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Development of STEM-Integrated Project-Based E-LKPD on Environmental Change Material

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A B S T R A C T

To equip students with 21st-century skills, appropriate and effective teaching materials integrated with technology are essential. However, an analysis revealed that while schools implemented simple project-based learning using LKPD, the existing materials only contained general questions and did not effectively facilitate project creation. This study aims to develop a STEM-integrated project-based E-LKPD on environmental change. The research follows the Research & Development (R&D) approach using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation. Data collection instruments included needs analysis sheets, validation sheets from material, media, and education experts, as well as teacher and student response questionnaires. The pilot study involved 36 tenth-grade students at SMAN 1 Kadugede. Validation results from experts indicated that the developed E-LKPD was highly valid for use in learning. Teacher and student response questionnaires showed very effective results, with average percentages of 94.04% and 81.02%, respectively. Student learning outcomes demonstrated an average score of 90, categorized as very good. These findings conclude that the STEM-integrated project-based E-LKPD is feasible and effective for use in STEM-based project learning.

1. Introduction

Implementing educational reform can enhance the quality of education in Indonesia (Mulyana et al., 2020). Educational reform signifies a transition from conventional learning to an approach that emphasizes critical thinking skills (Suastrawan et al., 2021). One form of educational reform is the adoption of learning approaches (Purnomo & Triwiyono, 2019). Learning approaches can serve as a foundation or perspective that can inspire, reinforce, and support learning methods within specific scopes (Chiba et al., 2018). This can be achieved through the STEM approach, as STEM encompasses interconnected scientific discipline. Science relies on mathematics as a tool for data processing, while technology and techniques are practical applications of scientific principles (Kelley & Knowles, 2016).

The integration of STEM in learning can facilitate students in developing 21st century skills (Forawi, 2018). STEM learning connects science, technology, engineering, and mathematics, training students in critical thinking, creativity, collaboration, and applied problem-solving through technology (Kelley & Knowles, 2016). In learning, the STEM approach provides opportunities for students to develop creative ideas and gain diverse information, fostering creativity and product development (Siregar et al., 2019). However, students currently lack training in analyzing each STEM aspect, as teachers have not utilized the STEM approach (Kimmel et al., 2014). Implementing the STEM approach is crucial to facilitating 21st century skills, as it enables students to understand the relationship between scientific concepts and everyday life, rather than merely memorizing concepts (Kelley & Knowles, 2016). To develop 21st century skills in students, the learning model used must be appropriate and effective, such as the Project Based Learning (PJBL) model, so that learning objectives are more easily achieved (Sulistyo et al., 2019).

Project-based learning integrated with STEM can improve critical thinking skills and help students easily understand learning materials. It can develop creative attitudes, effectiveness, and foster curiosity, imagination, and challenges. Additionally, this approach can enable students to plan learning activities, collaborate on projects, and create products (Jariyah, 2017). Research indicates that project-based STEM learning involves thinking, designing, making, and testing processes (Setiawan et al., 2020). Furthermore, the collaboration between projects and STEM can guide students to create projects that develop their abilities and provide memorable learning experiences, thus triggering student motivation and interest (Jariyah, 2017). Learning that produces STEM-integrated products must be supported by appropriate teaching materials. These teaching materials include material books, teaching modules, handouts, and Learner Worksheets (LKPD) (Mentari et al., 2019).

The teachers at SMA Negeri 1 Kadugede have used LKPD in learning, and have provided simple project-based learning using LKPD. However, the LKPD need development as they do not facilitate students in making projects and only contain general questions. This allows students to directly copy answers from textbooks without exploring from various sources. While they have implemented project-based learning, they have not used the STEM approach, so the projects are still general. More specific LKPD are needed to facilitate STEM-integrated projects. Teachers have not used Electronic Student Worksheets and use conventional printed LKPD that are less attractive due to lack of color, excessive text, and few images. This demotivates students, preventing fully student-centered learning. Appropriate teaching materials are necessary for successful learning and to improve students' thinking abilities. Student learning outcomes on environmental change material are still not optimal due to limited time for delivering the content and complex material (Trance & Trance, 2019).

To address the need for effective teaching materials, it is necessary to develop Project-Based Electronic Student Worksheets integrated with STEM. These E-LKPD can be created using the web-based platform liveworksheet.com, which

offers convenience and appeal for students. This application allows teachers to develop electronic student worksheets that are easy to use, facilitate student-teacher interaction during learning, and have an attractive visual design to motivate students (Febryanti & Rusmini, 2022). Additionally, LKPD can be innovated in terms of presentation by integrating a "Salingtemas" approach, which encompasses Science, Environment, Technology, and Society (Rahayu et al., 2023). Using liveworksheet, teachers can create interactive E-LKPD that are also practical for students, as they can complete and submit answers online, saving paper. The students' answers and scores are automatically saved and can be accessed at any time, which can increase student learning activities (Febryanti & Rusmini, 2022).

