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Improving Computational Thinking & Creative Problem Solving: ESD & Micro:bit for Climate

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ABSTRACT
This study aims to validate the Student Worksheet titled "ESD-Climate Change," developed using the Understanding by Design approach and complemented by Micro:bit devices. The validation was conducted by three experts, including two academic experts in education and one distinguished educator. Main findings from this study is the validation results reveal that this worksheet adheres to high standards. The "Content" dimension achieved a score of 84.33%, labeled "Very Suitable," signifying its strong relevance to climate change-related learning objectives. The "Construct" dimension garnered a score of 79.17%, categorized as "Suitable," indicating potential for improvement in some construction aspects. The "Language" dimension received an impressive score of 85.90%, also labeled "Very Suitable," highlighting its excellent language quality and communication proficiency. Finally, the "Design" dimension received the highest score of 95.18%, categorized as "Very Suitable," affirming the worksheet's strong design, encompassing its cover and content presentation. Overall, these findings underscore the worksheet's high quality in terms of content, language, and design, with minimal room for improvement in the construction aspect. This study contributes to the development of technology and environment-centered educational materials, which are increasingly pertinent in addressing future challenges associated with climate change.

Keywords: *ESD, computational thinking, creative problem solving*

INTRODUCTION

Education for Sustainable Development (ESD) is an essential foundation in equipping young people with an understanding of global issues, such as climate change, to create a more sustainable society (Hobusch & Froehlich, 2021; Peedikayil et al., 2023; Rozhdestvenskaya & Korotenko, 2020; Sund & Gericke, 2020). ESD aims to develop the knowledge, skills, attitudes, and values necessary for students to participate in sustainable development actively (Ershad et al., 2022; Weber et al., 2022; Zwolińska et al., 2022). Its application in schools has excellent benefits in shaping students' sustainable thinking and acting anxiety (Badea et al., 2020; González-Sánchez et al., 2022; Perkiss et al., 2020). However, some obstacles arise in the implementation of ESD in schools. One of the main obstacles is the lack of a proper approach to integrating ESD into the curriculum (Fukui et al., 2021; Kemal & Altan, 2021a; Lemarchand et al., 2023a; Menton et al., 2020; Mohd Zaki & Mohammad Zohir, 2021; Rasaili et al., 2021). One emerging solution is applying the Understanding by Design (UbD) approach. This approach emphasizes learning planning that focuses on deep understanding and application of knowledge in authentic contexts (Harpaz, 2022; Kimsesiz, F. Dolgunsoz, E., & Konca, 2017; Tshering, 2022; Uluçınar, 2021). By implementing UbD, educators can address the challenges of integrating ESD into the curriculum in contextualized and relevant ways (Chunpungsuk et al., 2021; Gombu et al., 2022; Harpaz, 2022; Llerena, 2020; Pramesti & Dewi, 2023; Rubio, 2022; Tung, 2020).

A vital advantage of the Understanding by Design approach is its ability to create meaningful and contextual learning, which aligns with ESD principles (Kuntari et al., 2019; OZYURT et al., 2021; Young & Young, 2020). In addition, this approach also allows the development of a variety of essential skills, including the ability to solve problems, computational thinking, and creative problem-solving. Previous research has shown the success of UbD in improving students' under-standing and developing higher thinking skills (Florian & Zimmerman, 2015; Gloria et al., 2018; Neill & Neill, 2019; OZYURT et al., 2021; S. Pertiwi et al., 2019; Rosanti et al., 2019; Setyanto et al., 2018; Young & Young, 2020).

Computational thinking and creative problem-solving skills are essential to stu-dents' lives and futures (Bilbao et al., 2021a; Esteve-Mon et al., 2020; Kelly & Gero, 2021a; Palts & Pedaste, 2020). In this digital age, computational thinking is indispensable for dealing with the ever-evolving work and technology demands (Bilbao et al., 2021a; Esteve-Mon et al., 2020; Kelly & Gero, 2021a; Li et al., 2020c, 2020a; Ortiz & Pereira, 2020a; Palts & Pedaste, 2020). Meanwhile, creative problem-solving allows students to face complex everyday and work challenges (Demir & Açıkgül, 2021a; Kartikasari et al., 2022a; Khalid et al., 2020a; Kovari & Rajcsanyi-Molnar, 2020a; Maliakkal & Reiter-Palmon, 2023a; Utari et al., 2023a). Therefore, developing these skills in school is a significant step.

