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Development of Guided Inquiry-based E-Worksheet to Stimulate Science Process Skills on Light Diffraction Materials

Meita Puteri Handayani[1], Kartini Herlina[2*], Agus Suyatna[2], Kamila Munna[3], Sparisoma Viridi[3]

[1] Department of Physics Teaching, Institut Teknologi Bandung, Bandung, Indonesia
[2] Department of Physics Education, Universitas Lampung, Lampung, Indonesia
[3] Department of Physics, Institut Teknologi Bandung, Bandung, Indonesia

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ABSTRACT

Understanding light diffraction requires higher-order thinking and the ability to apply science process skills. Therefore, this study aims to develop a guided inquiry-based e-worksheet that is valid, practical, and effective to stimulate science process skills in Light Diffraction materials. The study uses the Design and Development Research (DDR) approach, which consists of four stages: analysis, design, development, and evaluation. The data analysis uses a validity test assessed by three experts, a practicality test conducted by students and teachers, and an effectiveness test as measured by the N-Gain test. The validity test results obtained an average value of 3.54, which is "very valid" category. The e-worksheet's design and content correspond to the science process skill: formulating problems, formulating hypotheses, conducting experiments, drawing conclusions, and discussing. The practicality test produced an average student response result of 86% and an average teacher perception result of 88%, both of which are classified as "very practical." The effectiveness test produced an N-Gain value of 0.71 in the experimental class, which is classified as high and increased compared to the control class's value of 0.49, which is classified as moderate. Hence, an e-worksheet based on guided inquiry has been produced to stimulate valid, practical, and effective science process skills. The results contribute to the theoretical understanding of guided inquiry-based learning and provide practical guidance for teachers in implementing digital inquiry activities on light diffraction.

Keyword: E-Worksheet, Guided Inquiry, Light Diffraction, Science Process Skill

INTRODUCTION

Technological development, especially in the industry 4.0 era, has had a transformative impact on various aspects of life, including education. The adaptation of education to this era is known as 21st-century learning, which presents its own challenges. In this context, mastery of 21st-century skills is essential for students to prepare them to face future workplace challenges. These skills, including critical thinking, collaboration, communication, and creativity, can be effectively developed through science processes (Herlinawati et al., 2024; Widestra & Yulkifli, 2021).

Science process skills are the abilities needed to carry out learning activities related to scientific practice. In these activities, students experience, discover, and connect the results of

***Correspondence:**
Kartini Herlina, Department of Physics Education, Universitas Lampung, Lampung, Indonesia
✉ email: kartini.herlina@fkip.unila.ac.id

experiments with existing theories for themselves (Kurniahtunnisa et al., 2024). These skills involve activities that emphasize scientific processes, such as building science literacy and critical thinking, conducting experiments, analyzing data, and drawing conclusions. These activities encourage a deep understanding, enabling students to produce facts, concepts, theories, principles, and laws (Bau et al., 2024; Darmaji et al., 2022).

The demand to improve students' science process skills directs educators to consider how to apply them in the learning process. Science process skills can be developed through direct investigation activities. However, in physics education, such activities have not been implemented due to limited time and resources for conducting experiments (Putriyana et al., 2020). This condition makes it difficult for students to connect theory with practical scientific processes.

Learning physics involves studying natural phenomena and events that occur in everyday life, which help students develop critical thinking skills for solving various problems (Suryadi et al., 2022). However, several studies have revealed that high school students often struggle to understand physics topics, especially those who had not yet learned how to apply knowledge to new situations and real life. One of these topics was optics (Rizaldi & Fatimah, 2024). One of the reasons students have difficulty understanding physical optics topics, such as Light Diffraction, is that the material involves non-intuitive concepts. This means it is not easy to visualize or understand based on everyday experience. Additionally, the mathematical concepts and equations involved in this material can be a barrier for some students (Matejak Cvenic et al., 2023; Planinic et al., 2024). These challenges indicate the need for learning designs that help students build conceptual understanding through investigation and active engagement rather than passive reception.

Not only student but also teachers face difficulties in presenting light diffraction material effectively due to the lack of adequate learning resources (Wijaya et al., 2022). So far, the teaching of optical materials in schools still predominantly delivered in a conventional manner, such as through lectures, whiteboards, and PowerPoint presentations. These methods tend to emphasizes the delivery concepts while ignoring experimental and problem-solving activities. Direct observation activities, such as practicums, are rarely carried out (Kasanah & Kusumawati, 2022; Muhamad, 2024). Even when practical work is conducted, it still tends to use ordinary experimental procedures that resemble following a cooking recipe. This demonstrates that the science process skills of prediction, experimentation, drawing conclusions from observations and data, and discussion with peers has not been emphasized in practical activities (Wahyudi & Lestari, 2019).

