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Development of STEM-PJBL based Science electronic worksheets to Improve Students' Collaboration Skills

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Abstract: Learning in the 21st century focuses on the use of advanced technology. At the elementary school level, digital-based learning innovation is important in creating a dynamic and interesting learning environment. This research aims to develop STEM-PjBL based e-LKPD and determine its validity and effectiveness on students' collaboration skills. This development uses a 4D model made by Thiagarajan which consists of 4 stages, namely Define, Design, Development and Disseminate. With quantitative and qualitative data analysis techniques. Expert validation results show 86.9% is very valid and suitable for use. The responses of students and teachers showed very good results and were quite effective in supporting the improvement of students' collaboration skills, as seen from the n-gain scores of 0.5 and 0.4 in the "medium" category.

Keywords: Collaboration; Electronic worksheets, Science Learning; STEM-PjBL.

Introduction

In 21st-century education, students are required to become active learners in various aspects of the learning process. Therefore, in addition to planning students' academic achievements, it is necessary to develop desired skills such as communication and collaboration, which are crucial for students (Le et al, 2018; Setyowidodo et al, 2020; Sunbanu i ostali, 2019). Collaborative learning positively impacts the learning process by creating a more innovative learning environment, enabling students to absorb material more easily, and providing opportunities for students to collaborate in sharing ideas and knowledge to hone interpersonal, leadership, communication, and teamwork skills (Ghavifekr, 2020; Kirschner et al, 2018; Rabgay, 2018). Collaboration skills need to be facilitated through a supportive learning environment, relevant teaching strategies, and ample opportunities for students to participate in collaborative projects, discussions, and team activities (Al-Samarraie & Saeed, 2018). Enhancing students' collaboration skills is particularly important at the elementary school level (Muti'ah et al, 2021; Nemiro, 2021). These skills can be trained through various educational tools, models, methods, approaches, designs, and learning strategies. Examples include the ASICC model (Santoso et al, 2021), learning design through sharing and jumping tasks (Verawati et al, 2020), project-based learning (Priyatni & As'ari, 2019; Setyowidodo et al, 2020), STEM approaches (Latip et al, 2020), and LKPD teaching materials (Putri et al, 2023). According to Amali (2019), student worksheets (LKPD) are one of the tools that support the implementation of science learning. Furthermore, Astalini (2019) highlights the practicality of technology-based worksheets, which can make the learning process more engaging. A concrete example is E-LKPD, which is easily accessible and usable by students.

One of the most relevant learning approaches in this context is the STEM-PjBL approach. STEM emphasizes the integration of four main disciplines: Science, Technology, Engineering, and Mathematics

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(Arlinwibowo et al, 2021; Chai et al, 2019). The proposed PjBL model emphasizes learning through real-world projects involving students in problem-solving, research, and teamwork (Isa & Azid, 2021; Miller & Krajcik, 2019). According to Ardiansyah et al (2020), STEM-based Project-Based Learning (PjBL) is a project learning method integrated with STEM, encompassing five process steps: reflection, research, exploration, application, and communication.

The needs analysis results show that 61% of fourth-grade students at SDIT in Bogor City (referred to as "A") face difficulties in completing group tasks. Teachers also reveal challenges in group assignments and projects, as evidenced by some groups failing to complete tasks. Interviews with teachers regarding the LKPD used indicate that teachers currently only develop experimental LKPDs for students. The use of STEM-PjBL-based LKPDs has largely not been developed or implemented by teachers, and the model predominantly used in science learning is discovery learning. These findings are corroborated by interviews with three students, which reveal that the worksheets used only contain short questions, lack color and pictures, and rarely involve experiments or project-making activities.

Several previous studies are relevant to this research. First, Mawaddah et al (2022) developed a student worksheet for Subtheme 1 based on STEM. Based on expert validation results, student responses, and differences in average scores in pretest-posttest classes, the developed worksheet was found to be feasible and effective in enhancing students' collaboration skills. Adhiati et al (2023) also developed STEM-based worksheets for science learning. Based on expert validation results and pretest-posttest results, the product was deemed feasible and effective for improving collaboration skills. The difference in this research is that it uses the ASSURE model, while the current research will use the 4D model (define, design, development, and disseminate) to develop STEM-PjBL-based E-LKPD. Research by Agustina & Yanthi (2023)(Agustina & Yanthi, 2023) developed STEM-based worksheets using the ADDIE model, which were feasible and effective for supporting science learning in fifth-grade elementary school classes, comprising four activities. The difference lies in the STEM-based worksheets, while the current study will focus on STEM-PjBL-based E-LKPD to enhance students' collaboration skills using the 4D model. The novelty of this research is the E-LKPD, which features innovative learning activities integrating four STEM disciplines in contextual, project-based formats. It is tailored to fourth-grade science material for one semester, designed to support students' collaboration skills in an engaging format.

