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Development of Digital Student Worksheet Based on Process Differentiation with STEM-PjBL Approach on Light Wave Material

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ABSTRACT
The independent curriculum employs a differentiated approach to learning. The differentiation approach is employed to adjust the ability of students to comprehend the material. One model that can be applied is the PjBL model, which is integrated with STEM. Learners will engage in problem-solving activities in the context of physics education, utilizing technology as a tool. The integration of the model with the learning media employed is a harmonious process. Digital student worksheets represent a potential solution for the integration of the STEM-PjBL model. This research is a development research (RnD) project that employs the ADDIE development model. The development of digital student worksheets is comprised of three stages: analysis, design, and development. The analysis stage involves determining the characteristics of digital student worksheets. The design stage entails designing content for digital student worksheets. Finally, the development stage aims to obtain validation of feasibility and practicality from experts. The results of the validation of material and media experts indicate that digital student worksheet is suitable for use with revisions. The results of the practicality test of digital worksheets by teachers indicate that they are feasible, while the results of the test by students indicate that they are very feasible.

INTRODUCTION

The global pandemic of 2020 has precipitated a multitude of alterations in various aspects of life, necessitating a swift and comprehensive readjustment. Among the domains affected is the sphere of education, where the phenomenon of learning loss has led to a decline in the attainment of student competencies. In response to this challenge, the government has initiated the implementation of the Merdeka Curriculum. The Merdeka Curriculum is a program designed to restore learning. It encompasses three key characteristics: project-based learning, which develops soft skills and character in accordance with the Pancasila learner profile; learning essential material; and a more flexible curriculum structure [1].

The implementation of the Merdeka Curriculum places an emphasis on learner-centered learning, wherein the teacher is not the primary actor in the learning process. Instead, the teacher serves as a facilitator, employing a variety of approaches that are not monotonous and that engage students in a dynamic manner. The approach promoted by the Merdeka Curriculum is differentiation. Differentiation is a learning approach that adapts to the diverse levels of understanding of students. It entails competency-oriented learning, which necessitates the use of varied and periodic assessments [2]. The philosophy of differentiated learning is a methodology for addressing the diverse needs of learners. Teachers employ a range of pedagogical approaches to accommodate the varying abilities and preferences of their students. One strategy that has been shown to enhance learning outcomes is process differentiation. This refers to the manner in which teachers provide instructions to learners during instructional activities.

In the context of physics education, it is essential for teachers to provide instructions that align with the specific sub-chapter of material being studied. This is because physics learning encompasses both concrete and abstract concepts. One such abstract concept is that of waves, which must be understood by students. Based on recent research, it has been found that 60.6% of students consider light waves to be a challenging topic to grasp [3]. The majority of students encounter difficulty in comprehending the intricacies of light wave sub-materials due to the abundance of formulas and the dearth of supplementary instructional materials provided by educators. A novel learning model is therefore essential to ensure that students do not solely rely on formulas for understanding [4]. One pedagogical approach that can be employed to facilitate students' comprehension of light wave material and mitigate boredom is the implementation of the Project-Based Learning (PjBL) model.

Project-based learning is a learner-centered knowledge model that provides a meaningful learning experience for students. The project learning model facilitates understanding of the material by offering direct practice rather than merely imagining, thus enabling students to analyze problems, provide critical responses, and find solutions. This model also makes it easier for educators to provide learning experiences to students [5]. The application of the PjBL model to light waves can be enhanced by the incorporation of technology to facilitate the learning process. The PjBL model is most effective when combined with the Science, Technology, Engineering, and Mathematics (STEM) approach [6]. The integration of Project-Based Learning (PjBL) and STEM is a promising approach to enhance students' science process skills. PjBL is a learning model that employs a STEM approach, wherein students are tasked with solving problems based on scientific, technological, engineering, and mathematical principles.

A worksheet is a pedagogical instrument that can be employed by educators to enhance student engagement and activity within the learning process [7]. Teachers may provide students with worksheets on material that has been previously delivered, thereby facilitating a more active and student-centered learning process. Learners may work on student worksheets in accordance with the directions and instructions provided therein.