While the importance of ESD and the UbD approach is recognized, their implementation in practice remains suboptimal. Many schools have yet to fully integrate ESD into their curricula (Peedikayil et al., 2023; Weber et al., 2022; Zwolińska et al., 2022) and UbD-based learning is not yet commonplace (Gloria et al., 2018; S. Pertiwi et al., 2019; Rosanti et al., 2019; Setyanto et al., 2018). A preliminary study of 90 teachers across different regions highlights a significant need for improvement in implementing these two approaches. Furthermore, a new curriculum in Indonesia emphasizes equipping students with skills to solve community problems by applying classroom learning (Hamdi et al., 2022; Herwanti et al., 2022; Novita et al., 2022; P. D. Pertiwi et al., 2023; Prihatini & Sugiarti, 2022; Setiawan & Suwandi, 2022).

This study aims to address these gaps by developing UbD-based learning for computational thinking and creative problem-solving skills within the Climate Change learning unit. The primary focus is on validating the "ESD-Climate Change" Student Worksheets, intended for implementation in secondary schools as a step towards enhancing students' understanding and skills related to climate change and ESD. By combining ESD, UbD, and Micro:bit technology, this research offers an innovative approach to preparing the younger generation to face the challenges of climate change and become sustainable agents of change.

METHODOLOGY

The primary objective of this research is to develop innovative and effective student worksheet for teaching climate change in secondary schools. This worksheet is designed to enhance students' computational thinking and creative problem-solving skills, utilizing the Understanding by Design (UbD) approach and Micro:bit technology. The development of this worksheet followed the 4-D model (Define, Design, Develop, Disseminate) proposed by Thiagarajan (1974).

In the Define stage, the researchers conducted preliminary research in the form of a needs analysis by distributing questionnaires to 90 respondents, consisting of 45 male teachers and 45 female teachers. These teachers were selected as respondents because they teach physics at the secondary school level in several districts in Lampung. Thus, they can provide valuable insights into the implementation of climate change education in their classrooms, including the challenges faced and the need for more effective learning resources.

Table 1. General Procedure of 4D

	Define	Design	Develop	Disseminate
Concept	Defining needs in the development	Designing products according to needs	Developing product	Application to real targets
General Procedure	1. Curriculum Analysis (Learning concepts and objectives) 2. Analysis of teacher needs 3. Learner needs analysis	1. Specify the product format. 2. Specify media or content. 3. Make a preliminary storyboard. 4. Designing data collection instruments	1. Developing product 2. Expert Test (validity and practicality) 3. Teacher's response to developed worksheet 4. Limited Trials (Readability test, practicality test)	1. Product application to the actual target 2. Product effectiveness test 3. Publication of application results and effectiveness tests
	Analysis Summary	**Initial Design and Data Collection Instruments**	**Ready-to-apply product**	**Publish-ready product**

After the needs analysis, the researchers proceeded to the worksheet development stage. In this stage, the researchers involved 3 validators consisting of 2 physics education lecturers and 1 physics teacher who has completed a master's degree and holds a teaching certificate. These validators were chosen based on their expertise in physics learning design and experience in teaching physics in schools. The input from these experts is crucial to ensure the quality and relevance of the developed worksheets.

Therefore, this study not only develop innovative worksheets but also ensures that these worksheets are aligned with the needs of students and teachers in the field and meet the quality standards set by experts in the field of physics education. The product development stage is shown in Figure 1.