Various learning models have been implemented to enhance students' science process skills, including problem solving, guided inquiry, project-based learning, and discovery learning. The problem-solving model encourages creativity through planning, exploring multiple solutions, and evaluating alternatives, fostering fluency, flexibility, and novelty of thinking. Similarly, project-based learning engages students in collaborative research to design innovative products and develop creative ideas through teamwork and real-world problem contexts. Discovery learning, meanwhile, promotes creativity by allowing students to construct knowledge independently through exploration and manipulation of their environment. However, because this approach provides minimal teacher guidance, students may struggle when dealing with abstract or mathematically complex topics. In contrast, guided inquiry learning combines the strengths of these models by maintaining student autonomy while still providing structured teacher support. Through questioning, hypothesizing, investigating, and constructing explanations, guided inquiry helps students engage deeply in scientific reasoning while preventing cognitive overload. Therefore, guided inquiry is considered more effective in developing science process skills because it ensures both active student participation and conceptual scaffolding throughout the learning process (Sasmita & Kusuma, 2023; Siahaan et al., 2021).

In guided inquiry learning, teachers act as facilitators by providing phenomena and guiding questions that help students actively construct their understanding. Students become more active and enthusiastic about developing their thinking, and the teacher directs them toward the learning topic. Teachers also instruct students on the experimental process and help develop their self-confidence (Sulistyani et al., 2022). The application of guided inquiry learning is a relevant method for collecting information and applying logical analysis to various phenomena through guided questions, enabling students to solve problems based on the facts they discover (Sari et al., 2023). Therefore, guided inquiry is pedagogically aligned with the development of 21st-century competencies and science process skills.

To support guided inquiry implementation for enhancing science skill process, digital learning media such as electronic student worksheet (we called *Lembar Kerja Peserta Didik digital,* e-LKPD, or e-worksheet) can be used. e-LKPDs are worksheets that make it easier for students to conduct learning activities interactively through devices such as computer, laptop, or smartphone (Putriyana et al., 2020). Using e-worksheet makes students more active participants in their learning because they become both objects and subjects of learning, allowing them to discover the concepts for themselves (Nestiadi et al., 2024).

Several studies have developed e-worksheets in physics learning, including a project-based e-worksheet on Light Interference by Febriansyah et al. (2021) and an inquiry-based e-worksheet on the Solar System by Erni et al., 2024. However, these studies generally focused on only two aspects of development—validity and practicality—without comprehensively assessing all three (validity, practicality, and effectiveness) in a single guided inquiry-based design. Furthermore, to date, there has been no research reporting the development of a guided inquiry-based e-worksheet specifically designed for Light Diffraction materials, nor one integrated into Heyzine interactive media that includes everyday phenomena, animations, interactive exercises, and digital practicum simulations.

The novelty of this research lies not only in the integration of guided inquiry stages into digital learning media (e-worksheet) in specific application to the Light Diffraction topic, but also in the pedagogical integration. Pedagogically, it demonstrates how digital interactivity can scaffold students' inquiry processes. Conceptually, it extends inquiry-based digital learning to a complex and abstract physics topic that has rarely been addressed through interactive worksheets. Theoretically, this study enriches the understanding of how guided inquiry principles can be embedded within digital learning environments to stimulate science process skills. Practically, it provides teachers with a validated and effective model of e-worksheet design that can be adapted to similar physics topics in the 21st-century learning context.

Therefore, this study aims to develop a guided inquiry-based e-worksheet on Light Diffraction that is valid, practical, and effective in stimulating students' science process skills. The e-worksheet is designed to integrate the stages of inquiry into interactive digital learning and is evaluated through expert validation, user practicality assessment, and effectiveness testing. This research adopts the Design and Development Research (DDR) approach, consisting of the stages of analysis, design, development, and evaluation.

METHOD

Research Design

Development of a Guided Inquiry-Based E-Worksheet to Stimulate Science Process Skills on Light Diffraction Materials. This research procedure for product development uses the Design and Development Research (DDR) approach adapted from Richey & Klein (2014). The DDR approach consists of four stages: analysis, design, development, and evaluation. Figure 1 presents the flow diagram of this research.

The analysis phase involves analyzing needs and identifying available products to determine the purpose of developing these products. A needs analysis was carried out by administering questionnaires to physics teachers in several high schools in the Lampung province regarding light diffraction. The purpose of the needs analysis is to determine potential issues in schools. The information obtained from the needs analysis serves as the basis for researchers to conduct their studies.

The design stage is the second stage of the product development process. It requires conceptualizing the product based on previous analyses and projected results. The researcher will design a product plan for 12th grade high school student, namely an e-worksheet that stimulates science process skills. This e-worksheet is adjusted to the guided inquiry stages integrated with science process skills. The results are uploaded to the Heyzine website, allowing anyone to access them anytime, anywhere.

The development of the e-worksheet product commenced based on the researcher's established design. Subsequently, a comprehensive validity test was conducted to ascertain the product's appropriateness as instructional material. This validation process engaged a team of material experts to evaluate the e-worksheet's content indicators, particularly for the Light Diffraction module, and a team of design experts to assess the overall e-worksheet series. Once validated, the product proceeded to practicality, readability, and teacher perception assessments. The practicality test aimed to gather physics teachers' perceptions of the developed product, implemented within authentic learning environments with Class XI students. Following confirmed validity and practicality, an effectiveness test was administered. This involved deploying pretest and posttest instruments to Class XI students from a public high school in Lampung. Effectiveness was determined through the analysis of students' cognitive understanding, specifically by quantifying the improvement in learning outcomes from the pretest to the posttest, utilizing tailored e-worksheet evaluation questions.