Developing attractive E-LKPDs to motivate students requires a design tool. Canva, a graphic design application, can easily create various designs for online display (Fitria, 2022). Using Canva allows producing more visually appealing E-LKPDs.

The environmental change material was selected for developing this E-LKPD because it involves daily life challenges, such as addressing pollution problems, which necessitates solutions in waste management. Accordingly, the environmental change material is applied in a project-based LKPD integrated with STEM, where students will be invited to integrate various STEM disciplines. STEM is an interconnected field of science, as science requires mathematics as a tool for data processing, while technology and engineering are practical applications of scientific principles. By integrating STEM, students are expected to enhance their problem-solving capabilities, cultivating skills as inventors, logical thinkers, and technology-literate individuals capable of addressing environmental waste management challenges in a straightforward manner. This approach provides an opportunity for students to express their ideas and translate them into design solutions, culminating in a project assignment (Rois et al., 2020). This study aims to develop a feasible, practical, and effective project-based STEM-integrated E-LKPD focused on environmental change material, in terms of both validity and effectiveness.

2. Methodology

This research and development project aimed to create a new product through a development process. In this study, an electronic project-based STEM-integrated Student Worksheet was developed as teaching material on environmental change content for grade X. This research was conducted at SMA Negeri 1 Kadugede located at Jl. Syech Manglayang No.65, Babatan. Kadugede District, Kuningan Regency. The research period was conducted in October – November 2024. The population in this study were grade X students at SMA Negeri 1 Kadugede. The sample used in this study was class X-E students totaling 36 students at SMA Negeri 1 Kadugede. The research design is based on the ADDIE which consists of 5 stages: analysis, design, development, implementation, and evaluation. This

model was selected due to its simplicity and systematic approach, making it more accessible for developers to navigate.

The Development Techniques

a. Analysis

At this stage, an analysis is conducted to determine learning needs, identify issues, and perform a literature review. The needs analysis is undertaken to gather information related to the requirements of teachers and students in biology learning. This analysis is performed through observation and interviews with teachers and students. The first interview was conducted with 2 grade X biology teachers about the curriculum used at SMA Negeri 1 Kadugede, aiming to determine the reference in preparing teaching materials to ensure alignment with the applied curriculum. Additionally, information was collected about the biology learning process in the school, the availability of teaching materials, and the models and methods employed in learning. Then, the second interview was conducted with 10 grade X students to understand the problems they face and their learning needs. According to the analysis, the biology learning process at school. The use of teaching materials used are textbooks and Learner Worksheets (LKPD), but the LKPD used by teachers at school still needs development because the LKPD has not facilitated students in making projects and the LKPD used contains only general questions.

b. Design

Based on the results of the analysis, the next stage is the design of STEM integrated project-based E-LKPD. In this stage, the researcher makes a media design or product to be made. The following are the actions taken during this design stage:

1. Preparation of the E-LKPD Outline

The preparation of the STEM-integrated project-based E-LKPD outline contains the initial plan of what will be written in the E-LKPD. The E-LKPD will be created using Canva to create a more attractive design using the Liveworksheet application with its online use. At this stage, the researcher begins to design the content of the E-LKPD to be made such as cover, layout, and content consisting of material, work instructions, questions, and others which will be equipped with a more attractive visual display presentation in the form of pictures, videos, and so on to further enhance the students' experience in learning.

2. Designing the Content of the E-LKPD

At this stage, the researcher will compile the material to be included in the E-LKPD. The selected material is about environmental change about how to deal with different types of waste and how to recycle waste for the benefit of life. In addition to the material, the content of the E-LKPD will also be accompanied by videos or articles and pictures about examples of existing problems, as well as instructions for students to make observations in the surrounding environment to find problems, then proceed with the preparation of the content part of the E-LKPD which is about project design.

c. Development Stage

Development in the ADDIE model includes the activities of realizing the product design.

a. Preparation of E-LKPD Initial Products

This phase is the initial phase of creating the product to be developed, namely STEM integrated project-based E-LKPD. The initial preparation of the product will begin with making an attractive cover, determining the font, spacing, and typeface that will be used in the preparation of E-LKPD. Then determine the combination of colors and interesting variations, then enter the contents of the E-LKPD that have been made in the design stage, such as material, work instructions, and work instructions.

