheets (Febriansyah et al., 2021). These issues certainly become obstacles that need attention. One of the learning supports is e-Worksheet teaching materials. According to Haryanto et al. (2020), e-Worksheets can serve as a means to assist and facilitate teaching and learning activities, thereby creating effective interactions between students and teachers to enhance student engagement in improving learning outcomes. Besides, the use of eworksheets has the potential to change the views of students to read and consume interactively and comfortably, where e-worksheets have pictures, narratives, and graphics.

Research conducted by Aksari et al. (2021) shows that the resulting guided inquiry-based e-Worksheet is suitable for use by integrating various applications, namely Phet and video tutorials. Research conducted by Sulistyowatiningsih & Achmadi (2019) and Sa'diah et al. (2022) has developed Worksheet to train science process skills. Based on these studies, there has been no development of e-Worksheet using a simple Spectrophotometer practicum tool. This is the main basis for conducting the research "Development of Inquiry-Based e-Worksheet Using Spectrophotometer Practicum Tools to Train Science Process Skills in Light Wave Material".

METHODS

This research design uses the Design and Development Research (DDR) approach adapted from Richey and Klein (2007). The research phase was conducted at SMAN 1 Abung Semuli with the subjects being 25 students from class XI MIPA 6 and involving 1 lecturer from the Physics Education study program at the University of Lampung and 2 high school teachers in Lampung. The Design and Development Research (DDR) approach is a systematic approach involving several processes, such as design and development processes and evaluation based on empirical research, consisting of 4 stages: analysis, design, development, and evaluation.

The Analysis phase was carried out by providing a needs analysis questionnaire to several physics education teachers and students in several high schools in Lampung province. The needs analysis was conducted to identify the potential and problems in these schools. The second stage is design, which involves designing a product to be developed based on the results of the analysis that has been carried out and the indicators to be achieved. After the product aligns with the design that has been made, the next stage is development, which is carried out based on the e-Worksheet product design that has been created. Then, validity tests, practicality tests through readability tests, response tests, and perception tests are conducted to determine the level of product feasibility, product readability, and effectiveness tests, as well as responses from students after using the e-Worksheet, and teachers' perceptions of the use of e-Worksheet in the learning process. The final stage is evaluation, which is carried out at each stage of e-Worksheet development to refine the product by making revisions or improvements based on suggestions from the expert team as well as teacher perceptions and student responses.

The research instruments used in this study were validity test questionnaires, readability questionnaires, practicality test questionnaires (teacher perception questionnaires and student response questionnaires), and pretest and posttest questions. Data collection techniques used in this study were validity, small-scale tests obtained from readability tests, and large-scale tests consisting of practicality and effectiveness tests. The data analysis technique in this study used a mixed method, namely qualitative and quantitative. The assessment on this questionnaire uses a Likert scale adapted from Ratumanan & Laurent (2011).

The results of the validity test were calculated using the following equation:

$$p = \frac{\Sigma\, Score\ obtained}{\Sigma maximum\ score} \times 100$$

The calculated results are then interpreted to determine the quality of the developed product. The interpretation of scores can be seen in Table 1.

Table 1. Conversion of Validity Assessment Scores

Presentation	Criteria
0,00% - 20%	Invalid
20,1% - 40%	Less Valid

Presentation	Criteria
40,1% - 60%	Fairly Valid
60,1% - 80%	Valid
80,1%-100%	Very Valid

(Arikunto, 2011)

Readability test and practicality test data are analyzed using percentages based on the formula according to Sudjana (2005) as follows:

$$\% X = \frac{\Sigma score\ obtained}{\Sigma maximum\ score} 100\%$$

The data obtained from the readability test and practicality test results are then converted so that their criteria can be determined. The conversion of assessment scores can be seen in Table 2.

Table 2. Conversion of Readability & Practicality Assessment Scores

Presentation	Criteria
0,00% - 20%	Not readable/Not good
20,1% - 40%	Less readable/Less good
40,1 % - 60%	Fairly readable/Fairly good
60,1% - 80%	Readable/Good
80,1% - 100%	Very readable/Very good

(Arikunto, 2011)

The data used to determine product effectiveness is obtained based on tests (quantitative data). The test is conducted twice, namely pretest and posttest. The results of the pretest and posttest answers are analyzed using normality tests, N-Gain tests, and Paired Sample t-tests. The criteria for interpreting N-Gain values can be seen in Table 3.