Evaluation constitutes the final stage of this process, initiated following the completion of the analysis, design, and development phases. The outcomes derived from the evaluation serve as vital feedback for product revision or enhancement. Consequently, these stages allow for a definitive conclusion regarding the e-worksheet's validity, practicality, and effectiveness.

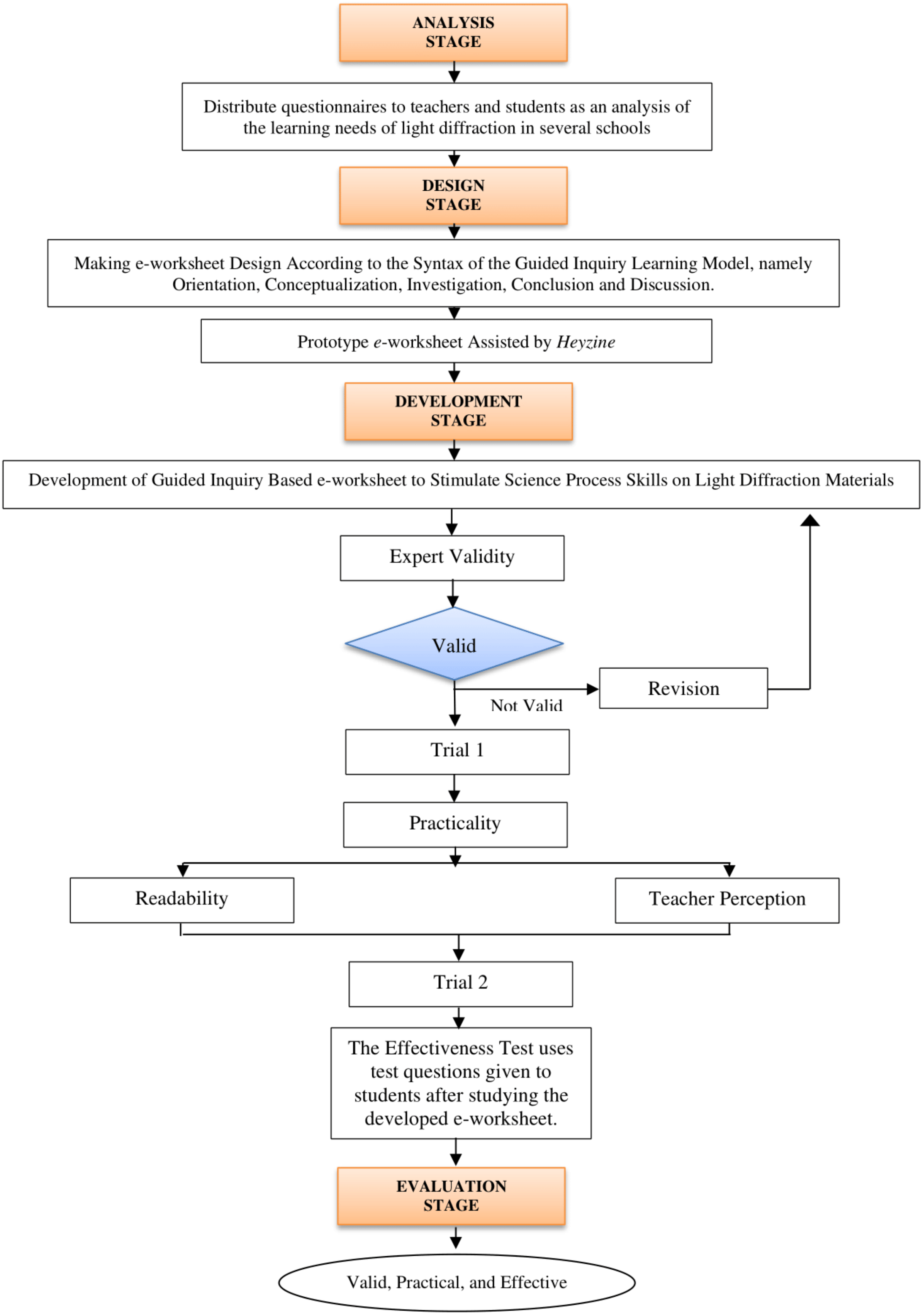

Figure 1. Research Flowchart.

Participants

This study involved 1 teacher and 34 Grade XII students from a public high school in Lampung. The study was conducted over a period of 2 weeks. The research sampling method used was *a quasi-experimental method* with *a pretest-posttest control group design*, using two classes, namely an experimental class and a control class (Fraenkel *et al*., 2012). The students were asked to complete a questionnaire at the beginning of the study and follow the instructions on the e-worksheet, which was guided by the teacher. The objective of this study is to improve students' cognitive understanding and science process skills regarding Light Diffraction materials.

Instruments

The research instruments used in this study were questionnaires and pretest and posttest questions which were arranged according to science process skills indicators in Table 1.