Based on this, a development research project will be conducted with the objective of producing digital student worksheets based on process differentiation with a STEM-PjBL approach to the subject of light waves. This is with the aim of determining the feasibility and practicality of digital student worksheets based on process differentiation with a STEM-PjBL approach to the subject of light waves.

METHOD

This research employs a type of research and development, a process utilized to develop and validate educational products. Research and development encompasses a multitude of models, with the ADDIE model representing a prominent example. The ADDIE model is a development model that can facilitate the creation of media, teaching materials, learning models, and learning strategies. This model is comprised of five stages, namely Analysis, Design, Development, Implementation, and Evaluation [8]. In this study, the ADDIE stages were only implemented until the development stage. Data collection methods included observation and questionnaires. Observation was employed to obtain information about the conditions in the field. Questionnaires in the form of validation and practicality questionnaires were used to determine the feasibility of student worksheets.

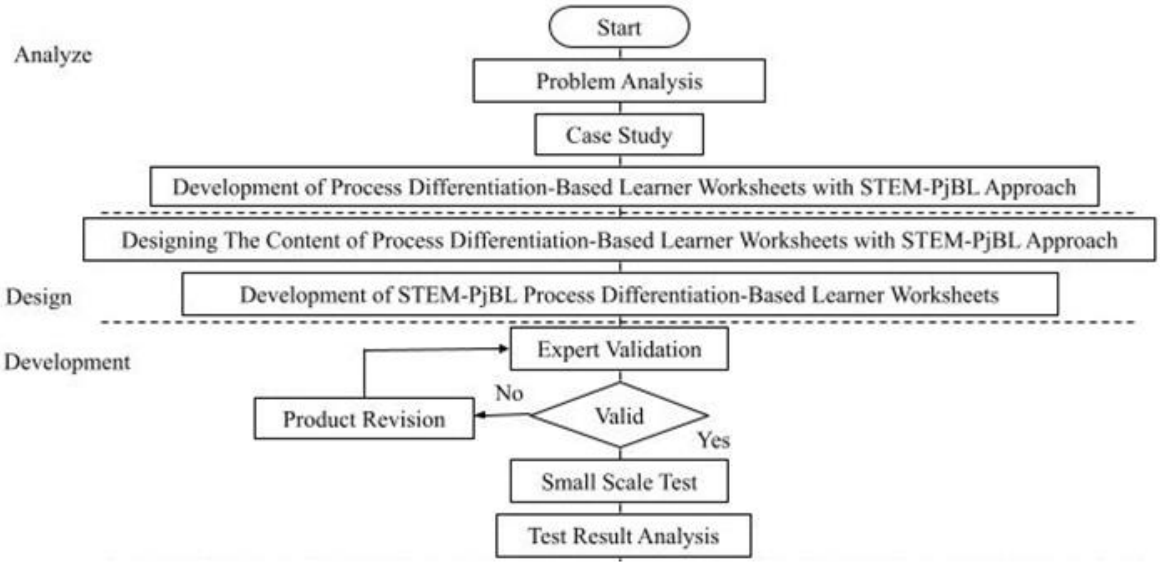

Fig 1. *Research Stages*

The results of the practicality test of digital student worksheets are calculated using the percentage formula, while the feasibility of digital student worksheets is calculated using the V-Aiken's formula. The equation and practicality criteria used are as follows [9].

$$NP = \frac{R}{SM} \times 100\% \quad (1)$$

Description:
NP : percentage value
R : number of assessment scores
SM : maximum score

Table 1. Practicality Criteria

Percentage range	Criteria
81% - 100%	Very Feasible
61% - 80%	Worth
41% - 60%	Decent Enough
21% - 40%	Less Feasible
0% - 20%	Not Worth it

The V-Aiken equation and the criteria employed are as follows [10].

$$V = \frac{\Sigma s}{[n(c-1)]} \quad (2)$$

Table 2. V-Aiken's Criteria

Value Range	Criteria
0,81 – 1,00	Very Valid
0,61 – 0,80	Valid
0,41 – 0,60	Moderately Valid
0,21 – 0,40	Less Valid
0,00 – 0,21	Not Valid

RESULTS AND DISCUSSIONS

The development of digital student worksheets is a process that begins with research and ends with the implementation of the final product. The process is divided into five stages: analysis, design, development, implementation, and evaluation. In the analysis stage, the characteristics of digital student worksheets are determined. This is done through a process of differentiation based on the STEM-PjBL approach. In the design stage, the design of the digital student worksheets is created. This is done with the goal of determining the feasibility and practicality of the digital student worksheets. The stages of developing digital student worksheets are as follows.