b. Validation Test of STEM-Integrated Project-based E-LKPD by Experts

The developed STEM-integrated project-based E-LKPD products were tested for validity by media experts, material experts, and education experts. The developed E-LKPD products were then tested for validity by media experts, material experts and education experts. This validation aims to see the validity of the developed product. Whether the developed product is valid or not is determined by the results of content validation from various experts in the form of numbers, comments, and suggestions.

d. Implementation stage

In the implementation stage, after the product is revised based on the suggestions and input from experts, a small-scale trial is conducted by applying the developed product, namely the STEM-integrated project-based E-LKPD in biology learning activities at SMA Negeri 1 Kadugede to 36 students. The STEM-integrated project-based E-LKPD was given to teachers and students. After teachers and students were given the E-LKPD, then teachers and students were given a questionnaire to see how effective the E-LKPD developed. The response questionnaire was constructed using a Likert scale, as it has the function of measuring a person's attitudes and opinions about an object that has alternative answers, namely Strongly Disagree, Disagree, Agree, and Strongly Agree (Zhu & Lu, 2017). Then, after knowing the results of the teacher and student response questionnaires, the product was revised again.

3. Results and Discussion

Results

1. Analysis

Based on the results of the teacher and student needs analysis, it is necessary to develop STEM-integrated project-based E-LKPD because it is expected to help students reinforce and better understand concepts.

2. Design

a. Preparation of the E-LKPD Outline

The preparation of the E-LKPD outline is the first step in the design phase. At this stage, the researchers compiled the contents of the E-LKPD such as covers, instructions on how to use the E-LKPD, preparation of materials on environmental changes related to different types of waste, and preparation of learning activities consisting of observation activities in the surrounding environment to find problems and project design. The materials included in the E-LKPD are taken from scientific journals on pollution and different types of waste. In addition, the researcher determines the video that will be included in the E-LKPD, the video is taken from youtube regarding environmental pollution and its countermeasures and determines the images that will be included in the E-LKPD in the material section, the image is taken from the internet or google the image is about solid waste, liquid waste and gas waste.

b. E-LKPD Content Design

At this stage, researchers will create an E-LKPD design using canva, which will produce a final product in pdf format. The pdf format created using Canva will then be uploaded to the liveworksheet so that it becomes an electronic LKPD.

3. Development

a. Home Page

The home page of the E-LKPD consists of a cover designed in accordance with the title and content of the E-LKPD. This cover shows an image in which there are two different realms, namely nature that is clean, healthy, and there is no pollution in it. Then there is nature that is dirty, dry, unhealthy, and there is pollution in it. The meaning of the image is the occurrence of environmental changes due to pollution. In addition, the cover also contains the title of the STEM integrated project-based E-LKPD, the names of the group members for students, and a description of the STEM integrated project-based E-LKPD for SMA/MA Class X Semester 2 students.

In addition to the cover page, this first page contains a table of contents that lists the number of pages from the first page to the last page in the E-LKPD, neatly and correctly arranged to make it easier for users to use the E-LKPD. Can be seen in Figure 1 below

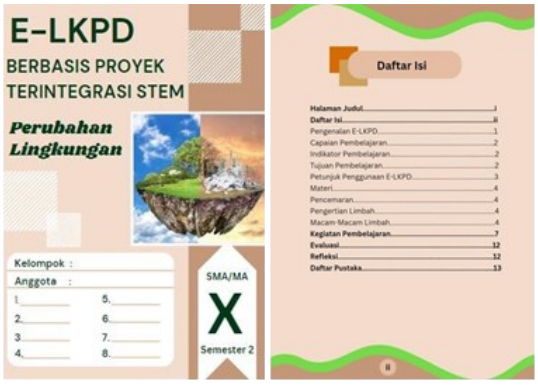

Figure 1. E-LKPD Cover and Table of Contents

This first page also includes an explanation of E-LKPD, project-based learning, and an explanation of STEM. It can be seen in figure 2 below.