Table 1. Science Process Skills Indicators

Science Process Skills Indicators	Score	Explanation
Formulating problems	4	Able to explain predictions according to the well-presented experiment table
	3	Able to explain predictions but not quite in line with the experimental table that has been presented
	2	Less able to explain predictions but less consistent with the experimental table that has been presented
	1	Inaccurate in explaining predictions and inconsistent with the experimental table provided.
	0	Did not provide an answer
Formulating a hypothesis	4	Able to formulate problems based on well-made predictions
	3	Able to formulate a problem statement but it is not in line with the predictions that have been made
	2	Less able to formulate problems and less in line with the predictions that have been made
	1	Unable to formulate problems and inconsistent with predictions made by
	0	Does not provide an answer
Defining variables	4	Able to correctly determine the three variables
	3	Able to correctly determine the two variables
	2	Able to determine one variable correctly
	1	Poor at determining variables
	0	Did not provide an answer
Hypothesis testing	4	Able to test hypotheses based on precisely formulated problems

	3	Able to test hypotheses accurately but not in accordance with the problem formulation that has been made
	2	Able to test hypotheses but less accurately and less relevant to the variables
	1	Inadequate in testing hypotheses and insufficiently aligned with the problem statement
	0	Does not provide an answer
Presents data	4	Able to present data accurately according to the variables found
	3	Able to present data accurately but less in accordance with the variables found
	2	Able to present data but less accurately and less in accordance with the variables found
	1	Inadequate in presenting data and insufficiently aligned with the identified variables
	0	Does not provide an answer
Presents results	4	Able to explain conclusions accurately along with appropriate reasons
	3	Able to explain conclusions accurately but the reasons given are not quite appropriate
	2	Able to explain conclusions accurately, but the reasons given are less appropriate
	1	Unable to explain the conclusion and the reasons given are not appropriate.
	0	Did not provide an answer

The questionnaire used in this study was in the form of a list of questions given to respondents to obtain information from respondents regarding a problem. The data in this study were obtained using questionnaires in the form of questionnaires analyzing the needs of teachers and students, validity test questionnaires, practicality test questionnaires and instrument pretest and posttest questions. The results of the validity test were obtained by conducting a validation test which was seen from two aspects, namely media and design as well as material and constructs which were carried out by three experts. Examples of items on the validation instrument include several key assessments, such as assessing whether the light diffraction material presented is accurate and in accordance with the Basic Competencies, whether the steps of the inquiry activity are logical and syntactically correct (orientation, conceptualization, investigation, conclusion, and discussion). Validators also assess the readability of the language, the clarity of the work instructions, and the suitability of physics terms to the students' level of understanding. In terms of appearance, validators assess the neatness of the layout, the readability of the font size, and the quality of the images or illustrations used to aid conceptual understanding. These items provide a comprehensive overview of the suitability of the content, construction, language, and appearance of the e-LKPD that has been developed. While the practicality test is seen from 3 aspects, namely the readability test and the teacher's perception test.

Data Analyis

The data analysis techniques consist of validity test sheets and practicality test questionnaires. The assessment for the validity and practicality tests uses a Likert scale adapted from Devi et al. (2023) dan Fadilah et al. (2023), as seen in Tables 2 and 3. The developed product is considered valid and practical if it has an interval score of 2.50 < score < 3.25 on the assessment results, which is in the vulnerable range. Practically, it is in the 40.1%–60% range, with moderate/less practical.

Table 2. Likert Scale in the Validation Test.

Score Intervals	Criteria
3.25< score <4.00	Very Valid
2.50< score <3.25	Valid
1.75< score <2.50	Less Valid
1.00< score <1.75	Not Valid

Table 3. Likert Scale in Practicality Test.

Percentage	Criteria
0,0%–20%	Very low/very impractical
20,1%–40%	Low/impractical
40,1%–60%	Moderate/less practical
60,1%–80%	High/practical
80,1%–100%	Very high/very practical

The data used to determine the product's effectiveness is quantitative. The effectiveness test was conducted twice, before and after, and then analyzed using the N-Gain test. In addition, the effectiveness analysis was reinforced with inferential statistical tests to determine the significance of the differences in learning outcomes before and after treatment. A normality test is first conducted to determine the distribution of data. If the data is normally distributed, a paired sample t-test is used; however, if the data is not normally distributed, the Wilcoxon Signed Rank Test is used as an alternative. The use of this inferential test is necessary to ensure that the increase seen in the N-Gain value is not merely a random change, but a statistically significant increase. It measures the amount of improvement achieved by a student or group of students between the two assessments and normalizes it against the total possible improvement (Sukarelawan et al., 2024). The N-Gain value determines the magnitude and category of improvement in students' science process skills.

Table 4. N-Gain Interpretation Criteria (Anisa & Astriani, 2022).

N-Gain Value	Criteria
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Medium
$g < 0.30$	Low

RESULTS AND DISCUSSION

Results

This developmental research produced an e-worksheet based on guided inquiry to stimulate science process skills in 12th grade students from a public high school in Lampung. The research was conducted in four stages: need analysis, design, development, and evaluation.

Need Analysis

Based on the results of the learning needs analysis questionnaire distributed to high school teachers, the Light Diffraction material is generally only delivered through lecture and discussion methods. Only a few schools use worksheets to assist with implementation. However, the available worksheets do not yet include interactive images, animations, or practice questions. Consequently, learning has not been very effective, nor has it emphasized science process skills. These results provide a foundation for researchers to develop a Light Diffraction e-worksheet based on guided inquiry to stimulate students' science process skills.