Analysis Stage

A literature search was conducted by entering keywords into Google Scholar. Articles were found based on the keywords entered into the search, including "digital student worksheets," "process differentiation," and "STEM-PjBL." The first search was conducted four times by entering the keyword "digital student worksheet," and 11,100 articles from 2020-2024 were obtained. The second search by entering the keyword "process differentiation" obtained 15,700 articles. The third search, conducted by entering the keyword "STEM-PjBL," yielded 17,200 articles. The fourth search, which involved entering all keywords into "process-differentiated digital student worksheets with a STEM-PjBL approach," returned two articles within the 2020-2024 range. The results of the search for articles that are most closely aligned with the research are used for comparison of the digital student worksheets developed. The initial article addresses the topic of differentiation in research, encompassing aspects such as process, content, and product. The differentiation of the process is achieved through the provision of distinct guiding questions, tailored to the predetermined learning readiness group. Additionally, differentiation of the process is accomplished through the implementation of variations in time allotted for learners to complete the student worksheet [11]. The second article presents an application of the STEM-PjBL model, assisted by e-student worksheet, with renewable energy as the material. The STEM-PjBL model, designed in the e-student worksheet, guides students in the construction of simple windmills for power generation. The e-student worksheet incorporates STEM aspects, which facilitate the organization of learner activities in the windmill project process [12].

The results of the literature search conducted through Google Scholar indicate that the primary characteristic of the digital student worksheet lies in its integration of the STEM-PjBL learning model with process differentiation. The STEM-PjBL model, comprising six distinct learning syntaxes, serves as the foundation for the activities within digital student worksheet. These activities are then combined with process differentiation through the formation of groups tasked with completing the aforementioned activities within the digital student worksheet.

Design Stage

The design stage involves the design and preparation of digital student worksheets. The design of digital student worksheets is adjusted to align with the level of class XI/phase F with light waves material. The digital student worksheet scheme comprises several sections, namely an introduction, content, and closing. The introduction section comprises a cover, table of contents, learning outcomes, and objectives. The content section comprises material and activities that will be carried out by students. The closing section contains conclusions and a cover. The framework of the digital student worksheet can be seen in Table 3.

Table 3. Framework of digital student worksheets-based process differentiation with STEM-PjBL

Content	Description	STEM-PjBL Learning Syntax
Cover	Contains the title of the student worksheet, Figure on light waves, identity column to be filled in by students, author's identity	
Table of Contents	Contains the table of contents of the student worksheet developed	Reflection Phase
Introduction	Contains instructions for conducting group discussions with 2 members and discussing learning videos about light wave events in life. The video contains several light wave events. At the bottom of the video will be given a google form link which will be the place to collect the first task.	
Light Wave Material	Contains literature materials for students in the form of written material descriptions and videos on the properties of light waves.	Research Phase
Problem Solving	Contains the problems of the properties of light waves that have been presented and instructions to conduct group discussions of 4 people to find solutions to problems. There is a blank column that will be used by students to template answers to questions that will be sent on google form.	Discovery Phase
Practicum Guide	Contains a practicum guide that will be carried out by students on the properties of light waves. The results of the practicum that have been carried out are used to fill in the columns available under the practicum guide. The blank column will guide students in collecting data during the practicum. Supporting questions will be presented under the data collection column.	Implementation Phase
Conclusion	Contains a conclusion column that will be filled in by students regarding the results of the practicum that has been carried out and will be presented with instructions for making infographics regarding the results of the practicum that has been carried out.	Evaluation Phase

The digital student worksheet scheme is created using a graphic design application, namely Canva, which is then converted into PDF form. Digital student worksheets that have been designed in accordance with references and literature are then surveyed to physics subject teachers in class XI/phase F to determine the suitability of the characteristics of digital student worksheets developed with learning in schools in terms of process differentiation and STEM-PjBL learning models. The survey was conducted online via a questionnaire that compared the digital student worksheets developed with those already available on the internet. The survey was conducted with three physics subject teachers of class XI/phase F. The survey results can be seen in Figures 2, 3, and 4.

