Online Learning in Educational Research
Volume 4, Issue 2, 71-85.
e_ISSN: 2798-2351
https://www.journal.foundae.com/index.php/oler/index
DOI: 10.58524/oler.v4i2.401

Validity of the 'Dunya Hejo (Du-Jo)' Problem-Based Learning E-Worksheet on Climate Change and Global Warming

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Article Info

Article history:

Received: June 27, 2024
Revised: August 22, 2024
Accepted: August 25, 2024
Published: December 20, 2024

Keywords:

Climate Change;
Global Warming ;
Google Sites;
Student worksheets;
Wordwall.

Abstract

Climate change and global warming are critical environmental issues that require effective educational strategies to enhance students' understanding. Student worksheets can play a significant role in facilitating active learning on these topics. This research aims to determine and describe the validity of the "Dunya Hejo (Du-Jo)" E-Worksheet on climate change and global warming. The research method used is the Educational Design Research Plomp model. There are 3 research stages, but this research only consists of 2 stages, namely the initial investigation stage and the design stage. Because this research only describes the validity of the "Dunya Hejo (Du-Jo)" E-Worksheet. Validation was conducted by two media experts, two material experts, and five teachers. This e-worksheet will be used by high school students in class X. Validation results from the experts and teachers indicated that the "Dunya Hejo (Du-Jo)" e-Worksheet received excellent ratings for software engineering, visual communication, and learning design. Therefore, this e-worksheet is suitable for use in climate change and global warming learning activities for class X high school students.

To cite this article: Atmaja, D. Y. S., & Samsudin, A. (2024). Validity of the 'Dunya Hejo (Du-Jo)' Problem-based learning e-worksheet on climate change and global warming. *Online Learning in Educational Research, 4*(2), 71-85

INTRODUCTION

Climate change and global warming are closely tied to natural processes on Earth and are rooted in physics. This topic encompasses the causes, impacts, and potential solutions related to these pressing issues. A key concept in this discussion is the greenhouse effect, which describes how certain gases in the Earth's atmosphere trap heat, leading to an increase in temperature. (Mabsutsah & Yushardi, 2022; Panahandeh et al., 2017). The rapid rise in Earth's average surface temperature over the last century, mainly caused by greenhouse gases from human activities, is the primary force behind global warming (Li et al., 2023; Rahimi, 2021). As a result, climate change, which involves shifts in global or regional climate patterns, emerges as a significant consequence of these warming trends (Taylor et al., 2018). Grasping these ideas can be quite difficult for students. The abstract nature of the greenhouse effect and global warming involves physical processes that aren't easy to see directly (Hayati & Mufit, 2023). It can be challenging for students to grasp how these processes happen on a global scale. Often, teachers ask students to create and present related materials, but achieving a deeper understanding usually calls for more organized methods.

To address these challenges, teachers can implement various learning models in the classroom, one of which is Problem-Based Learning (PBL). In this learning model, students are

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introduced to real-life problems related to the topic, encouraging active exploration and critical thinking (Fuadiyah et al., 2022; Yulianti & Sahidu, 2020). Widiasworo (2019) in his book "Character-Based Edutainment Learning Strategy", argues that the problem-based learning model emphasizes presenting real-world, contextual problems to motivate students to learn. Students are introduced to the problem before the learning process begins, encouraging them to research, explain, and find solutions. The steps in this model include introducing students to the problem, organizing their learning activities, guiding individual and group investigations, developing and presenting their work, and evaluating the problem-solving process (Arends, 2015).

To successfully use Problem-Based Learning, teachers need resources like Learner Worksheets that are tailored to fit this model. These worksheets not only guide students through problem-solving activities but also serve different roles based on their purpose. There are five types of Learner Worksheets: one to help students discover new concepts, another to help them apply and integrate these concepts, one to guide their learning, one to reinforce concepts, and finally, one that serves as a practicum guide (Prastowo, 2014). The Learner Worksheet helps students better understand the material, providing accurate information on climate change and global warming (Akhsan et al., 2022), it also fosters effective interaction among students and boosts their engagement in achieving learning goals (Umbaryati, 2021). With advancements in technology, these worksheets are designed for both online and offline use, allowing students to work from various locations. This approach encourages independent and responsible learning (Atikah et al., 2021). Throughout the learning process, students can use their devices or laptops to access information and complete evaluations using the technology (Yumiarti & Ambiyar, 2020).

Several previous studies have developed student worksheets on the topic of global warming, such as socio-scientific issues (SSI)-based worksheets (Ameliawati et al., 2023; Rahayu et al., 2017), and integrated worksheets with terrarium media (Fajarianingtyas, 2020) to improve understanding of environmental topics like climate change and global warming, new approaches have successfully linked students to relevant social issues while promoting environmental literacy. However, most existing studies focus on delivering content or using specific media tools without incorporating a problem-based learning (PBL) approach that actively involves students in solving real-world problems. This study aims to fill that gap by integrating PBL into the development of the digital worksheet "Dunya Hejo (Du-Jo)." The worksheet not only helps students understand scientific concepts but also encourages them to engage in critical discussions and problem-solving activities that connect to their everyday experiences. Designed with interactive features like videos, animations, and platforms for immersive, inquiry-driven learning, the PBL structure pushes students to explore complex environmental issues, collaborate, and develop solutions based on scientific reasoning. The study also seeks to validate the "Dunya Hejo (Du-Jo)" e-worksheet by evaluating its content, teaching methods, and usability through expert reviews and testing with teachers and students. By bridging the gap between traditional knowledge delivery and the need for contextual problem-solving, this research offers insights into how digital learning tools can be optimized for effective science education, especially when addressing global challenges like climate change and global warming.