This research is essential because it addresses the challenges of 21st-century education, particularly in enhancing students' collaboration skills. By integrating the STEM-PjBL approach in E-LKPD, this study meets the needs of contextual learning relevant to real-life situations while also encouraging students to communicate and collaborate effectively in completing projects. This creates a more interactive and meaningful learning experience for elementary school students.

Method

This development research aims to create a STEM-PjBL-based electronic worksheets IPA to improve students' collaboration skills. The research and development steps are carried out using modifications and Thiagarajan's development model called 4-D. This development model uses 4 stages consisting of define, design, development, and dissemination. The development model in this study refers to the 4D (four-D) research and development model (Thiagarajan, 1974). Research and development of LKPD is carried out through a series of procedural stages. The stages are as follows:

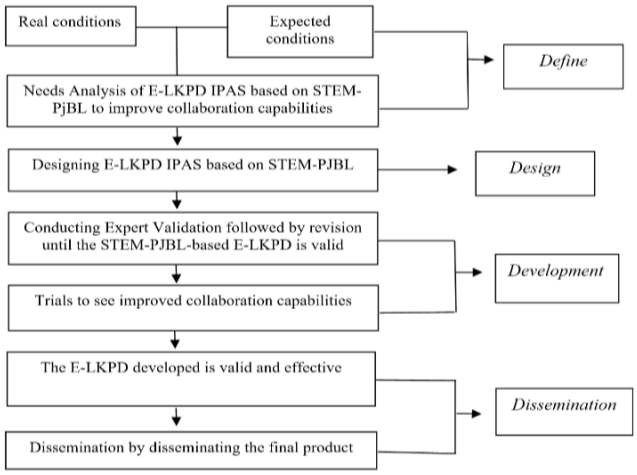

Figure 1: Stages of 4D Development

The data collected in this study were qualitative data and quantitative data. This data is used to measure the validity and evaluate the products developed. Qualitative data was obtained from product descriptions and the results of evaluation descriptions by material experts, linguists, and media experts. Meanwhile, quantitative data was obtained from validation instruments of material experts, linguists, and media experts in the form of Likert scales and student response instruments as well as data on the results of collaboration skills instruments. The indicators of the collaboration skills instrument used are based on formulations (Greenstein, 2012). The following is one of

the grids of collaboration skills instruments through observation.

Table 1. Grid of collaborative skills assessment instruments through observation.

Indicator	Description
Demonstrate an attitude of responsibility	Students are active in various group work situations and complete tasks well.
Work productively	Students focus on not doing activities outside of group assignment activities and can complete the task completely according to the time given.
Adapt to various activities	Students interact with their peers to work together to overcome challenges and find solutions in completing project tasks together.
Show appreciation	Students discuss, listen, and appreciate the contributions made by group members.

Data analysis included the analysis of validation instruments used to test the feasibility of STEM-PjBL-based electronic worksheets by material, language and media experts using a validation questionnaire with a measurement scale used, namely the *Likert* scale with criteria 5. It can be interpreted as the numbers 1-5. Number 1; very little, 2; less, 3; enough, 4; good, 5; Excellent. Validation data can be processed using formulas (Arikunto, 2013):

$$P = \frac{\sum x}{\sum xi} X\ 100\% \quad (1)$$

Information:
P : Eligibility percentage
∑x : The sum of the values from the validator
∑x1 : Maximum number of values

To interpret the results of the data analysis, the following interpretation is used:

Table 2. Qualification Level

Achievement Level (100%)	Qualification	Information
80 < P ≤ 100	Excellent	Highly valid, no revision required
60 < P ≤ 80	Good	Valid, revised as necessary
40 < P ≤ 80	Enough	Quite valid, quite revised
20 < P ≤ 40	Less	Less valid, a lot to revise
0 ≤ P ≤ 20	Very less	Invalid, must be completely revised

Source: (Widayanti et al, 2022)

Analysis to determine the development of collaboration skills using the N-Gain Score Test. The N-Gain Score test is carried out by calculating the difference between the pretest and posttest scores or the gain score (Fita et al, 2021). The division of N-Gain Score earning categories can refer to the Table 4.