Fig 2. *Survey result of process differentiation characteristics of digital student worksheet*

Fig 3. *Survey result of digital student worksheet with PjBL characteristics*

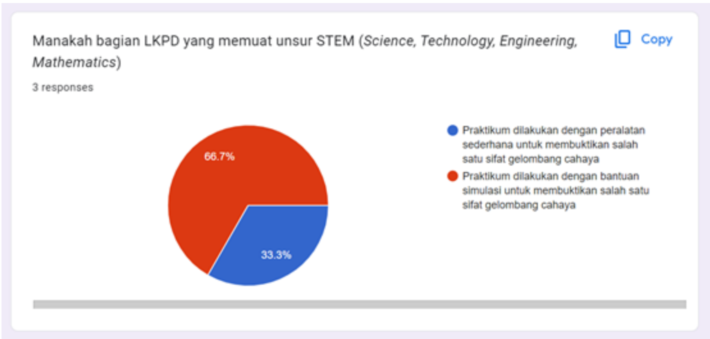

Fig 4. *Survey result of STEM characteristics of digital student worksheet*

The survey results indicate that the developed digital student worksheet schematic figures meet the requirements of the STEM-PjBL learning model and process differentiation. The schemes are then refined into digital student worksheet with references and literature related to the STEM-PjBL learning model and process differentiation. The digital student worksheet consists of several parts adapted to the syntax of the STEM-PjBL learning model.The material presented in the student worksheet is light waves, with the subject matter of the six properties of light waves, namely reflection, refraction, dispersion, diffraction, interference, and polarization, in accordance with the independent curriculum. The digital student worksheet section that has been prepared adapts to the characteristics of learning in high school as follows.

a. The reflection phase is evident in Activity 1 (concocting), wherein students are tasked with identifying and categorizing an event that aligns with the nature of light waves. This activity aligns with the reflection phase.

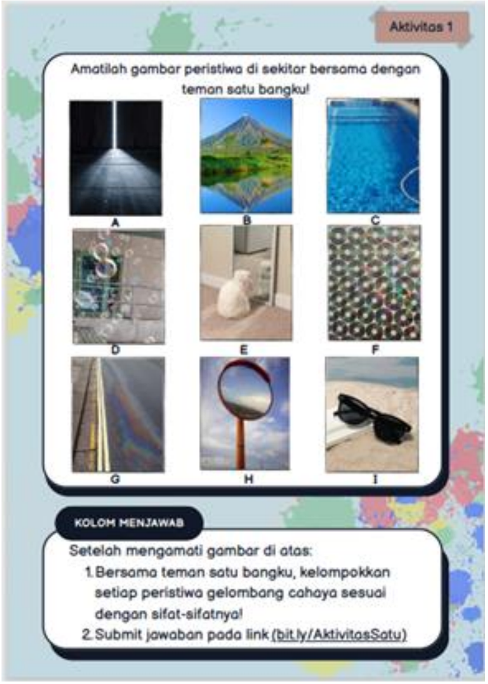

***Fig 5.** Activity page 1 on digital student worksheet*

b. The research phase encompasses a comprehensive examination of light wave material, encompassing six distinct properties of light waves. Each property will be accompanied by a detailed analysis, illustrated by figures and videos, to ensure that students have access to a diverse range of learning resources. In addition to the detailed description of the material on the nature of light waves, each sub-chapter will feature a practical video demonstration, accompanied by a detailed analysis of the results of the practical demonstration.