METHOD

Research methods

The research method used is Educational Design Research with the Plomp development model. There are 3 research stages, namely the initial investigation stage, the design stage, and the testing and evaluation stage (Jupinta & Yerimadesi, 2024; Plomp & Nieveen, 2010). Educational Design Research (EDR) is research that bridges theory and practice. For this reason, Educational Design Research (EDR) can also develop educational products, processes, programs, and policies in learning activities (McKenney & Reeves, 2019). In this research, it only reached the prototyping phase (prototype III) which included expert review and one-to-one evaluation validation. The following is the flow of the research method used.

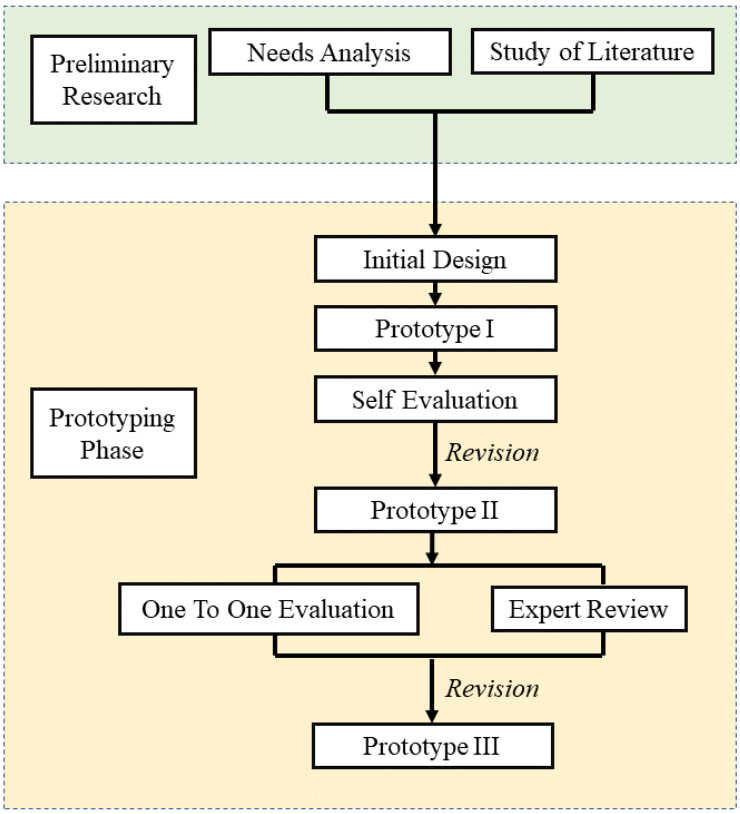


Figure 1. Flow of the Research Method

The preliminary research stage consists of needs analysis and literature study. Next, the prototyping phase is in the form of a student e-worksheet "Dunya Hejo (Du-Jo)". The design and development stage of this prototype consists of three stages, namely I, II, and II. The flow of the Plomp method will help in preparing, designing, developing, and improving the student e-worksheet "Dunya Hejo (Du-Jo)". This is because the student e-worksheet prototype "Dunya Hejo (Du-Jo)" will go through 3 forms of evaluation, namely self-evaluation, one-to-one evaluation, and expert review consisting of 2 media experts, 2 material experts, and 5 teachers.

Validation Instrument

To determine the quality of the "Dunya Hejo (Du-Jo)" student e-worksheet, a series of validations will be conducted using 26 indicators across three main aspects: learning design, software engineering, and visual communication (Fadhila, 2020; Wahono, 2006). The validation involves media experts, material experts, and teachers, who provide their assessments through a Google Forms-based questionnaire for ease of access (Ristanti, 2018). Software engineering includes indicators of effectiveness and efficiency in its use, usability/Easy to use and simple in operation, accuracy in selecting tools for development, clarity of media usage instructions, level of media durability, and compatibility/Can be run on various hardware). Visual communication includes indicators type and size of letters, moving media (animation, video), visuals (layout design, typography, color), text that can be read well, suitability of writing layout, communicative/by the message/in line with the target's wishes, creative in ideas). And learning design includes indicates the compatibility of the E-worksheet with Problem-Based Learning syntax, clarity of learning objectives, the relevance of learning objectives to the CP Curriculum, scope and depth of learning objectives, interactive, contextual, and topical, suitability of material with learning objectives, depth of material, easy to understand, systematic, coherent, clear logical flow, clarity of examples and practice questions, accuracy in selecting evaluation tools and providing feedback on evaluation results.

Internal validity in design research depends on the quality of data collection and interpretation, which leads to valid conclusions (Prahmana, 2017). Typically, validation data collection is conducted to assess the feasibility of a media before it is applied in the testing or

distribution stage. This process determines whether the media is effective in supporting the learning process. Based on the validation results, along with suggestions and feedback received, revisions and improvements will be made to enhance the quality of the developed worksheet (Selaturrohmi & Haikal, 2024). To validate the student e-worksheet "Dunya Hejo (Du-Jo), there are a total of 26 positive questions, and each answer to the indicator measured was given a Likert scale score of 1-5 (Ernawati, 2017). Information on the Likert scale used to measure indicators can be seen in Table 1.

Table 1. Likert Scale Description

Scale Score	Information
5	Very good
4	Good
3	Not good
2	Not good
1	Very not good

Data Analysis Techniques

The data obtained was then analyzed using percentages. The formula used to calculate the percentage of validation results from media, material, and teacher experts uses calculations from Rahmawati et al., (2022) as follows:

$$P = \frac{\Sigma x}{\Sigma x_m} x100\%$$

Description:
$P \quad = The\ Percentage\ of\ Achievement$
$\Sigma x \quad = Total\ scale\ score\ obtained$
$\Sigma x_m = Total\ expected\ scale\ score$

Based on the calculation results, the percentage of achievement obtained is then categorized based on Table 2.