Table 3. Criteria for interpreting N-Gain values

N-Gain Value	Criteria
N-Gain > 0,7	High
0,3 ≤ *N*-Gain ≤ 0,7	Medium
N-Gain < 0,3	Low

. (Hake, 2002)

RESULTS AND DISCUSSION

This development research produced an inquiry-based e-Worksheet (electronic student worksheet) using spectrophotometer practicum equipment to train science process skills. It was designed using the Canva application and then uploaded through the Liveworksheets platform. The resulting product can be accessed online, allowing students to directly answer and discuss on the provided link. The e-Worksheet display on the Liveworksheets platform can be seen in Figure 1.

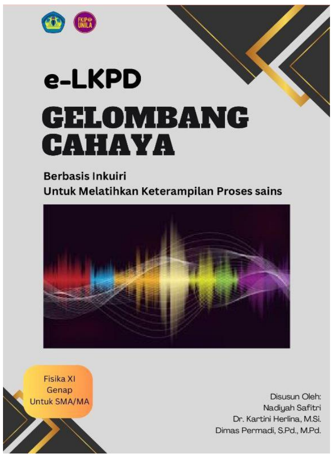

Figure 1. *e*-Worksheet Display on The Liveworksheets Platform

This *e*-Worksheet has gone through the evaluation stage, followed by expert validation tests. The product validation test consists of two categories: media and design aspects, and material and construct aspects. This product validation was carried out by three experts consisting of one Physics Education Lecturer and two high school Physics teachers. The results of the product validation test can be seen in Table 4.

Table 4. Results of Expert Validity Test

Aspect	**Validator**			**Percentage Score Average**	**category**
	Expert 1	**Expert 2**	**Expert 3**		
Media and Design Validation	92,10%	80,26%	93,42%	88,59%	very Valid
Material and Construct Validation	95%	86,66%	93,33%	91,66%	very Valid
Average Percentage Score	93,55%	83,46%	93,37%	90,12%	very Valid

Based on the validity test results, all aspects received an average percentage score of 90.12% with a very valid category. Of the three validators, there was one validator whose average score was below 90%, namely the second expert validator. This was because validator 2 had different criteria from other validators, such as the use of less bright colors, font size usage, and the display of images or videos without sources. However, this does not mean that the developed e-Worksheet product is of poor quality, but it can be improved or perfected to become a better e-Worksheet product.

The next validation test aspect is the material and construct aspect, which contains 15 questions. The material and construct aspects assess accuracy, completeness, interest, learning presentation, ease of use of e-Worksheet, and integration of learning steps. Based on the results of the expert material test assessment on the material and construct aspects, it obtained a percentage score of 91.66% with a very valid category. This score indicates that the developed e-Worksheet product meets the criteria for material and construct aspects.

Based on the results of the validity test questionnaire by 3 experts on the assessment of media and design aspects, which can be seen in table 14. The media and design aspects contain 19 questions covering display or illustration quality, readability, and e-Worksheet management quality. The display or illustration quality indicators assessed include the suitability of form, layout, color selection, and the relevance of illustrations presented to the learning content on the cover and content design. For readability indicators, they include font type, size, and color. And for e-Worksheet management quality, they include composition balance, overall appearance, and attractive and simple e-Worksheet design. The assessment of media and design aspects received a percentage score of 88.59%, categorized as very valid. This percentage score indicates that the developed e-Worksheet product meets the criteria for media and design aspects. Based on the results of these overall aspect tests, it can be concluded that the developed product is very effective and suitable for use in learning to train students' science process skills. Valid and reliable instruments can provide accurate and consistent results, allowing researchers to make more precise conclusions. These results align with the theory of validity in learning instruments, which emphasizes the importance of content and construct validity. The development of learning materials should be based on strong theory and the consistency among the components of the learning model used. (Suniasih, 2019).