Design Stage

The e-worksheet design is based on the guided inquiry learning model, which triggers students' science process skills. The worksheet has three parts. The first part includes the cover, foreword, table of contents, instructions for use, core competencies, basic competencies, indicators, and learning objectives. The second section contains learning activities, including five guided inquiry activities: orientation, conceptualization, investigation, conclusion, and discussion (Pedaste et al., 2015). The final section contains practice questions and a bibliography. Results of the e-worksheet design are uploaded to the Heyzine website for easy access. The e-worksheet can be accessed via the following link: https://heyzine.com/flip-book/5da1e6638d.html#.

Figure 2. E-Worksheet on the Heyzine Website

Figure 2. E-Worksheet on the Heyzine Website (continued)

Development Stage

There are three types of testing at the development stage: validation, practicality, and effectiveness. The validation test results shown in Table 5 reveal an average score of 3.54, indicating qualitative validity. These results demonstrate the validity of the e-worksheet's material, construct, media, and design.

Table 5. The Average Results of Validity Test Scores by Experts.

Aspect		Validators			Average Score	Category
		Expert 1	Expert 2	Expert 3		
Media and Design Validation	Cover Section	3,66	4,00	3,44	3,70	Very Valid
	Contents Section	3,70	3,60	3,50	3,60	Very Valid
Material and Construct Validation	Suitability of Material	3,23	3,64	3,47	3,44	Very Valid
	Construction	3,57	3,42	3,28	3,42	Very Valid
Total		3,54	3,66	3,42		Very Valid
Overall Average					**3,54**	**Very Valid**

The practicality test consists of a student readability test and a teacher perception test in the form of a questionnaire. The readability test was administered to 34 12nd grade students from a public high school in Lampung who had worked with the developed e-worksheet. The purpose of this test was to determine users' responses, suggestions, and input regarding the e-worksheet's readability. The results of the readability test are presented in Table 6. The resulting e-worksheet received an average score of 86%, which is classified as "very practical." The teacher perception test was administered to ten high school physics teachers from ten different schools in Lampung Province. This test was conducted to determine if the developed product could be implemented in the classroom learning process. The teacher perception test results showed an average score of 88%, which is also classified as "very good," as shown in Table 7. Thus, the practicality test shows that the e-worksheet is very practical.

Table 6. Results of the Readability Test on Students.

Questions	Σ per question	Maximum Score	Percen-tage	Category
The guided inquiry-based e-worksheet is structured systematically and sequentially, making it easy to understand.	123	136	90%	Very Practical
The spacing, type, and size of the letters in the e-worksheet are suitable and comfortable to read.	115	136	84%	Very Practical
The layout of e-worksheet is good and ideal, making it easy to read the sequence of materials.	112	136	82%	Very Practical
The language used in the e-worksheet is easy to understand.	124	136	91%	Very Practical
The features in the quided inquiry-based e-worksheet are easy to operate and understand.	111	136	82%	Very Practical
The commands or questions in the e-worksheet are clear and easy to understand.	110	136	96%	Very Practical
The steps in the guided inquiry-based e-worksheet are easy to understand.	120	136	88%	Very Practical
The guided inquiry-based e-worksheet is equipped with pictures, videos, and illustrations, which help me understand the material.	116	136	85%	Very Practical
The phenomena presented in the e-worksheet are easy to understand.	117	136	86%	Very Practical
The learning activities in the guided inquiry-based e-worksheet are concise and easy to understand.	113	136	83%	Very Practical
The pictures, illustrations, and videos in the guided inquiry-based e-worksheet can be clearly observed.	117	136	86%	Very Practical
Total	1299	1496	86%	Very Practical

Table 7. Results of the Teachers' Perception Test.

Learning Steps	Σ per Step	Maximum Score	Percentage	Category
Orientation	34	40	85%	Very Good
Conceptualitation	108	120	90%	Very Good
Investigation	104	120	86%	Very Good
Conclution	72	80	90%	Very Good
Discussion	73	80	91%	Very Good
Total Score	**391**	**440**		
Average Score			**88%**	**Very Good**

Table 8. Average Practicality Test Score of e-Worksheet.

Aspects	Average Score	Category
Readability	86%	Very Practical
Teachers' Perception	88%	Very Good
Average	**87%**	**Very Practical**

As for the effectiveness of the guided inquiry-based e-worksheet in stimulating science process skills in light diffraction learning is determined by the N-Gain value of the pretest and posttest. The experimental class used a guided inquiry model with an e-worksheet for learning, while the control class used a conventional learning model. The question items on the pretest and posttest refer to the Science Process Skills indicators seen from the mapping of the average student learning outcomes in Table 9.

Table 9. Average Per-Indicator Score of Science Process Skills.