Table 2. Assessment Categories

The Percentage of Achievement (%)	Category
$\mathbf{80 < P \leq 100}$	Very good
$\mathbf{60 < P \leq 80}$	Good
$\mathbf{40 < P \leq 60}$	Enough
$\mathbf{20 < P \leq 40}$	Less
$\mathbf{0 < P \leq 20}$	Not good

Source: Development from Husniah et al. (2020) and Riduwan (2013)

The results of this data will be analyzed using a descriptive approach to provide a comprehensive overview and draw conclusions based on the established indicators. This analysis will also identify areas that need improvement and assess the overall feasibility of the "Dunya Hejo (Du-Jo)" Student e-worksheet in enhancing students' understanding of climate change and global warming.

RESULTS AND DISCUSSION

Preliminary Research

The research began by analyzing the needs and reviewing the literature on how teachers approach teaching climate change and global warming, as well as their use of student worksheets. In the preliminary study, 21 teachers reported that they preferred assigning students to present material on these topics. However, the findings suggest that teaching methods should be more problem-based, allowing students to explore real-world facts and phenomena from their everyday lives. To support this, student worksheets should encourage research and problem-solving to

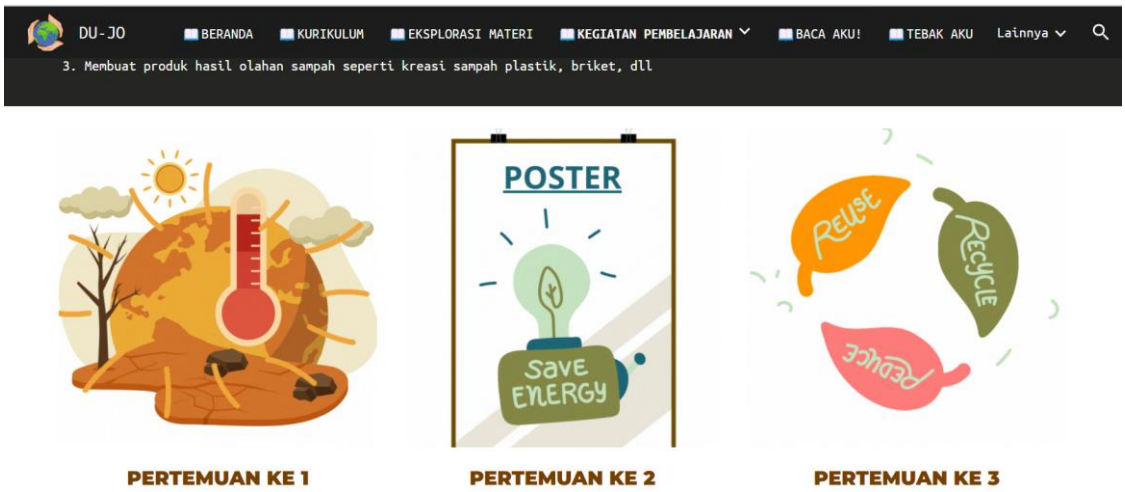
deepen students' understanding and knowledge (Ricky, 2022). According to literature studies, technology is advancing rapidly, as seen in the digitization of education. Student worksheets, once printed, are now available in electronic formats accessible via smartphones and computers. These digital worksheets can display text, images, graphics, audio, animations, and videos, enhancing the learning process (Winatha, 2018).

Prototyping Phase

Initial Design of Student e-Worksheet "Dunya Hejo (Du-Jo)" using Google Sites which is equipped with YouTube videos, games using Wordwall, and discussion display screens using Padlet. Initially, the pages on this student's e-worksheet only consisted of Home, Curriculum, Learning Activities, Read Me, and Guess Me. This is the prototype I. After carrying out a self-evaluation, Material Exploration was added with the help of several AIs in the form of Mindmaps (Chatmind) and Comics. The header section of the Student e-Worksheet "Dunya Hejo (Du-Jo)" has also been changed to be more attractive and in line with the name of this worksheet. And Figure 2 shows what prototype II looks like.

Figure 2. Initial Display

Figure 2 is the initial view of the Student e-Worksheet "Dunya Hejo (Du-Jo)". The Student e-Worksheet consists of several sections, Home, Curriculum, Material Exploration, Learning Activities, Guess Me, Read Me, Let's Test Yourself, and Profile presented in Figure 3.



(a)

(b)

(c)

Figure 3. Several Sections (a) Learning Activities (b) 1st Meeting Activities (c) "Guess Me" Display Using Wordwall

One to-One Evaluation and Expert Review

Next is the one-to-one evaluation stage by interviewing 3 students in the class with the criteria for students with high, medium, and lowest levels of understanding. It was found that the display of student e-worksheets was very attractive, there were quizzes in the form of crossword puzzles, easy to access because they did not need to be installed, and the learning activities were different from usual learning activities.

Next is the Expert Review stage where the Student e-Worksheet "Dunya Hejo (Du-Jo)" enters the evaluation stage. The Student e-Worksheet "Dunya Hejo (Du-Jo)" was tested for validation by 9 validators consisting of 2 media experts, 2 material experts, and 5 teachers with 3 assessment aspects prepared by Wahono in 2006, namely software engineering, visual communication, and learning design (Fadhila, 2020).

Media Expert Validation Data

At the stage of developing the Student e-Worksheet "Dunya Hejo (Du-Jo)", the researcher took media expert validation data carried out by the lecturer as a basis for assessing the student e-worksheet that had been created. The assessment carried out by 2 media experts covered two aspects of assessment, namely software engineering and visual communication. The results of the media expert test can be seen in Table 3.