After the e-Worksheet product was declared valid, a small-scale test was conducted. The small-scale test was carried out through a readability test conducted on a small group consisting of 25 eleventh-grade students from SMA Negeri 1 Abung Semuli. The readability test questionnaire instrument given to students consisted of attractiveness and ease aspects with 11 questions. The results of this readability test can be seen in Table 5.

Table 5. Results of Student Readability Test

Aspect	Score Presentage	Category
Attractiveness	86,6%	Very Readable
Convenience	83,8%	Very Readable
Average Percentage Score	85,2%	Very Readable

This readability test questionnaire contains questions about the ease of using the developed e-Worksheet product. Based on table 5, the readability test results obtained an average percentage of 85.2% with a very readable category. This percentage score indicates that the developed e-Worksheet product meets the criteria for the ease aspect. Good teaching materials should be readable and understandable by students according to their level so that learning objectives can be achieved by students (Utami et al., 2021).

After conducting a small-scale test through a readability test on the e-Worksheet product, a large-scale test was conducted through practicality and effectiveness tests. The practicality test consists of a student response test conducted by 25 students and a teacher perception test conducted by 8 physics teachers. The student response test questionnaire consists of 29 questions covering 4 aspects.

Table 6. Results of Student Response Test

Aspect	Percentage	Category
Teaching material characteristics	83%	Very Good
Application of knowledge and skills	82%	Very Good
Student perception of satisfaction	82%	Very Good
Use of activity-based e-LKPD with inquiry model	84%	Very Good
Average Percentage Score	82,75%	Very Good

Based on table 6, the readability test results for all aspects obtained an average percentage score of 82.75% with a very good category. From the results of these overall aspect tests, it can be concluded that the developed product is very effective and suitable for use in learning to train students' science process skills. Student satisfaction is an emotional response to the experience they expect. Students feel satisfied if the learning process service they receive meets their expectations. To achieve high satisfaction, an understanding of students' desires is needed by developing the school's potential to meet students' needs (Kummalasari, 2017).

The teacher perception test questionnaire on the application of e-Worksheet aims to assess the extent to which the developed e-Worksheet can be applied in the learning process. The teacher perception questionnaire focuses on assessing the suitability of inquiry-based learning model activities to the skills to be trained. The perception test questionnaire instrument given to teachers consists of 5 questions. The results of the teacher perception test can be seen in Table 7.

Table 7. Results of Teacher Perception Test

Question No.	Percentage	Category
1	100%	Very Good
2	86%	Very Good
3	87%	Very Good
4	90%	Very Good
5	87%	Very Good
Average Percentage Score	90%	Very Good

Based on table 7, the teacher perception test results obtained an average percentage of 90% with a very good category, meaning that the developed e-Worksheet product is very good to be applied in the learning process of light wave material, and all e-Worksheet activities developed can improve students' science process skills. The question with the highest score is question number 1, which states that the e-Worksheet product guides students in observing light spectrum phenomena to explore students' initial knowledge that can train science process skills in the indicator of formulating problems, with an average percentage score of 100% in the very good category. The first activity in the developed e-Worksheet presents a light spectrum phenomenon illuminated by white light. Meanwhile, the question with the lowest score is question number 2, which states that in activity 2 of the e-Worksheet product, students are guided to formulate problems and hypotheses based on given statements, obtaining an average percentage score of 83% in the very good category.

After the e-Worksheet product was declared valid and practical, an effectiveness test was conducted to determine whether there is a difference in the average scores of students before and after using the developed e-Worksheet. The test was conducted twice, namely pretest and posttest. The effectiveness test consists of Normality test, N-Gain test, and Paired Sample T-Test. The e-Worksheet was implemented directly by the researcher in class XI 6 at SMAN 1 Abung Semuli with 25 students. First, a normality test was conducted to determine whether the sample data from the pretest and posttest results were normally distributed. This normality test was carried out using the Kolmogorov Smirnov statistical test. The results of the data normality test can be seen in Table 8.