Table 4. N-Gain Score Earning Categories

g	Criterion
g > 0.7	Tall
0.3 ≤ g ≤ 0.7	Keep
g < 0.3	Low

Source: (Hake, 1999)

The N-Gain score can be calculated by using the Formula 2.

$$< g \geq \frac{(S_{post} - S_{pre})}{(S_{max} - S_{pre})} \quad (2)$$

Source: (Hake, 1999)

Information:
<g> = average n-gain score
(S_{post}) = posttest score
(= prettest scoreS_{pre})
(S_{max}) = max score

Result and Discussion

This research and development aim to develop, test the validity, and test the effectiveness of STEM-PjBL-based electronic worksheets to improve the collaboration skills of elementary school students using the 4D research model proposed by Thiagarajan with the stages of define, design, develop, and dessiminate. At the define stage, conduct a needs analysis from various aspects related to the development of electronic worksheets (Andriana et al, 2022). This analysis aims to identify needs related to the development of e-liked, both in terms of content, design, and learning goals to be achieved. In addition, this stage also includes an initial analysis by teachers to improve the efficiency and effectiveness of learning, as well as an analysis of student characteristics, including students' abilities, learning motivation, and background of learning experiences (Arvyaty et al, 2021). Based on the observation that students in the learning process do not actively participate when discussing with friends, only a few people can complete group assignments and worksheets used using books that have been provided by the school, from the teacher's statement through the learning interview process in the classroom, especially

science learning, more often uses the discovery model and is rarely project-based, and have never applied a STEM approach in learning. Based on the characteristics of grade IV students, they need contextual learning, which is to connect the subject matter with daily life so that it is easier to understand and relevant for students, especially in science subjects. The STEM-PjBL (Science, Technology, Engineering, Mathematics through Project-based Learning) learning model is very suitable for this characteristic. In the STEM-PjBL model, students are invited to solve real problems through projects involving science, technology, engineering, and mathematics (Purwaningsih et al, 2020). This is in line with the needs of grade IV students who tend to be interested in exploratory activities and hands-on experiential learning. With STEM-PjBL, students can develop collaboration skills while applying the concepts learned to real-life situations. LKPD can facilitate student activities more efficiently. It is important to design an LKPD that supports the learning process with a display that can increase motivation and encourage positive student engagement (Finali et al, 2020).

Based on the results of the student needs questionnaire, students rarely use LKPD in science learning, and the LKPD used is considered less attractive. As many as 65% of students like worksheets that have pictures, and colors, and there are several media in them. This SDIT school is building a digital classroom so that it can support the development of electronic worksheets. Electronic worksheets with an attractive design can help students focus more and increase interest in learning (Siregar et al, 2024). In this context, it can be seen that students need a STEM-PjBL-based electronic worksheets IPA so that learning becomes more meaningful and contextual. With the STEM-PjBL approach, students can be actively involved in projects that integrate science, technology, engineering, and mathematics, and can apply these concepts in real-life situations that can provide new and exciting experiences for students (Uden et al, 2023). STEM-PjBL-based electronic worksheets also allows students to work collaboratively.

In the second stage of Design, researchers designed electronic worksheets using Canva Pro and Heyzine to add audio and create flipbook shapes, videos, and hyperlinks. The learning module development process involves several stages which include: (a) Preparation of materials, creating four innovative STEM projects according to the material in the teacher's handbook in the school, namely the Mini Garden and Auto Watering, Aromatherapy Candles, Water Rockets, Simple Wind Turbines; (b) The selection of media design and content is based on the analysis that has been carried out at the definition stage to create an electronic worksheets that is by the characteristics of millennial generation students who are familiar with digital technology; (c) Selection of format by considering the layout design, color, content, text, and format by the electronic worksheets; (d) Preparation of the initial draft for electronic worksheets. This design stage is very crucial in the development of electronic worksheets, because it includes the preparation of an organized and systematic writing format to meet the learning needs of students (Gustina et al, 2021). The design of this electronic worksheets incorporates various multimedia elements including text, images, videos, sounds, and animations and there are navigation buttons that students can use. By utilizing these various elements, it is hoped that students can actively participate in the learning process and gain a deeper understanding of the material being studied.