Indicator	Class	Average (%)	
		Pretest	Posttest
Formulate a Problem	Experiment	42.02	75.03
	Control	45.53	76.79
Make a Hypothesis	Experiment	35.24	86.19
	Control	32.68	66.91
Determining Variables	Experiment	25.58	74.29
	Control	25.92	53.06
Hypothesis Testing	Experiment	22.91	73.62
	Control	21.56	58.43
Presenting Data	Experiment	39.67	90.43
	Control	38.14	70.89
Presenting Results	Experiment	33.45	82.16
	Control	26.87	72.12
Avarage	Experiment	**33.14**	**80.29**
	Control	**31.78**	**66.37**

Table 9 shows that indicators that have increased with high categories are in the indicators of making hypotheses, presenting data and presenting results in the experimental class. Based on this data, it is known that the average value of the KPS activity of the experimental class is 80.29. This shows that the KPS activity in physics learning based on Guided Inquiry is as expected.

The average N-Gain value in the experimental class was classified as high, while in the control class it was classified as medium, as presented in Table 10 and Figure 3.

Table 10. The Result of Effectiveness Test.

Class	Gain Score			
	Upper N-Gain	Lower N-Gain	N-Gain Average	Category
Experiment	0,94	0,44	0,71	High
Control	0,66	0,32	0,49	Medium

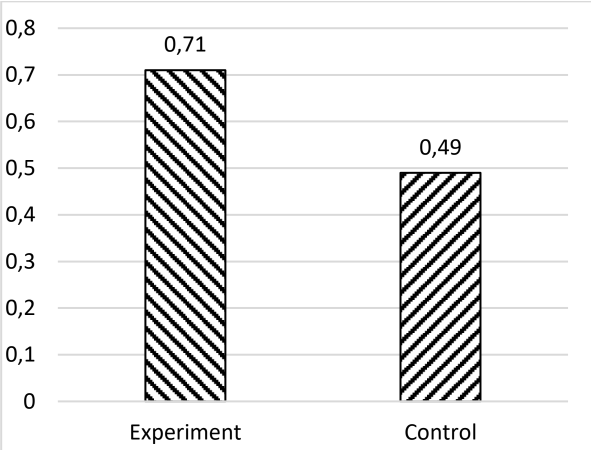

Figure 3. Graph of Average N-Gain Results for Science Process Skills.

Evaluation Stage

At this stage, the researcher evaluates the results of the previous stage's tests. This study found that the guided inquiry-based e-worksheet compiled by the researcher and applied to students and teachers is valid, practical, and effective.

Discussion

Need Analysis

The preparation of e-worksheets begins with a needs analysis as preliminary research. The analysis revealed several significant challenges in learning Light Diffraction material at the high school level. According to the data obtained from teachers via questionnaires, the dominant learning methods are still limited to lectures, discussions, and demonstrations. Limited practical tools are the main obstacle hindering optimal concept delivery, so students need more time to understand the material. Although some teachers have used worksheets, these worksheets generally have not incorporated visual media, such as images, animations, or interactive practice questions. These types of media have the potential to increase learning effectiveness and train science process skills. Mastery of science process skills is not only useful in science learning but also for students' daily lives (Sholihah et al., 2020). Therefore, teachers must focus on teaching science skills in the form of facts, concepts, and theories through students' scientific investigations (Zeidan & Jayosi, 2015).

From the students' perspective, the results of the questionnaire showed that they were uncomfortable with the learning process. This discomfort was caused by difficulty understanding concepts and technical obstacles, such as time limitations and poor signal quality, especially during online learning. Limitations in interactive learning media and a lack of contextual practices linking material to everyday phenomena in worksheets also contributed to students' low mastery of science process skills and conceptual understanding.

These results align with those of previous studies by Wahyudi & Lestari (2019) and Muhamad (2024).

Based on the results of the needs analysis, a guided inquiry-based digital worksheet was created for the light diffraction material because e-worksheets are considered effective at increasing student motivation and interest in learning through flexibility and interactivity. The guided inquiry model was chosen because it encourages students to actively participate in the learning process through scientific stages. Additionally, images and experimental stages can help teachers deliver material and train students to think critically, communicate, and find knowledge systematically (Pratiwi & Margunayasa, 2022).

Quality of e-Worksheet Development

Before applying the e-worksheet to students, a validation test was conducted with three experts. The results of the expert validation were then used to revise and improve the e-worksheet and other supporting materials (Yunus et al., 2022). The validation test, which consisted of aspects of material and construction, as well as media and design, showed an average score of 3.54 (with a maximum score of 4.00), indicating qualitative validity, as presented in Table 5. Therefore, the Light Diffraction e-worksheet can be used with students.

In addition to the validity test, a practicality test was conducted with the main actors who implement e-worksheets: teachers and students. Teaching materials are considered practical if they are easy to apply and understand, suitable for use, and efficient in terms of time and usability (Ferdian et al., 2025). According to the readability test for students in Table 6, the average practicality score of the e-worksheets is 86%. This indicates that the developed e-worksheets are highly readable for students. Meanwhile, the teacher perception test results in Table 7. show that the average e-worksheet score is 88%, which is classified as very good. These results demonstrate the feasibility of implementing every step of the guided inquiry learning model through the Light Diffraction e-worksheet in the learning process. The e-worksheet contains text, images, and illustrations that convey information to students in an interesting and effective way, transforming learning from an isolated, teacher-centered, text-focused approach to a more interactive, student-centered one.