Table 8. Results of Normality Test

Students	**Kolmogorov-smirnov**			
	statistic	**Df**	**Sig.**	**Interpretasi**
Pretest-posttest Results	0.86	25	0.200	Normal

Based on table 8, the normality test results show that the results of the pretest and posttest scores have a significance value greater than 0.05, which means the data obtained is normally distributed. Next, the N-Gain test data was conducted to measure the improvement in science process skills and cognitive learning outcomes of students before and after classroom learning. The N-Gain test results can be seen in Table 9.

Table 9. Results of N-Gain Test Based on Pretest-Posttest Scores

N-Gain	**Category**
0.63	medium

Based on table 9, the average N-Gain score of 0.63 means that the improvement in students' science process skills is in the medium category. This is due to the fact that each student has a different level of understanding of the material being taught. Some students already have a strong foundation, while others still struggle, and the time available to implement the inquiry-based learning model has not been sufficient to provide in-depth understanding for all students. However, this indicates that after being treated with the inquiry-based e-Worksheet learning model, students' posttest scores increased significantly compared to before the treatment. The next test conducted was the Paired Sample t-test, which aims to determine the difference in the average score of students' science process skills before and after treatment. The results of the Paired Sample t-test can be seen in Table 10.

Table 10. Results of Paired Sample t-test

Paired Sample t-test	***Pretest-Posttest***
Asymp. Sig (2-tailed)	0.000

Based on table 10, the results of hypothesis testing using the paired sample t-test show a Sig. value of 0.000, indicating that students' science process skills increased significantly after the application of inquiry-based e-Worksheet on light wave material. Therefore, the results of the pretest and posttest research show that the inquiry-based e-Worksheet developed for light wave material is effective in training science process skills in students. These results are supported by previous studies that have shown that inquiry-based learning models are effective in enhancing science process skills (Sen & Vekli, 2016; Zeidan & Jayosi, 2014; Sulistyowatiningsih & Achmadi, 2019). Furthermore, research by Bunterm et al. (2014) and Simsek & Kabapinar (2010) also confirms that active inquiry can enhance students' conceptual understanding through direct involvement in the scientific investigation process.

The test instrument used to determine the effectiveness of the inquiry-based e-Worksheet model given to the sample class used 5 questions with essay questions. The pretest and posttest questions are related to science process skills indicators as shown in Figure 2, which maps the average questions answered by students.

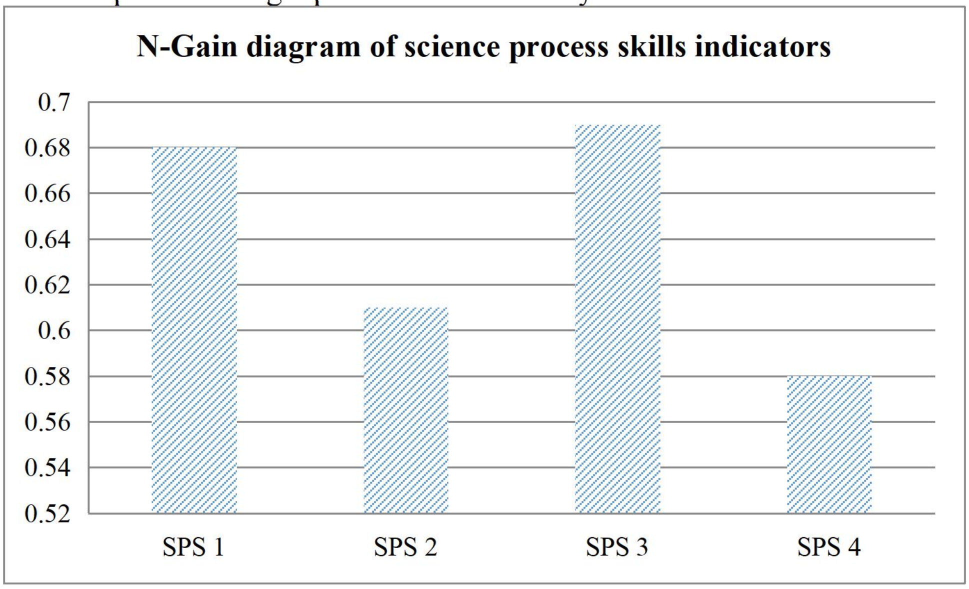

Figure 2. N-Gain Diagram of Science Process Skills Indicators

Based on the research results, the N-Gain values for the indicators of formulating problems (SPS 1) and determining variables (SPS 3) show that students have better abilities compared to the N-Gain values for the indicators of making hypotheses (SPS 2) and presenting results (SPS 4). Students were able to formulate problems and determine variables correctly according to the given concepts and data.