After the LKPD product design stage is completed, it is continued with the stage of preparing instruments consisting of, electronic worksheets product validation instruments for media, language, and material experts, then compiling collaboration skills instruments consisting of pre-test and posttest assessments through observation, assessments between friends and interviews aimed at testing the effectiveness of electronic worksheets, which is compiled in the form of analytical rubrics and open-ended questions. This test instrument was developed based on indicators of collaboration skills.

The third stage, namely development, is an evaluation of the electronic worksheets which has been designed to ensure that the content is valid and can improve the collaboration ability of students. The stages of the validity test of the LKPD product are illustrated in the Figure 1.

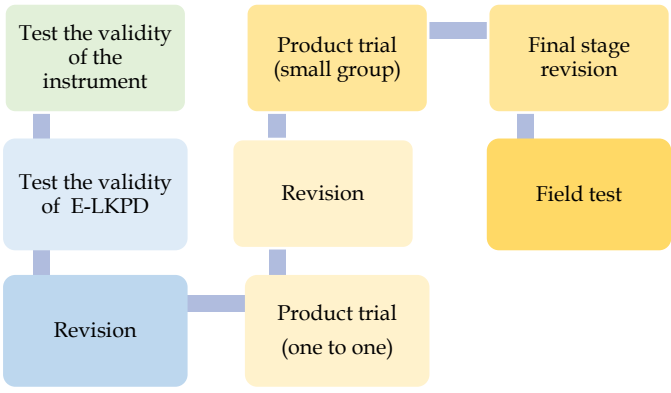

Figure 1. Stages of LKPD validity test

A validity test is a stage that aims to obtain input and suggestions to improve the quality of the product that has been developed (Iskandar et al, 2023). Input from validators can be used as a guideline in improving and perfecting the electronic worksheets developed. At this stage, product validation is carried out by involving media experts, material experts, and language experts to

ensure that the resulting electronic worksheets is feasible and valid.

The validation of media experts resulted in a feasibility percentage of 84.57%. This figure is included in the "Very Good" category, which means that the electronic worksheets is considered very valid. Media experts gave high appreciation to the appearance of the electronic worksheets design, its attractiveness, and its ease of use. This shows that electronic worksheets is not only informative but also visually appealing and easy to operate by users.

Table 5. Product Validation Results (Media Expert)

Component	Number of Per-Aspects	Maximum	Percentage
Electronic worksheets design display	27	35	77.14
The Appeal of electronic worksheets	22	25	88.00
User Friendly	31	35	88.57
Sum	80	95	253.71
Average Percentage			84.57

Table 6. Product Validation Results (Linguist)

Component	Number of Per-Aspects	Maximum	Percentage
Language Clarity	31	35	88.57
Precision in use Language	31	35	88.57
Sum	62	70	177.14
Average Percentage			88.57

From the linguistic aspect, electronic worksheets received a very satisfactory assessment from linguists with a feasibility percentage of 88.57%. This score is also included in the "Very Good" category, which indicates that the electronic worksheets is very valid and does not require revision in the linguistic aspect. This assessment reflects that the language used in the electronic worksheets is very clear and precise, so that it can facilitate users' understanding of the content presented.

Table 7. Product Validation Results (Material Expert)

Component	Number of Per-Aspects	Maximum	Percentage
Feasibility of content and material	62	70	88.57
Accuracy of evaluation questions	17	20	85.00
Sum	79	90	173.57
Average Percentage			87.70

The material expert gave an assessment with a feasibility percentage of 87.7%, which is also included in the "Very Good" category. This means that in terms of material, the electronic worksheets is considered very valid and does not require revision. They considered that the content and materials presented in the electronic worksheets were very relevant and in accordance with the learning objectives. The included evaluation questions were also considered appropriate, showing that this electronic worksheets was effective in measuring students' understanding of the material taught.