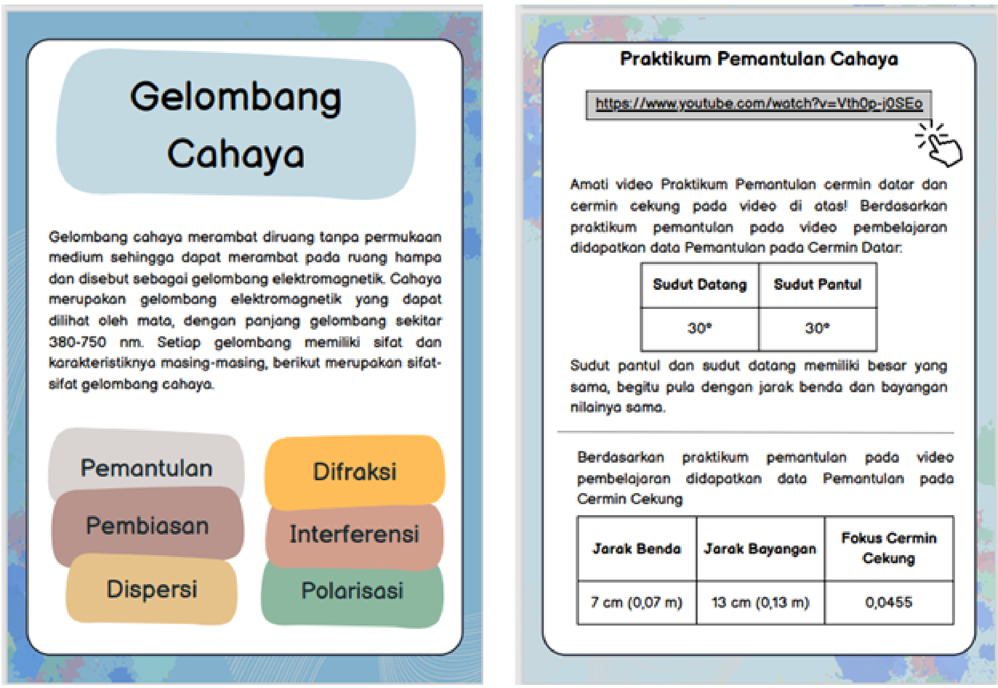

***Fig 6.** Light wave material page*

c. The discovery phase is situated within Activity 2 (discussion column), which comprises a discussion column that is guided by a series of questions. Learners will engage in discussion with a new group that comprises individuals who are distinct from those who participated in Activity 1 (gathering).

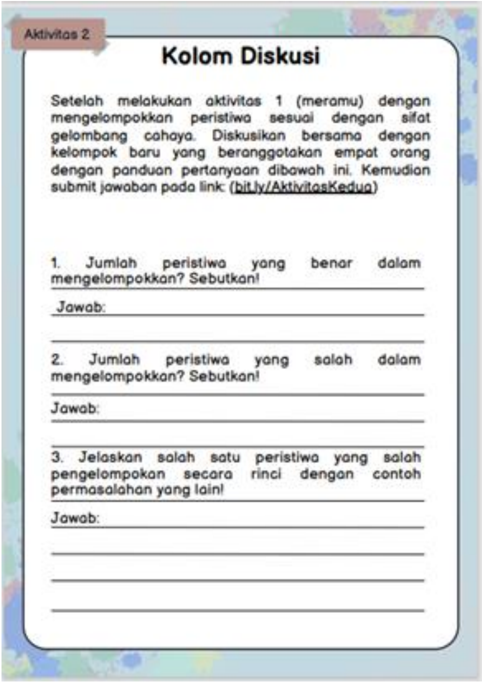

Fig 7. *Activity page 2 of the digital student worksheet*

d. The Application Phase is included in Activity 3, and the Practical Guide contains several commands and practical instructions for students to follow. There are six practicum guides, each corresponding to a different wave property of light. The practicum instruction sheet includes a table that students will use as a reference for taking practicum data.