Table 3. Media Expert Test

No.	Assessment Aspects	Indicator	Percentage of Achievement	Average Percentage of Achievement	Category
1	Software Engineering	Effective and efficient in its use	90%	90%	Very good
		Usability/ Easy to use and simple to operate	90%		

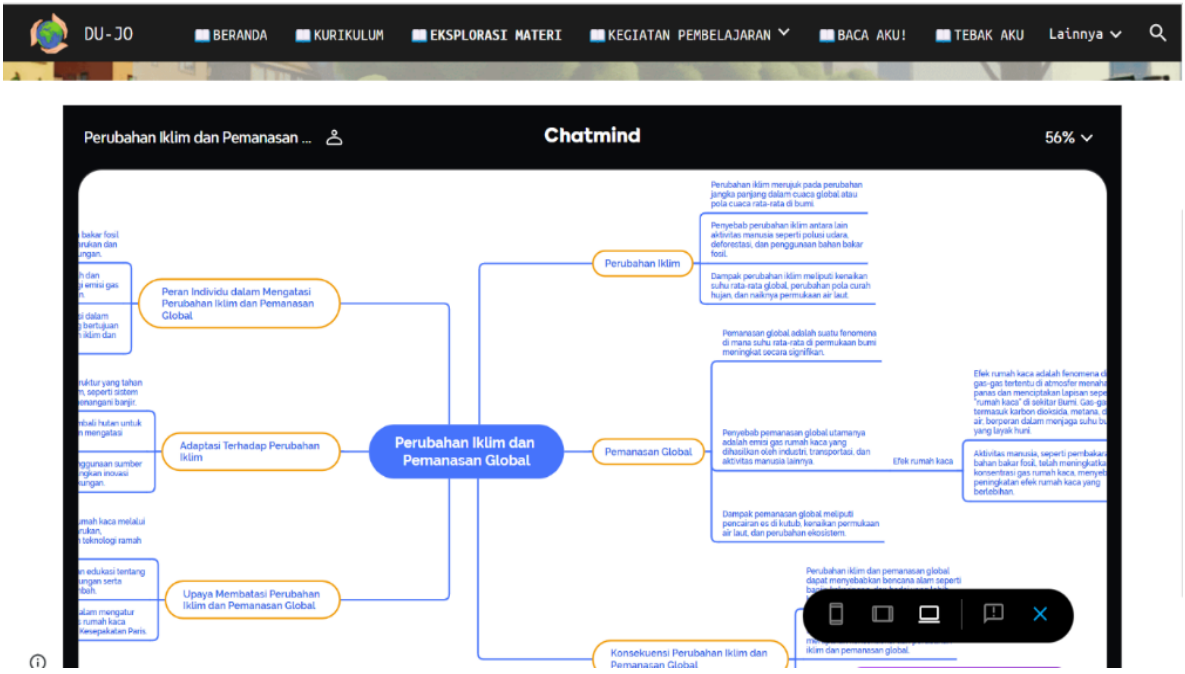
		Accuracy in choosing tools for development	90%		
		Clarity of instructions for media use	90%		
		Media durability level	100%		
		Compatibility/ Can be run on various hardware	80%		
2	Visual Communication	Font type and size	80%	89%	Very good
		Moving media (animation, video)	100%		
		Visual (layout design, typography, color)	90%		
		The text is readable well	80%		
		Suitability of writing layout	80%		
		Communicative/ In line with the message/ In line with the target's wishes	90%		
		Creative in ideas	100%		

Based on the assessment categories according to (Husniah et al., 2020) Table 3, the results of media expert interpretation show that the software engineering aspect received an average achievement percentage of 90% (very good) and the visual communication aspect 89% (very good). If examined based on each assessment aspect, for software engineering it shows that the Student e-worksheet "Dunya Hejo (Du-Jo)" is very effective and efficient in its use because on one site it can contain worksheets for all sub-material changes. climate and global warming which will be implemented during the learning process. Apart from that, students do not need to download and install various applications, it can be said that researchers are very precise in choosing media for development. The instructions given in the worksheet are also very clear. Apart from that, the Student e-Worksheet "Dunya Hejo (Du-Jo)" can be said to be very durable because it is not in physical form and can be run on various devices such as laptops or smartphones (Nurulsari et al., 2023).

For aspects of visual communication assessment, such as the selection of font type, font size, and suitability of the writing layout, it can be said to be good so that the text can be read well too. This aligns with the findings of, who noted that proportionality of font type and size, facilitates easier reading and comprehension for students (Nurhidaya et al., 2023). Apart from that, in the Student e-worksheet "Dunya Hejo (Du-Jo)" there are animations and videos that support the learning process. From a visual perspective (layout design, typography, color) this worksheet is very good. This supports the process of delivering communicative messages (Lindasari & Farida, 2021; Misbah et al., 2022; Yu et al., 2022). From the two aspects of assessment according to media experts, the Student e-worksheet "Dunya Hejo (Du-Jo)" has very good quality and can be used for teaching and learning activities in the classroom.

There were several suggestions given by media experts, such as in the "Material Exploration" section, the text used was too small and broke when zoomed in and in the "Read Me" section, media experts recommended removing the button. After carrying out the evaluation, to improve the mind mapping writing in the "Material Exploration" section, the researcher agreed to improve the student e-worksheet "Dunya Hejo (Du-Jo)" according to input from media experts. However, to eliminate the "Read Me" button, the researcher had a reason to put the "Read Me" button in the "Learning Activities" section. This is because, in the "Learning Activities" section, all learning techniques have been prepared in the student e-worksheet "Dunya Hejo (Du-Jo)". So, if the "Read Me" button is removed, this will cause teachers and students to ignore the order that has been determined. The following are the results of the improvements presented in Figure 4.

(a)



(b)

Figure 4. (a) Before revision, the writing on the mind map looks broken when zoomed in (b) After revision, mind mapping can be zoomed and the writing doesn't break.