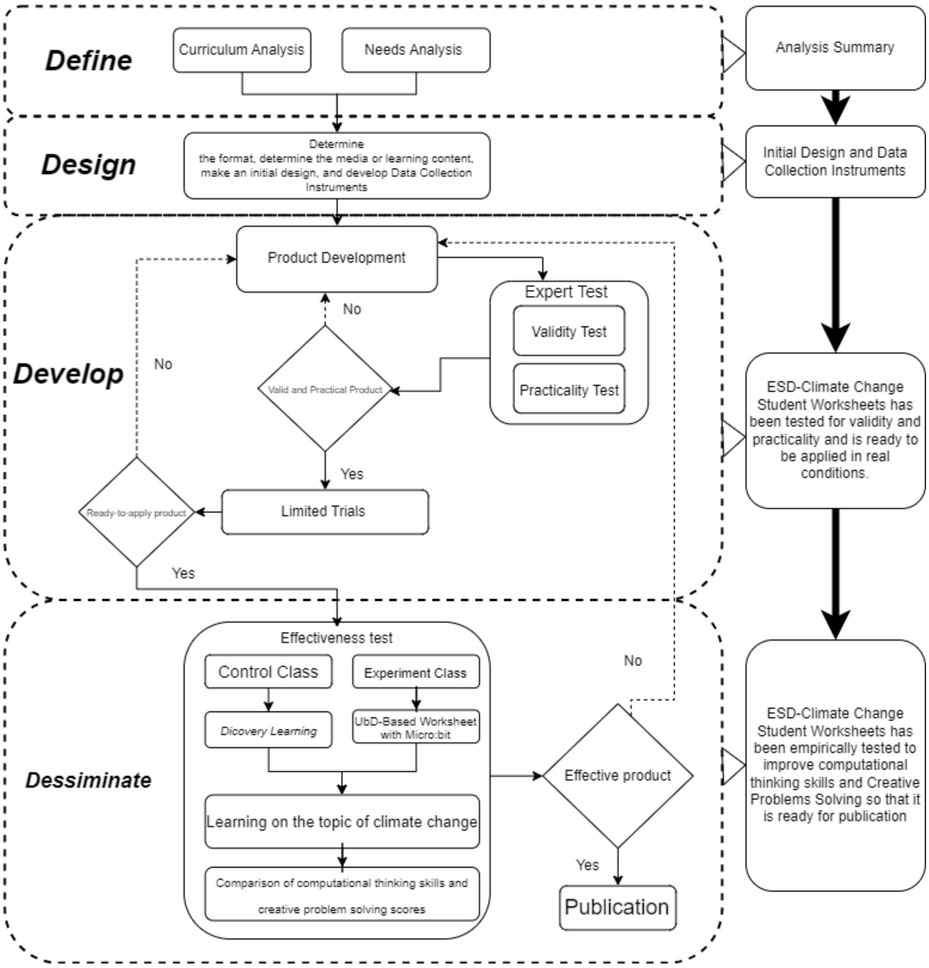

Figure. 1. Flowchart of ESD-Climate Change student worksheet development

The validity test scale is used to determine the validity of the worksheet from the dimensions of content, construct, language, and design. The validity test is carried out by three experts, who check the validity of the product developed by filling out the validity test scale that has been prepared. In the scale, experts are also allowed to provide feedback on the product that has been developed and advise on whether the product is feasible or not to use. Table 2 shows the aspects assessed in the validity test.

Table 2. Aspects assessed in the validity test.

Validity	Aspects	Number of Statement
Content	Worksheet step presentation	13 Items
	Social System	3 Items
	Reaction principle	4 Items
	Support System	2 Items
	Instructional and Nurturant effect	3 Items
Construct	Description /step / Presentation of Worksheet	4 Items
	Social system	9 Items
	Reaction principle	4 Items
	Support System	5 Items
	Instructional and Nurturant effect	4 Items
Language	Straightforward	3 Items
	Communicative	3 Items
	Dialogical and Interactive	1 Item

Validity	Aspects	Number of Statement
	Suitability to the level of development of learners	2 Items
	Demand ability and cohesiveness of mindsets	2 Items
	Use of terms, symbols, or icons	2 Items
Design	Cover	9 Items
	Content	10 Items

Each statement item on the scale is given a choice of scores of 1-4 with criteria that are not suitable, less suitable, suitable, and very suitable. The data analysis is done by summing the scores of each statement item and calculating the presentation of each dimension of validity. The presentation results are then converted to the criteria available in Table 3. A product is considered valid if each dimension of validity meets a percentage of at least 60%.

Table 3. Validity Assessment Criteria

Range			Criteria
25%	< score <	43,75 %	Not suitable
43,75%	< score <	62,50 %	Less suitable
62,50%	< score <	81,25 %	Suitable
81,25%	< score ≤	100 %	Very suitable

RESULT AND DISCUSSION

The define stage summarized the analysis derived from curriculum analysis and teacher and student needs analysis. Based on the results of this analysis, researchers designed a worksheet that will be developed to determine the format, determine the media or learning content, make an initial design, and develop Data Collection Instruments. Researchers also created storyboards that become designs of worksheet. Furthermore, at the development stage, researchers began to develop worksheets to produce products that matched the storyboard's design. Figure 2 shows the cover section and some pages contained in the worksheet.