The quality of the e-worksheets is determined by the results of the effectiveness test. The effectiveness of guided inquiry-based e-worksheets in stimulating science process skills in light diffraction learning is evident in the N-gain results. Table 9 and Figure 3 demonstrate that the learning process in the experimental class, which used guided inquiry-based e-worksheets, was more effective than that in the control class, which used conventional worksheets. After receiving treatment with guided inquiry-based e-worksheets, the experimental class obtained an average N-gain value of 0.71, which is considered high. Meanwhile, the control class obtained an average N-gain value of 0.49 with a moderate category after being given treatment using conventional LKPD. It is evident that the science process skills of students in the experimental class are higher than those in the control class. These results demonstrate the effectiveness of guided inquiry-based e-worksheets in stimulating science process skills.

Consequently, the quality of the e-worksheet developed by the researcher is excellent. It has been proven that the e-worksheet is valid, practical, and effective for teaching Light Diffraction to high school students. Additionally, this e-worksheet is designed to stimulate science process skills in students.

Science Process Skills

The e-worksheet lists science process activities, such as formulating problems, making hypotheses, determining variables, testing hypotheses, and presenting data and results. As illustrated in Figure 4, indicators of science process skills are integrated with guided inquiry in the activities on the e-worksheet. These activities are designed to encourage students to actively find solutions to problems related to light diffraction.

The first stage of the e-worksheet is the orientation stage, which is related to the indicators of science process skills in formulating problems. During this stage, students are shown pictures related to Light Diffraction, such as laser light forming when passing through a narrow slit. Using images as visualizations in the learning process encourages students to think more broadly about what they see. This helps students describe and communicate their understanding inclusively, both individually and in groups (Farrar et al., 2024). Using images of light diffraction, students observe the phenomenon and formulate problems.

The second stage is conceptualization, which involves formulating a hypothesis. At this stage, students are guided in formulating temporary answers (hypotheses) to previously identified problems. These hypotheses are generated from observations of phenomena and in accordance with existing literature (Indawati et al., 2021). Students' ability to formulate hypotheses is assessed by their responses to questions on the provided e-worksheet.

In the third stage, the investigation stage, students learn to determine variables and test hypotheses, two science process skills. During this stage, students conduct direct light diffraction experiments, collect data, and analyze it based on the experimental design in the e-worksheet. Students determine the necessary tools and materials for the experiment. Then, they distinguish the experimental variables that are carried out. This is an advantage of guided inquiry learning, in which students become more active and contribute to building their own knowledge by answering questions they have formulated (Megawati, 2023). Students were enthusiastic about conducting the experiment. They reported obstacles and sought solutions to them. The investigation stage fosters active learning and builds understanding through experience.

After conducting experiments and collecting data, the learning process enters the fourth stage: drawing conclusions. Each group presents data as a form of science process skills in the form of a table as a result of the experiments that have been conducted. Most students have been able to present data well in this learning activity. They were able to do so because they followed the steps in the e-worksheet, understood the problem, and carried out the experimental procedure systematically. e-worksheet has features involving audio and visuals that can have a positive effect, so that students are expected to be more enthusiastic about participating in each stage of learning (Seçer et al., 2015). These data presentation skills include presenting the results of the experiment in a table with correct values, which makes it easier for students to draw conclusions in the next stage. Then, the conclusions from the results of the experiment are compared with the hypothesis that the students made in the second stage. Based on the experiments conducted, most students can draw conclusions from their experimental data. Students make conclusions based on experiments that have been completed in accordance with the objectives, but they are less precise.

The next stage is a discussion related to science process skills, specifically presenting and communicating results. Students carry out reflective activities by presenting their experimental results and communicating the knowledge they have gained to others. Students are not only given the opportunity to convey information, but also to respond and ask questions about the results of the group presentation. In other words, they are given the opportunity to discuss with each other. Discussions allow for the exchange of logical ideas and arguments between group members and provide a medium for comparing observations and understanding among students (Shalihin et al., 2019). This activity stimulates and develops students' critical thinking and problem-solving skills in the learning process.