Material Expert Validation Data

In the development stage of the Student e-worksheet "Dunya Hejo (Du-Jo)", researchers took data from the validation results of two material experts as a basis for assessment. This assessment includes aspects of learning design assessment. The results of material expert validation can be seen in Table 4.

Table 4. Material Expert Validation Data

No.	Assessment Aspects	Indicator	Percentage of Achievement	Average Percentage of Achievement	Category
1	Learning Design	Conformity of Du-Jo with Problem-Based Learning syntax	90%	91%	Very good
		Clarity of learning objectives	90%		
		The relevance of learning objectives to the CP Curriculum	90%		
		Scope and depth of learning objectives	90%		
		Interactive	100%		
		Contextual and actuality	100%		
		Suitability of material to learning objectives	100%		
		Depth of material	90%		
		Ease of understanding	90%		
		Systematic, coherent, clear logical flow	90%		
		Clarity of examples and practice questions	80%		
		Accuracy of selection of evaluation tools	90%		
		Providing feedback on evaluation results	80%		

Based on the assessment categories according to (Husniah et al., 2020), Table 4, the results of material expert interpretation show that the learning design aspect has an average achievement percentage of 91% (very good). It can be seen that the quality of the Student e-worksheet "Dunya Hejo (Du-Jo)" reflects a very good level of conformity with Problem-Based Learning syntax, clarity in writing learning objectives in the "Curriculum" section, and its relevance to achievements learning on the national curriculum. This can significantly enhance student engagement and responsibility in the learning process (Wahyuni et al., 2020). Apart from that, the scope and depth of learning objectives, interactive, contextual, and actuality of the material, are all presented very well. The depth of the material, ease of understanding learning activities and the material presented, systematic/structured sequence, clear logical flow, and selection of appropriate evaluation tools, all contribute to strengthening the effectiveness of the Student e-worksheet "Dunya Hejo (Du-Jo)" is very good at supporting the learning process. However, several aspects still need to be improved, such as clarity of examples in practice questions and feedback on evaluation results, which are currently in the good category. As studied Samosir & Simatupang (2022), student worksheets must have a clear structure, sequence, and purpose to make it easier for students to use them.

Several suggestions from material experts led to changes in the "Let's Test Yourself" section, where results were previously visible but are now hidden. The researchers decided to make it a daily test to prevent students from seeing their scores, as displaying scores through Google Forms would reveal correct and incorrect answers. This could potentially allow students to share answers, so the researchers chose to keep grades and feedback hidden. For the "Guess Me" section, it was noted that the Wordwall was moving slowly. This issue might be due to the device's quality or internet connection. Additionally, the example questions were missing from the Student e-worksheet "Dunya Hejo (Du-Jo)." The researchers plan to add these example questions to the "Read Me" section. You can see these updates in Figure 5.

Figure 5. Addition of Example Questions

Teacher Validation Data

After being validated by media and material experts, the researchers conducted trials on teachers to obtain validation data that assessed the suitability of the Student e-worksheet "Dunya Hejo (Du-Jo)". This assessment includes three aspects of assessment, namely software engineering, visual communication, and learning design. Validation results can be seen in Table 5.

Table 5. Teacher Validation Data

No.	Criteria	Assessment Aspects	Percentage of Achievement	Average Percentage of Achievement	Category
1	Software Engineering	Effective and efficient in its use	100%	95%	Very good
		Usability/ Easy to use and simple to operate	92%		
		Accuracy in choosing tools for development	96%		
		Clarity of instructions for media use	96%		
		Media durability level	88%		
		Compatibility/ Can be run on various hardware	96%		
		Font type and size	84%		
		Moving media (animation, video)	96%		
2	Visual Communication	Visual (layout design, typography, color)	100%	95%	Very good
		The text is readable well	96%		
		Suitability of writing layout	100%		
		Communicative/ In line with the message/ In line with the target's wishes	92%		
3	Learning Design	Creative in ideas	96%	97%	Very good
		Conformity of Du-Jo with Problem Based-Learning syntax	100%		
		Clarity of learning objectives	100%		
		The relevance of learning	92%		

No.	Criteria	Assessment Aspects	Percentage of Achievement	Average Percentage of Achievement	Category
		objectives to the CP Curriculum			
		Scope and depth of learning objectives	88%		
		Interactive	100%		
		Contextual and actuality	100%		
		Suitability of material to learning objectives	96%		
		Depth of material	92%		
		Ease of understanding	100%		
		Systematic, coherent, clear logical flow	96%		
		Clarity of examples and practice questions	96%		
		Accuracy of selection of evaluation tools	100%		
		Providing feedback on evaluation results	96%		

Meanwhile, based on percentage categories according to (Husniah et al., 2020), the interpretation of teacher validity results in Table 5 shows that the software engineering aspect received an average assessment percentage of 95% (very good), the visual communication aspect of 95% (very good), and learning design of 97% (very good). If we analyze various software engineering assessment indicators, it shows that the Student e-worksheet "Dunya Hejo (Du-Jo)" is very effective and efficient in its use. In one site, students can access all worksheets for all sub-materials related to climate change and global warming that will be implemented during learning activities. So, the researcher considered the choice to develop student worksheets as very appropriate. The instructions given in the worksheet are also very clear because they are in one section, namely "Learning Activities". Apart from that, the "Dunya Hejo (Du-Jo)" is very durable because it is digital, as long as the user (student/teacher) has internet access and is compatible with various devices/devices such as laptops and smartphones.