Table 8. Product Validation Recapitulation Results

It	Expert Respondents	Percentage
1	Media Members	84.57
2	Linguist	88.57
3	Material Expert	87.70
	Average	86.90

The STEM-PjBL-based electronic worksheets has been declared valid and suitable for use based on the results of the analysis of the assessment of several validators, the next stage carried out is a trial consisting of one to one as many as four students, then correcting the obstacles found in the one to one trial and seeing the response of students, then a small group trial of six students. The product feasibility criteria obtained from the students' responses were very good, there were only a few shortcomings of electronic worksheets during the one-to-one trial that as background that interfered with the text, after being corrected in the small group trial, there were no constraints. Furthermore, conducting a field test stage, implementing STEM-PjBL-based electronic worksheets products to 20 students to see the collaboration skills of students after using the product. The instruments used were observation assessments, between friends, and interviews using N-Gain Score test data analysis. This test aims to determine the effectiveness of using electronic worksheets designed in one group pretest and posttest research. Effectiveness is the impact that arises from an action (Purwaningsih et al, 2020). In this study, the impact of the use of electronic worksheets on the development of students' collaboration skills. The effectiveness test is used to see the level of success in learning activities that receive treatment is said to be effective if the electronic worksheets can have an impact on developing students'

skills where students' collaboration skills increase between before and after using electronic worksheets.

Table 9. Recapitulation of N-Gain Observation Data

Average Pretest Score	53
Average Posttest Score	76
Average N-Gain Value	0.5
Category	Keep

The recapitulation of n-gain data can be stated that the average n-gain obtained by all respondents is 0.5. The value of 0.5 in the n-gain score category is in the medium category. This shows that all respondents have been able to develop their collaboration skills through the use of the electronic worksheets developed.

Table 10. Recapitulation of N-Gain Data Assessment between friends

Average Pretest Score	53
Average Posttest Score	76
Average N-Gain Value	0.4
Category	Keep

Stated that the average n-gain value in the assessment between friends was 0.4 and was in the medium category. With this recapitulation, it can be seen that all respondents can assess their friends about the changes in collaboration skills experienced by their friends in each group. This shows that in the assessment between friends, collaboration skills can change or develop.

Of the two decapitations that have been made, both have or occupy the medium category in the n-gain score assessment. It can be concluded that the electronic worksheets used can develop collaboration skills, although not significantly, it has begun to see changes from all the data analysis carried out.

The results of the interview, which was conducted to see the skills of students, were conducted by interviewing 9 respondents, who had a qualification of 3 values posttest which experienced a high increase, 3 moderate value increases, and 3 low-value increases. 3 respondents with high scores have been able to apply the collaboration indicators that the researcher wants to achieve. At the time of the protest they did not understand and the level of collaboration was low, but after receiving treatment, the three respondents were able to work together in carrying out projects, discussing in groups, and inviting friends to find solutions when there were unresolved problems, dividing tasks according to their respective tasks, 3 respondents with low increases have begun to see the development of their collaboration skills, for example helping friends who are in difficulty, Take advantage of the time that has been given, discuss the problems at hand, respect friends who have opinions and take part in finding solutions together when it is difficult, not indifferent to group tasks. Although 3 respondents with a moderate level have experienced an increase in scores on the posttest the increase is still at a moderate level and has not reached a high level in understanding collaboration skills. These 3 respondents already have collaboration skills, they can already find solutions and discuss with friends, but some disputes occur, for example, some only follow the advice of friends, are not confident in their opinions, and divide tasks that are not optimal.

The fourth stage of dessiminate was carried out openly by disseminating directly at the research location, namely the SDIT class IV homeroom with the initials "A" in the city of Bogor.

Conclusion

Based on the results and discussions, this research and development was carried out refers to a 4D development model that has 4 stages, namely; Define, Design, Develop, and dessiminate, the result of this development It can be concluded that STEM-PjBL-based Electronic Worksheets is very valid. This is evident from the results of the calculation of the average expert validation instrument showing 86,9%. In the one-to-one and small group field trials, it received a positive response from students and provided an improvement in students' collaboration skills, as seen from the results The n-gain score was 0.5 and 0.4 obtained the "moderate" category so that the STEM-PjBL-based electronic worksheets was quite effective in improving the collaboration skills of elementary school grade IV students.

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Author Contributions

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Conflicts of Interest

The authors declare no conflicts of interest.

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