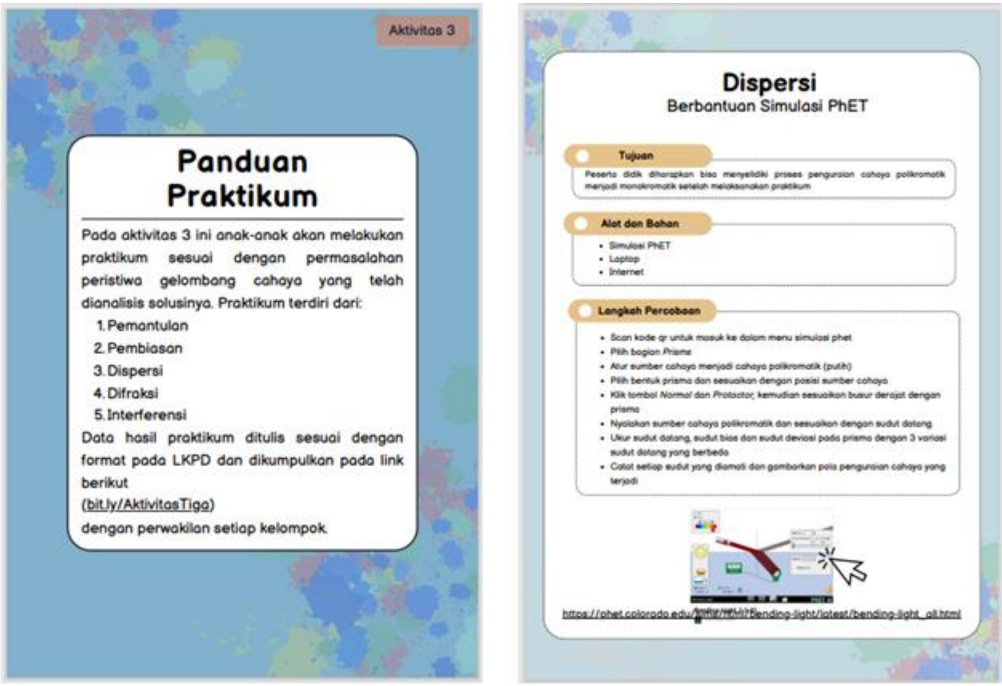

Fig 8. *Activity page 3 and lab guide*

e. The evaluation phase is located in Activity 4 (final project), which encompasses the conclusion activities that students will undertake to reflect on the learning outcomes achieved.

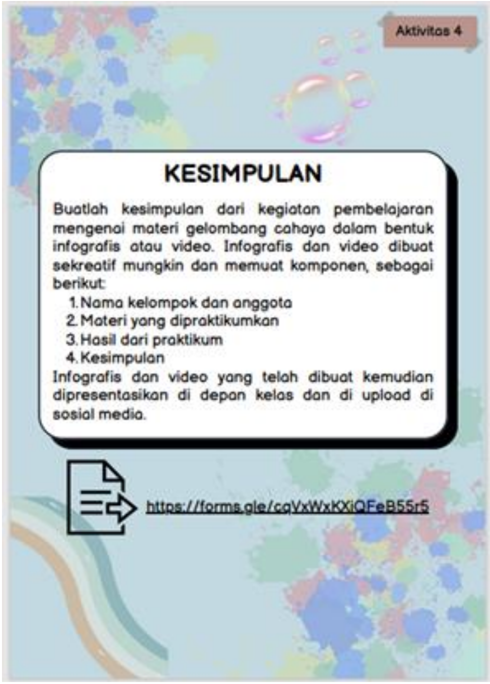

Fig 9. *Activity page 4*

Development Phase
The design of digital student worksheets that align with the learning objectives of high school is transformed into a product that is ready for testing for feasibility and practicality. The feasibility test of digital student worksheets was conducted on three lecturers and three physics teachers, who were selected as material experts and media experts.

1. Material expert validation
   The process of material expert validation encompasses three principal aspects: content feasibility, presentation feasibility, and linguistic feasibility. The results of the validation are presented in Table 4, which also includes the V-Aiken analysis.

Table 4. Recapitulation of material expert validation results

Aspect	Criteria	Mean V-Count	Description
Content Appropriateness	5	0,83	Valid
Presentation feasibility	8	0,88	Valid
Language feasibility	3	0,89	Valid
Mean		**0,87**	**Valid**

   The process of material expert validation encompasses three principal aspects: content feasibility, presentation feasibility, and linguistic feasibility. The outcomes of the validation were subjected to analysis using the V-Aiken method.