For indicators in the visual communication assessment aspect, such as the choice of font type, font size, and writing layout, it is very good so that teachers and students can read the writing on the worksheet. Apart from that, in the Student e-worksheet "Dunya Hejo (Du-Jo)" there are animations and videos that support the learning process. From a visual perspective, including layout design, typography, and color, this worksheet is very good for supporting communicative message delivery. The researcher also showed high creativity in developing the ideas on this worksheet. Meanwhile, in the learning design aspect, the Student e-worksheet "Dunya Hejo (Du-Jo)" is very by the Problem-Based Learning (PBL) syntax. Therefore, if learning objectives are clearly explained in the "Curriculum" section, learning becomes more focused and aligned with learning outcomes. In addition, the scope and depth of learning objectives, interactiveness, contextuality, and actuality of the material are all presented very well. Because teachers need to differentiate between the depth of material for lower secondary students and upper secondary students. Researchers create a flow of learning activities that is very easy to understand, systematic, and logical. The choice of Google Forms as an evaluation tool along with example questions and feedback on the evaluation results also plays a role in strengthening the effectiveness of the Student e-worksheet "Dunya Hejo (Du-Jo)".

From the results of the teacher's validation, there is input for developing better student e-worksheets, namely in the "Learning activities" section at the 1st meeting, there needs to be naming the videos displayed. Researchers also agreed and added a name to the video. The fix is shown in Figure 6.

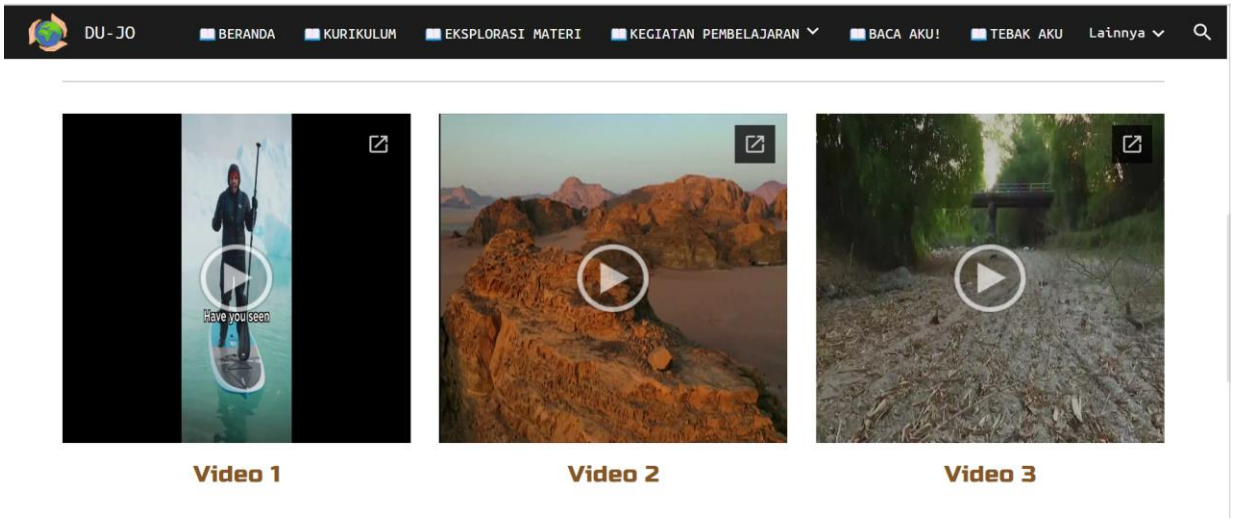


Figure 6. (a) Before revision, naming only includes the video and number

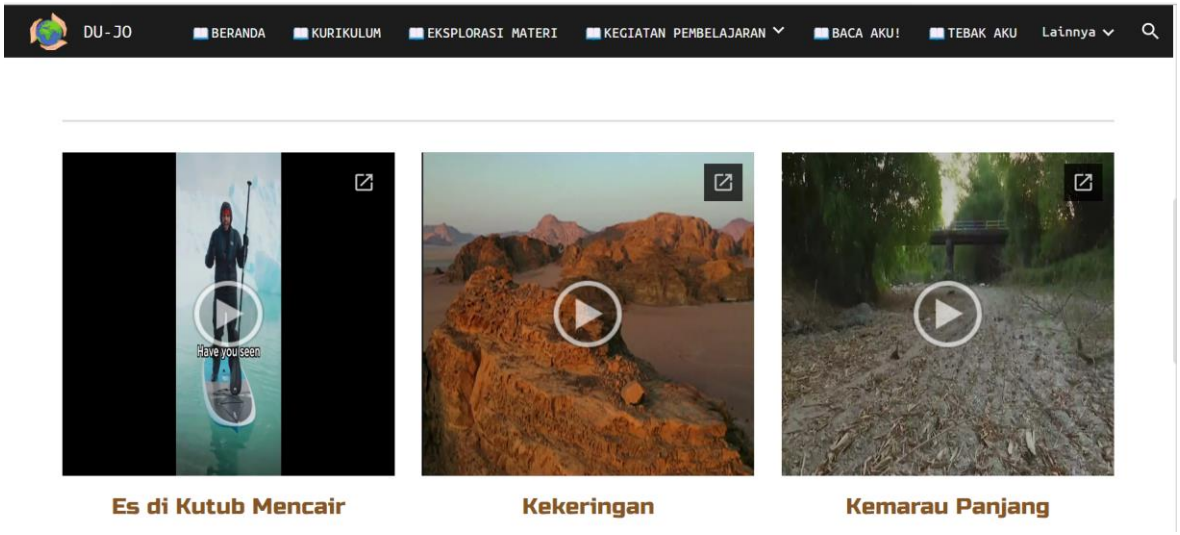


Figure 6. (b) After revision, the video has been named

After highlighting the strengths of the "Dunya Hejo (Du-Jo)" product in supporting interactive and problem-based learning, it's also important to recognize its limitations. One major issue is its dependence on technology and internet access, which might not be consistently available in all schools. Additionally, its reliance on digital platforms like Google Sites and Wordwall can be problematic if devices or internet connections are of poor quality. The limited automatic feedback in the "Let's Test Yourself" section might also impact learning effectiveness, as students don't get immediate responses. The worksheet design may not fully address the varying ability levels of students, and the content could benefit from more depth and a wider range of advanced exercises. These limitations are important to consider for future improvements to make the product more adaptable and effective in different learning environments.