Figure 2. Explanation of E-LKPD, Project, and STEM

b. Learning outcomes, indicators and objectives

The content of the learning outcomes and learning indicators contained in the E-LKPD are the outcomes and indicators that need to be achieved by students in learning about environmental change material, then there are learning objectives that are used as directions in the learning process. The picture is shown in figure 3 below:

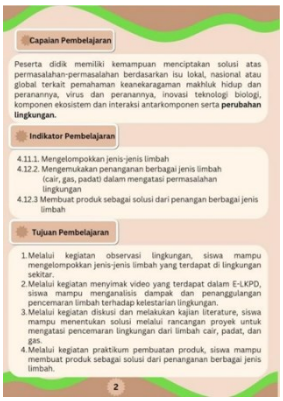

Figure 3. Learning Outcomes, Indicators, and Targets

c. Instructions for the use of E-LKPD

Instructions for use of E-LKPD presented in the STEM integrated project-based E-LKPD serves as a guide for teachers and students in using E-LKPD easily in which there are steps that must be followed to optimize the use of E-LKPD in the learning process. The picture is shown in Figure 4 below:

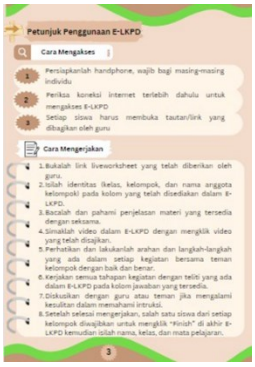

Figure 4. Instructions for using the E-LKPD

d. Materials page

This page contains materials that are in accordance with the learning objectives, namely about pollution, understanding waste, and different types of waste, taken from magazines and equipped with pictures of different types of waste, such as solid, liquid, and gaseous waste, taken from the Internet or Google. In addition, there is a video that explains about environmental pollution and its countermeasures, the video is taken from YouTube. The picture is shown in Figure 5 below:

Figure 5. Materials Page e-LKPD

e. Learning activities

In the learning activities on the E-LKPD there are several activities that must be carried out by students, the first is determining the fundamental question in it includes observation activities in the surrounding environment to find problems, in this activity students make observations then analyze the impact and find the right solution to overcome the pollution identified in the observation results.The second activity is designing project planning, in this activity students design the project to be done by determining the project title, project objectives, tools and materials, and project work steps. Students then analyze the STEM (Science, Technology, Engineering, and Mathematics) of the product to be made of the product to be made. This is shown in figure 6 below:

Figure 6. Determine the fundamental question and design the plan

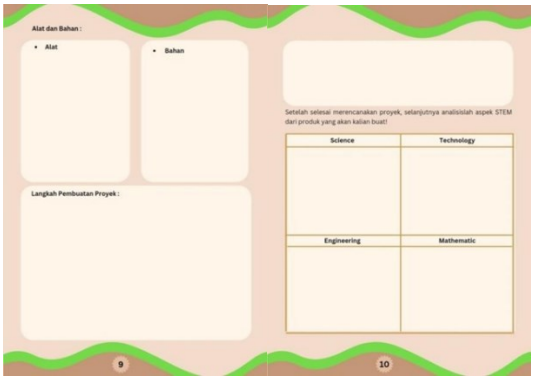

Figure 7. Determination of Materials Tools and STEM Analysis

The next activity is preparing a schedule, in this activity students compile a schedule from product design to product manufacturing by describing these activities along with the person in charge of each activity. The last activity is project implementation and documenting project results. In this activity students make projects then make videos of their making and document the results of the project then upload the photos and videos to google drive, then the link from google drive is inserted into the E-LKPD. Furthermore, evaluation activities, in this activity students evaluate whether the products made can overcome environmental pollution in accordance with the results of observations and reflection activities that students must fill in the E-LKPD, namely explaining the experiences gained during the process of making these products. The picture can be seen in Figure 8 below:

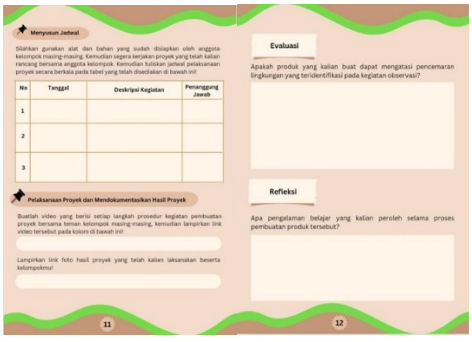

Figure 8. Evaluation and Reflection

f. Bibliography

The bibliography contained in this E-LKPD contains references to various sources such as articles and scientific journals in the development of STEM integrated project-based E-LKPD can be seen in Figure 9 below:

Figure 9. Bibliography

g. Project assessment

Project assessment in E-LKPD is an evaluation system used to assess student performance in project activities. The project assessment contained in this E-LKPD is in the form of a barcode in which there is a project assessment rubric to make it easier for teachers to assess the results of student project work, can be seen in figure 10 below:

Figure 10. Project assessment

Validation Result

After going through the revision process by the supervisor, the E-LKPD was given to expert validators consisting of material experts, media experts, and education experts. The following are the validation results from the experts presented in table 10 below:

Table 10. Results of Validation of STEM Integrated Project-Based E-LKPDs

No	Validation	Percentage	Description
1	Material Expert	92,3%	Very valid
2	Media Expert	94,3%	Very valid
3	Education Expert	98%	Very valid

Based on the data from the validation results above, it shows that the STEM-integrated project-based E-LKPD developed is very valid for testing. After the E-LKPD is validated by material, media, and education experts, validators provide

criticism and suggestions that aim to improve the E-LKPD to be developed to be maximally useful. Improvements were made by researchers before the trial stage was carried out to students.

4. Implementation

The pilot test was conducted on class X-E students consisting of 36 students and one biology teacher at SMA Negeri 1 Kadugede to obtain responses regarding the effectiveness of E-LKPD from students and teachers using a response questionnaire given to students and teachers. The results of filling out the questionnaire can be seen in table 11 below:

Table 11. Results of student responses in the implementation stage

No	Aspects	Percentage	Category
1	E-LKPD Content	81,25%	Very effective
2	Media Display	83,25%	Very effective
3	Expediency	79,75%	Very effective
4	Language	79,75%	Very effective
Average effectiveness		81,02%	Very effective

Teacher responses based on small-scale trials of STEM-integrated project-based E-LKPDs can be seen in table 12 below:

Table 12. Teacher Response Results

No	Aspects	Percentage	Category
1	E-LKPD Content	92,85%	Very effective
2	Media Display	91,66%	Very effective
3	Expediency	90,62%	Very effective
4	Language	100%	Very effective
Average effectiveness		94,04%	Very effective

These results indicate that the STEM-integrated project-based E-LKPDs that have been used are effective as teaching materials in the biology learning process at school. As the results of the research above, in the small-scale trial there were no suggestions and improvements from teachers and students so that this STEM-integrated project-based E-LKPD product is ready to be used in the next stage, namely the large-scale trial. The plan for conducting this large-scale trial will be carried out in class X at SMA Negeri 1 Kadugede which consists of six classes, namely classes X-A, X-B, X-C, X-D, X-E, and X-F with a total of 216 students. However, in this study, the large-scale trial stage could not be carried out due to time constraints in the research.

5. Evaluation

The plan that will be evaluated is the results of the assessment of the small-scale trial with the large-scale following comparing the responses of the small-scale and large-scale trials.

Discussion

Based on the results above, it shows that STEM-integrated project-based E-LKPD teaching materials can facilitate students in making projects so that they can solve the problems found in schools, namely the use of LKPD teaching materials has not facilitated students in making projects which only contain general questions, so that students can directly copy answers from the textbooks available at school and students do not explore from various sources. Although it has implemented project-based learning, it has not used the STEM approach, so the projects made are still general. Teachers also still use conventional LKPDs in the printed version with contents that are less attractive because they are not colorful, a lot of text, and use few images so that the available LKPDs are still less attractive to students, this causes students to be less motivated in the learning process. The statement is supported by student and teacher response questionnaires that get positive responses based on the implementation of learning using STEM-integrated project-based E-LKPDs well implemented as planned.

This research only reached the implementation stage of the small-scale trial because of time constraints, at each time the research takes a long time because students in this stage carry out project making activities. In addition, it also needs accuracy in assessing the project, choosing the project theme, and designing the project to be made which is associated with STEM analysis activities, compiling a project activity schedule, to the project creation activities, so that for the next plan, a large-scale trial research will be carried out. The results of the large-scale trial will be used as material for research at the evaluation stage.

4. Conclusion

Based on the results of the study, the STEM-integrated project-based E-LKPD on environmental change material obtained validation results from material, media, and education experts with a percentage of validity of 92.3%, 94.3%, and 98% respectively, all in the very valid category. The results of E-LKPD implementation received positive responses from teachers and students of 94.04% and 81.02% both in the very effective category because there are several advantages, namely the material presented is complete in the form of text, images, videos, and the material presented is contextual material, the activity steps in the STEM-integrated project-based E-LKPD are presented in accordance with the project learning syntax, E-LKPD is equipped with STEM analysis, and STEM-integrated project-based E-LKPD contains project assessments presented in the form of barcodes. The results of student learning using E-LKPD obtained a very good average score so that it showed an improvement in previous learning. Thus, the STEM-integrated project-based E-LKPD is feasible and effective to use in STEM-integrated project-based learning.

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