The indicator for formulating problems obtained an N-Gain value of 0.68 with a medium category. This shows that students have sufficient ability to identify relevant problems. The teacher plays a role in guiding students to find problems and then develop or express knowledge and information from demonstrations obtained through the process of recording or communicating with others. Through demonstrations, students can be active in the learning process by observing, understanding, and helping students answer their learning needs from clear factual events and data, thus increasing students' conceptual understanding (Wahyudi & Dinata, 2013; Trisni & Fauza, 2024).

The indicator for making hypotheses obtained an N-Gain value of 0.61 with a medium category. The teacher has provided direction to students in formulating hypotheses and identifying relationships of known information. However, in the learning process, students experienced some difficulty in making hypotheses, students lacked understanding of concepts, given data or information, and were not successful in connecting concepts with problems, thus requiring more practice in formulating hypotheses. According to constructivism theory, learning is not just passive reception of information, but a dynamic process where students actively build their own understanding by connecting new and old knowledge, and seeking meaning and relationships between concepts in the process (Bada & Olusegun, 2015; Alt, 2018; Suparlan, 2019).

The indicator for determining variables obtained an N-Gain value of 0.69 with a medium category. This shows that students were able to determine variables that fit the given data and problems. Students determined variables collaboratively among group members, then together analyzed and structured research based on the established variables to achieve the desired goals. Constructivism creates a learning environment that supports students to explore, experiment, and share findings by collaborating, so that the learning process not only focuses on knowledge transfer but also on building understanding through practical experience and exchange of ideas in a social context (Krahenbuhl, 2016; Harefa et al., 2024).

The indicator for presenting results obtained an N-Gain value of 0.58 with a medium category. This value indicates that students still have difficulty in presenting results that are consistent with the obtained data. This occurs because in the learning process, students lack understanding of the concepts underlying experiments or observations and lack understanding in presenting conclusions. Students often experience difficulties in writing effective scientific conclusions, caused by a lack of conceptual understanding, difficulty in connecting data with objectives, as well as limitations in understanding the structure of scientific arguments and connecting evidence with claims (Ruiz-Primo et al., 2010; Gonzalez-Howard & McNeill, 2020; Yunita & Nurita, 2021).

These findings indicate that the development of inquiry-based e-Worksheet has great potential for application in physics education to train students' science process skills. However, teachers need to provide more intensive guidance, particularly in the areas of hypothesis formulation and result presentation, while also considering students' readiness and characteristics. The implementation of e- Worksheet should also be adjusted to the time and facilities available at the school.

The educational implications of these results highlight the need for teacher training in developing and implementing inquiry-based e- Worksheet, as well as strengthening process-based science learning in the classroom. Additionally, the development of valid and reliable evaluation instruments is crucial to ensure the achievement of learning objectives.

CONCLUSION

The inquiry-based e-Worksheet to train science process skills is very valid, very practical, and effective for use in the learning process. This is based on the average value obtained from the three validators of 90.18%, indicating that the developed inquiry-based e-Worksheet is considered very valid. Then the average value obtained in the readability test was 85.2%, the average value obtained in the student response test was 82.75%, and the average value obtained in the teacher perception test was 90%. All averages obtained fall into the very practical category. Furthermore, it can be seen from the test results where the difference in the posttest average is greater than the pretest, the N-Gain value is classified as medium, and the average score of student learning outcomes after being treated using inquiry-based e-Worksheet shows a significant increase. This is due to the fact that the time available to implement the inquiry-based learning model may not be sufficient to provide all students with a deep understanding. Therefore, it is recommended that future research be conducted with adequate time, so that students can better understand and apply the concepts taught. From these results, it can be concluded that the inquiry-based e-Worksheet using spectrophotometer practicum equipment to train science process skills is suitable for use as teaching material in the learning process.

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