Despite these limitations, this research makes an important contribution to the development of innovative digital learning materials, particularly a Problem-Based Learning (PBL) Student e-worksheet for climate change and global warming topics. The integration of multimedia elements such as videos, animations, and interactive platforms in the "Dunya Hejo (Du-Jo)" worksheet reflects advancements in educational technology usage. This research also helps address the gap in developing student worksheets that not only focus on knowledge transfer but also emphasize student engagement in contextual problem-solving. Consequently, this study enriches the discourse on the effectiveness of using digital media to support interactive, problem-based learning processes.

CONCLUSION

Overall, the validation results from media experts, material experts, and teachers were quite positive. The "Dunya Hejo (Du-Jo)" Student e-worksheet was found to be very effective in terms of software engineering, visual communication, and learning design. It's suitable for teaching climate change and global warming to high school students in grade X. However, this study only involved expert and teacher validation and didn't include trials to assess the worksheet's effectiveness in a broader learning context. To get a fuller picture of its impact and benefits, further research should test the worksheet in a variety of learning environments.

ACKNOWLEDGEMENT

The author would like to thank the Education Fund Management Institute (LPDP/Indonesia Endowment Fund for Education) and the Ministry of Education, Culture, Research and Technology in Indonesia for supporting the publication of this article.

AUTHOR CONTRIBUTIONS

DYSA led the research design, execution, data collection, statistical analysis, and initial drafting of the manuscript. AS contributed to the development of visual tools, assisted in data collection, and played a significant role in the study design, and data analysis interpretation, as well as reviewing and revising the manuscript for intellectual depth and content.

REFERENCES

Akhsan, H., Sudirman, S., Syuhendri, S., Ariska, M., Laras Sapitri, C., & Mindia Vanessa Pratiwi, S. (2022). Pelatihan pembuatan lkpd berbasis projek untuk topik pemanasan global dan perubahan iklim untuk guru fisika MGMP Kabupaten Ogan Ilir. *Jurnal Pendidikan Dan Pengabdian Masyarakat*, *5*(4), 328–332. https://doi.org/10.29303/jppm.v5i4.4065

Ameliawati, M., Pramadi, A., Maspupah, M., & Ukit, U. (2023). The validity of developing student worksheets based on socio-scientific issues (SSI) on climate change materials. *AIP Conference Proceedings*, *2572*(1).

Arends, R. I. (2015). *Learning to teach ninth edition* (9th ed.). Library of Congress Cataloging.

Atikah, N., Gistituati, N., Fitria, Y., & Syarifuddin, H. (2021). Validitas e-modul matematika sekolah dasar berbasis pendekatan realistic mathematics education (RME). *Jurnal Basicedu*, *5*(6), 6103–6109. https://doi.org/10.31004/basicedu.v5i6.1799

Ernawati, I. (2017). Uji kelayakan media pembelajaran interaktif pada mata pelajaran administrasi server. *Elinvo (Electronics, Informatics, and Vocational Education)*, *2*(2), 204–210. https://doi.org/10.21831/elinvo.v2i2.17315

Fadhila, M. (2020). Pengembangan media pembelajaran berbasis android pada materi proyeksi ortogonal. *Repository.Upi.Edu*.

Fajarianingtyas, D. A. (2020). Improvement of science process skills through development of work sheets integrated by terrarium media global warming materials. *Indonesian Journal of Science and Education*, *4*(2), 132–138.

Fuadiyah, M., Norra, B. I., & Astutik, F. (2022). Biology learning model to improve critical thinking skills of ten grade students: A meta-analysis. *Assimilation Indonesian Journal of Biology Education*, *5*(2), 101–112. https://doi.org/10.17509/aijbe.v5i2.46084

Hayati, M., & Mufit, F. (2023). *Needs analysis of cognitive conflict teaching materials integrated with augmented reality global warming material*. *1*(4), 204–210. https://doi.org/10.24036/ple.v1i4.55

Husniah, L., Prihatiningtyas, S., & Putra, I. A. (2020). Pengembangan media pembelajaran video stop motion materi fluida statis. *Jurnal Riset Dan Kajian Pendidikan Fisika*, *7*(1), 15. https://doi.org/10.12928/jrkpf.v7i1.14625

Jupinta, A., & Yerimadesi, Y. (2024). Validitas e-modul termokimia berbasis guided discovery learning untuk fase F kelas XI SMA/MA. *Jurnal Pendidikan Tambusai*, *8*(1), 5289–5299. https://doi.org/https://doi.org/10.31004/jptam.v8i1.13210

Li, C., Yang, F., Xiao, Q., & Gao, Y. (2023). Climate change and its impacts on terrestrial ecosystems: recent advances and future directions. *Atmosphere*, *14*(7), 1176. https://doi.org/10.3390/atmos14071176

Lindasari, L. M., & Farida, F. (2021). Interactive learning media with realistic mathematics approach: Facilitating distance learning on linear program materials. *Online Learning in Educational Research*, *1*(1), 37–48.