(a) (b) (c)

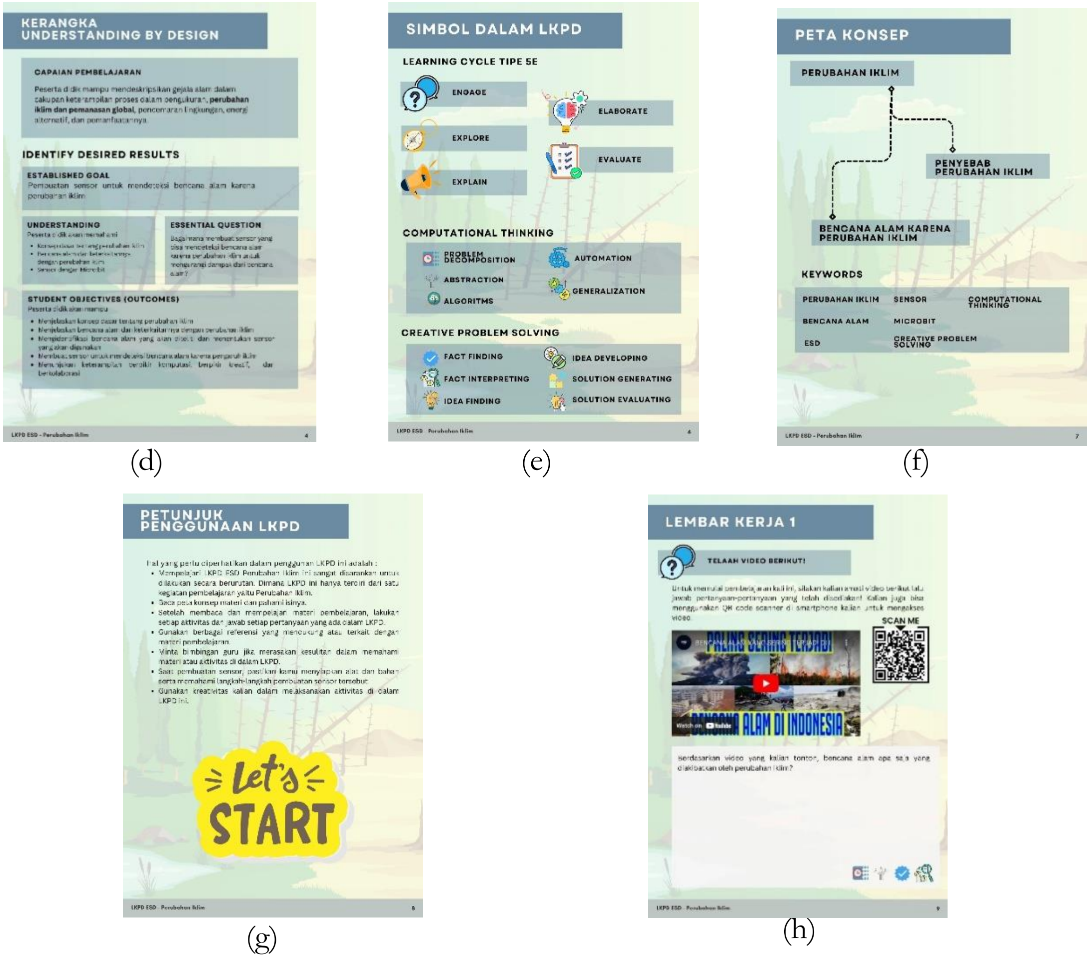

Figure 2. (a) Cover; (b) Preface (c) Table of Content; (d) UbD Framework; (e) Symbol Explanation; (f) Mind Map; (g) Instructions for use; and (h) Activity Sheet

After the product is successfully developed, the product is then tested by three experts using the validity scale. The validity test result for Worksheet content can be seen in Table 4.

Table 4. The validity test result for Worksheet content.

Validity	Aspects	Average Score From 3 Validators	Percentage (%)	Criteria
Content	Worksheet step presentation	45.0	86.54	Very suitable
	Social System	11.7	97.22	Very suitable
	Reaction principle	11.0	68.75	Suitable
	Support System	7.3	91.67	Very suitable
	Instructional and Nurturant effect	9.3	77.78	Suitable
Average percentage			**84.3**	**Very suitable**

Table 4 shows that the ESD-Climate Change Worksheet is very suitable for content. Meanwhile, the construct validity test result can be seen in Table 5.

Table 5. The validity test result for Worksheet construction.

Validity	Aspects	Average Score From 3 Validators	Percentage (%)	Criteria
Construct	Description /step / Presentation of Worksheet	13.0	81.25	Suitable
	Social system	31.0	86.11	Very suitable
	Reaction principle	12.3	77.08	Suitable
	Support System	13.0	65.00	Suitable
	Instructional and Nurturant effect	13.0	81.25	Suitable
Average percentage			**79.17**	**Suitable**

Table 5 shows that the ESD-Climate Change Worksheet is suitable for construction. Next, the language validity test result can be seen in Table 6.

Table 6. The validity test result for Worksheet language.