2. Media expert validation
   The validation of digital student worksheets is comprised of three main aspects: the size and format of the worksheets, the design of the covers, and the content design. The results of this validation can be seen in Table 5.

Table 5. Recapitulation of media expert validation results

Aspect	Criteria	Mean V-count	Description
Size and format	2	0,86	Valid
Cover design	2	0,83	Valid
Content design	2	0,90	Valid
Mean		**0,86**	**Valid**

The results of the feasibility study indicate that media expert validation is a viable approach, with an average acquisition of 0.86 across all valid categories on each criterion. The feasibility validation results demonstrate that digital student worksheet can be utilized with an average V-count of 0.87 in the valid category and with revisions from experts. Input suggestions from the six experts can be seen in Table 6.

Table 6. Expert input and suggestions

No	Input and suggestions
1.	Reinforcing the STEM-PjBL part of the student worksheet
2.	Improve the sentences contained in the theory so that they are easy to understand

The suggestions and input provided by the six experts were then incorporated into the digital student worksheet, with the aim of enhancing its usability and suitability for educational purposes. The revised student worksheet, which reflects the expert advice, is presented below.

1. The initial input is to be enhanced by the addition of a preface that will serve as a reference for users in accessing digital student worksheet. Furthermore, STEM signs are to be incorporated at each stage in accordance with the Science, Technology, Engineering, and Mathematics section.

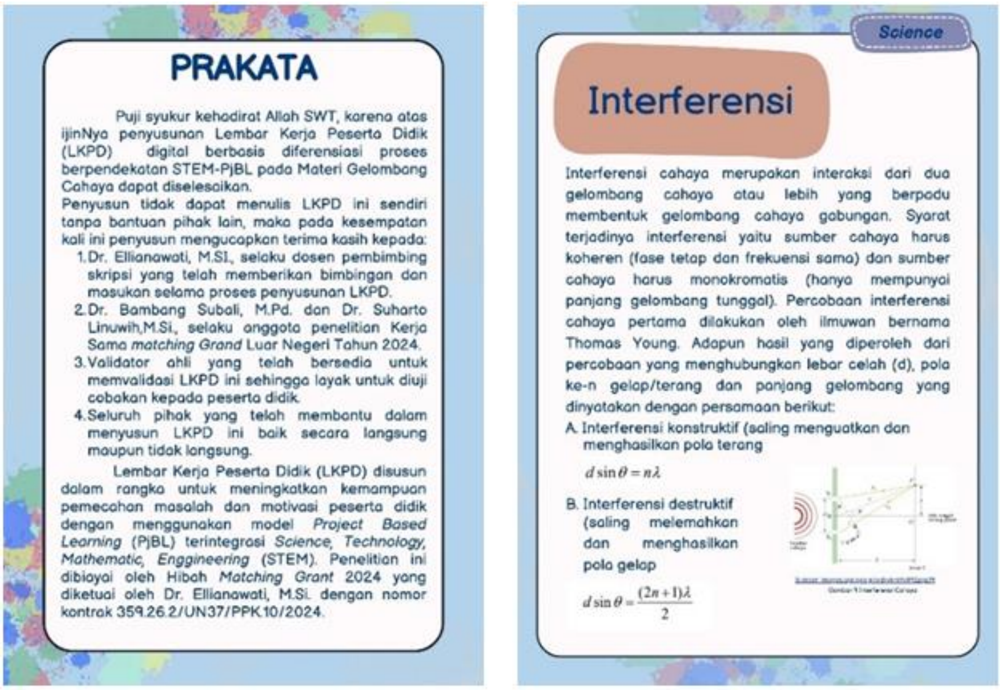

Fig 10. *Page for adding preface and STEM marks*

2. The third input was the introduction of modifications to the sentences within the theory, with the objective of enhancing their intelligibility.