Mabsutsah, N., & Yushardi, Y. (2022). Analisis kebutuhan guru terhadap e module berbasis steam dan kurikulum merdeka pada materi pemanasan global. *Jurnal Pendidikan Mipa*, *12*(2), 205–213. https://doi.org/10.37630/jpm.v12i2.588

McKenney, S., & Reeves, T. C. (2019). Conducting educational design research. In *Conducting Educational Design Research*. https://doi.org/10.4324/9781315105642

Misbah, M., Noor, R. N. F., Zainuddin, Z., Hartini, S., & Dewantara, D. (2022). Blended learning with schoology in impulse and momentum materials: The development of physics teaching materials. *Online Learning In Educational Research (OLER)*, *1*(2), 63–73. https://doi.org/10.58524/oler.v1i2.47

Nurhidaya, N., Adnan, A., & Muis, A. (2023). Practicality test of hots-based worksheet on evolution topic for high school students. *Jurnal Biolokus*, *6*(1), 1. https://doi.org/10.30821/biolokus.v6i1.1641

Nurulsari, N., Viyanti, V., & Yassine, B. (2023). HOTS-oriented student worksheets with blended learning: Improving students' science process skills. *Online Learning In Educational Research (OLER)*, *3*(1), 47–58.

Panahandeh, A., Asadollahfardi, G., & Mirmohammadi, M. (2017). Life cycle assessment of clinker production using refuse-derived fuel: A case study using refuse-derived fuel from tehran municipal solid waste. *Environmental Quality Management*, *27*(1), 57–66. https://doi.org/10.1002/tqem.21513

Plomp, T., & Nieveen, N. M. (2010). *An introduction to educational design research: Vol. 3rd print* (N.M. Nieveen (ed.)). Stichting Leerplan Ontwikkeling (SLO).

Prahmana, R. C. I. (2017). Design research. In *RAJAWALI PERS* (Vol. 4, Issue 1). PT RajaGrafindo Persada.

Prastowo, A. (2014). *Panduan kreatif membuat bahan ajar inovatif*. Diva Press.

Rahayu, S., Meyliana, M., Arlingga, A., Reny, R., Siahaan, P., & Hernani, H. (2017). Development of lesson plans and student worksheets based socio-scientific issues on pollution environmental topic. *Journal of Physics: Conference Series*, *895*(1), 12150.

Rahimi, M. (2021). Lithium-Ion batteries: Latest advances and prospects. *Batteries*, *7*(1), 8. https://doi.org/10.3390/batteries7010008

Rahmawati, N. I., Fiteriani, I., & Diani, R. (2022). Articulate storyline-based interactive learning media with character values on natural science learning for 10-11 years old students. *Online Learning In Educational Research (OLER)*, *2*(1), 31–47. https://doi.org/10.58524/oler.v2i1.119

Ricky, A. (2022). *Pengembangan LKPD elektronik (E-LKPD) interaktif berbasis keterampilan berpikir kreatif (creative thinking) pada konsep perubahan lingkungan*. UIN Syarif Hidayatullah Jakarta.

Riduwan. (2013). *Skala pengukuran variabel-variabel penelitian*. Alfabeta.

Ristanti, A. D. D. R. (2018). Kelayakan buku ajar berbasis etnosains pada materi pencemaran lingkungan untuk melatihkan berpikir kritis siswa SMP. *E-Jurnal Pensa*.

Samosir, K., & Simatupang, N. (2022). Analisis validitas dan praktikalitas terhadap pengembangan lembar kerja peserta didik (LKPD) berbasis masalah pada materi statistik. *Jurnal Fibonaci: Jurnal Pendidikan Matematika*, *3*(1), 22. https://doi.org/10.24114/jfi.v3i1.35078

Selaturrohmi, & Haikal, M. (2024). Validitas modul sistem pencernaan manusia berbasis problem based learning di MA sirojut tholibin taman sari pamekasan. *Journal of Authentic Research*, *3*(1), 1–9. https://doi.org/https://doi.org/10.36312/jar.v3i1.1477

Taylor, M., Lamm, A. J., Israel, G. D., & Rampold, S. D. (2018). Using the six americas framework to communicate and educate about global warming. *Journal of Agricultural Education*, *59*(2), 215–232. https://doi.org/10.5032/jae.2018.02215

Umbaryati. (2021). Pentingnya LKPD pada pendekatan scientific pembelajaran matematika

pentingnya LKPD pada pendekatan scientific pembelajaran matematika umbaryati. *Prisma*, 218–221.

Wahono, R. S. (2006). Aspek dan kriteria penilaian media pembelajaran. *Online)(Http://Romisatriawahono. Net/, Diakses Pada Tanggal 20 Mei 2016)*.

Wahyuni, R., Efuansyah, E., & Sukasno, S. (2020). Developing student worksheet based on missouri mathematics project model by using think-talk-write strategy of class VIII. *Infinity Journal*, *9*(1), 81. https://doi.org/10.22460/infinity.v9i1.p81-92

Widiasworo, E. (2019). *Strategi pembelajaran edutainment berbasis karakter*. Ar-Ruzz Media.

Winatha, K. R. (2018). Pengembangan e-modul interaktif berbasis proyek mata pelajaran simulasi digital. *Jurnal Pendidikan Teknologi Dan Kejuruan*, *15*(2). https://doi.org/10.23887/jptk-undiksha.v15i2.14021

Yu, G., Akhter, S., Kumar, T., Ortiz, G. G. R., & Saddhono, K. (2022). Innovative application of new media in visual communication design and resistance to innovation. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.940899

Yulianti, F., & Sahidu, H. (2020). Pengaruh model giving question getting answers melalui metode eksperimen terhadap motivasi dan hasil belajar. *ORBITA: Jurnal Pendidikan Dan Ilmu Fisika*, *6*.

Yumiarti, D. S., & Ambiyar. (2020). Evaluation of online learning during the covid-19 pandemic on Universitas Negeri Padang. *Edutec: Journal of Education and Technology*, *3*(2), 161–173.