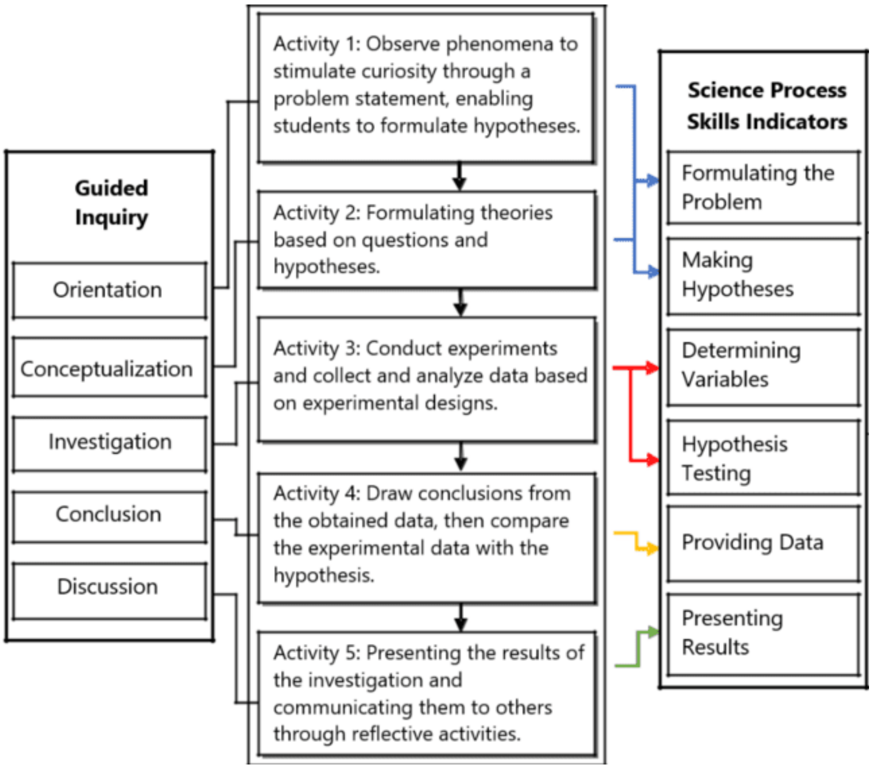

Figure 4. Integration of Guided Inquiry Activities in the e-Worksheet with Science Process Skills Indicators.

The learning carried out is that the experimental class with guided inquiry-based e-LKPD is more effective than the control class using conventional LKPD. In the experimental class, after being given treatment using guided inquiry-based e-LKPD, the average N-gain was 0.71 with a high category, while the N-gain in the control class after applying the treatment using conventional LKPD obtained an average N-gain value of 0.49 with a medium category. It can be seen that the science process skills of experimental class students are higher than the control class. The high gain is due to the fact that during learning using e-LKPD based on Guided Inquiry, students are actively involved in experimental activities and can think more concretely because the higher the involvement of students in experimental activities, the higher the achievement of students' understanding, skills and learning experience.

Based on observations and tests, the guided inquiry Light Diffraction e-worksheet effectively stimulates students' science process skills. The e-worksheet emphasizes guided inquiry learning, which involves students directly in the learning process to optimize their science process skills. This is supported theoretically, as guided inquiry allows students to construct knowledge through the stages of prediction–observation–explanation, making it more effective in overcoming misconceptions about wave optics (Planinic et al., 2024). In addition, the use of digital media such as Heyzine helps connect observational experiences with visual representations so that students can understand the relationship between theory, experiments, and observation results (Widestra & Yulkifli, 2021). Therefore, the effectiveness of e-LKPD does not only come from the learning model used, but also from the integration of science process skills and interactive media that enrich students' learning experiences. Scientific process skills are necessary tools for learning and understanding physics concepts. Not only scientists, but individuals must also possess scientific process skills to solve problems encountered in everyday life (Aktamis, 2010).

Although this study shows that guided inquiry-based e-worksheet is effective in improving science process skills in the subject of Light Diffraction, the interpretation of the results must take into account several limitations. First, the study was conducted on a relatively small sample and only involved one school, so the findings cannot be generalized to a wider population with different characteristics. Second, the implementation of e-worksheet took place over a short period of time, so that the measurable improvement reflects more of a short-term impact and does not yet describe the sustainability of students' understanding or retention of concepts. In addition, the use of the Heyzine platform requires a stable internet connection, so there is a possibility of technical disruptions that can affect the learning experience of students, especially in schools with limited digital infrastructure. This study also focused on cognitive aspects and science process skills without evaluating affective aspects such as motivation, scientific attitudes, and interest in learning, which actually play an important role in the success of inquiry-based learning. Considering these limitations, the results of this study still show a positive trend, but require further verification through research involving more diverse contexts, durations, and evaluation instruments.

CONCLUSION

The guided inquiry-based e-worksheet on light diffraction developed in this study has been proven to stimulate students' science process skills through a series of inquiry stages: orientation, conceptualization, investigation, conclusion drawing, and discussion. This development has resulted in a digital learning product that is in line with the theoretical principles of guided inquiry, particularly in encouraging students to engage in scientific reasoning, formulate hypotheses, conduct tests, and construct evidence-based conclusions.

Scientifically, this study makes an important contribution by showing that the integration of interactive digital tools in inquiry-based learning can improve students' understanding of abstract wave optics concepts. This finding reinforces previous theoretical studies that visual and interactive media can bridge the gap between conceptual models and experimental phenomena, thereby deepening conceptual mastery and science process skills. From a practical perspective, the developed e-worksheet provides an alternative solution for physics teachers, especially in schools with limited laboratory facilities. Its digital format allows for flexibility of use, facilitates independent learning, and provides a structured scientific workflow that simplifies the implementation of inquiry-based learning in line with curriculum requirements and 21st-century skills. For further research, it is recommended that the use of e-worksheet be tested on a larger sample from various educational units to improve the generalization of the results. Longer-term research is also needed to evaluate long-term retention and consistency in the development of students' science process skills. In addition, further studies can explore affective aspects such as learning motivation and scientific attitudes, as well as integrate new technologies such as advanced simulations, augmented reality, or virtual laboratories to enrich inquiry-based learning experiences on other physics topics.

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