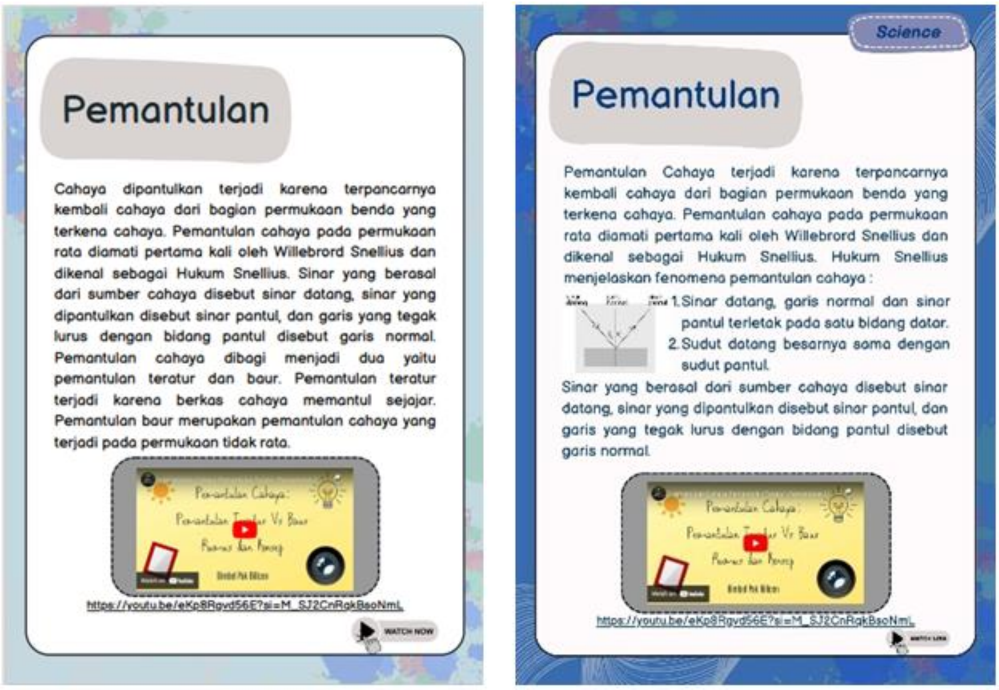

Fig 11. *Material page before and after revision*

The revised digital student worksheets underwent a practicality test conducted by physics teachers and students of class XII IPA 2 SMA Negeri 13 Semarang. The assessment of the digital student worksheet by teachers was carried out using a practicality questionnaire consisting of 12 criteria covering aspects of appearance, content, and benefits. The average score obtained was 3.75 with a percentage of 75% in the decent category.

A readability questionnaire was employed in the practicality test conducted by students, with 29 respondents. The questionnaire encompassed 11 criteria, addressing aspects of appearance, content, and presentation. The results of the practicality test conducted by students are presented in Table 7.

Table 7. Recapitulation of practicality test results by students

Aspect	Criteria	Mean Score	Percentage
Practicality of appearance	3	4,81	96,2%
Practicality of content	4	4,72	94,5%
Practicality of presentation	4	4,78	95,6%
Mean		**4,77**	**95,4%**

The results of the analysis indicate that the practicality of digital student worksheets obtained from the assessment of students is in a very feasible category, with an average score of 4.77 and a percentage of 95.4%.

CONCLUSION AND SUGGESTION

The characteristics of digital student worksheets based on process differentiation with a STEM-PjBL approach on the topic of light waves are characterized by a combination of STEM-PjBL learning syntax with process differentiation in each phase, in the form of group variations based on gender and learning style, and the validation of digital student worksheets based on process differentiation with a STEM-PjBL approach. The BL approach on light waves material is included in the valid category with a V-aiken value of 0.87 in the highly valid criteria. Digital student worksheets based on process differentiation with a STEM-PjBL approach on light waves material are practical, with an 87 in the very valid criteria. Digital student worksheets based on process differentiation with A STEM-PjBL approach is used in practice for physics learning, as evidenced by the acquisition of a practicality score from teachers of 3.88 with a percentage of 75% in the feasible category and the acquisition of scores by students of 4.77 with a percentage of 95.4% in the very feasible category.

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