Validity	Aspects	Average Score From 3 Validators	Percentage (%)	Criteria
Language	Straightforward	10.7	88.89	Very suitable
	Communicative	10.3	86.11	Very suitable
	Dialogical and Interactive	3.0	75.00	Suitable
	Suitability to the level of development of learners	7.0	87.50	Very suitable
	Demand ability and cohesiveness of mindsets	6.3	79.17	Suitable
	Use of terms, symbols, or icons	7.3	91.67	Very suitable
Average percentage			**85.90**	**Very suitable**

Table 6 shows that the ESD-Climate Change Worksheet is very suitable for language. Lastly, the design validity test result can be seen in Table 7.

Table 7. The validity test result for Worksheet design.

Validity	Aspects	Average Score From 3 Validators	Percentage (%)	Description
Design	Cover	35.7	99.07	Very suitable
	Content	36.7	91.67	Very suitable
Average percentage			**95.18**	**Very suitable**

Table 7 shows that the ESD-Climate Change Worksheet is very suitable for design. Furthermore, based on the validity tests of the dimensions of content, construct, language, and design, researchers determined that the ESD-Climate Change Worksheet was feasible or valid for learning about climate change in grade X phase E of high school.

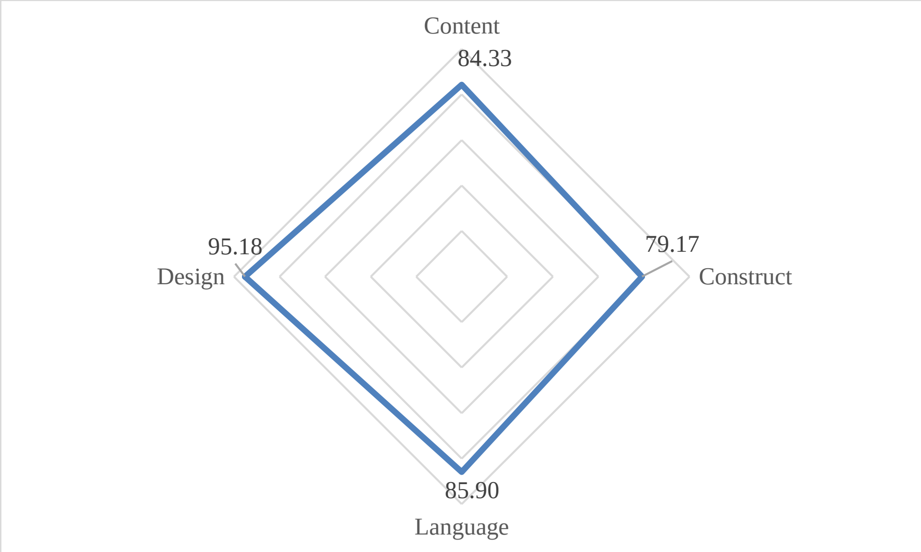

Figure. 3. Recapitulation percentage of validity test result

The development of the ESD-Climate Change worksheet begins with the process of curriculum analysis and analysis of the needs of students and teachers. For curriculum analysis, researchers found that the topic of climate change is part of the learning outcomes in phase E of class X. From the learning outcomes provided by the government, researchers then describe the learning objectives following these achievements. Meanwhile, researchers also conducted a preliminary study by distributing questionnaires to several teachers and students. This preliminary study gave researchers insight into the need to develop worksheets that help teachers develop computational thinking skills and creative problem-solving. Because so far, these two skills have not been optimally developed in learning. Next, the researcher designs the worksheet to be created. This design includes determining the format of the worksheet, the media and activities that appear in the worksheet, and the storyboard of the worksheet as a preparation guide. In addition, researchers also compile instruments that will be used to test the validation, practicality, and effectiveness of worksheets.

At the development stage, researchers begin to compile worksheets based on designs that have been made. The worksheets were created using the Canva application and compiled using the UbD teaching approach and the Cycle 5E learning model. The UbD learning approach and the Cycle 5E learning model have been tested to improve higher-order thinking skills, including computational thinking skills and *creative problem-solving*. In addition, researchers also included activities to make natural disaster sensors with the help of Micro: bit.

The activity is part of introducing the Internet of Things to students and is expected to provide a comprehensive experience for students to formulate solutions to overcome the problems they find related to climate change. The worksheets developed have been carefully designed to facilitate effective learning in the context of Climate Change, focusing on developing students' computational thinking and creative problem-solving skills. Table 8 reflects different stages of learning, designed to introduce students to climate change issues, help them understand the relationship between climate change and natural disasters, and teach them how to find creative solutions to address climate change.

In the engage stage, learning activities begin by examining videos related to natural disasters caused by climate change. This activity aims to get students to "engage" in the issue of climate change in an exciting way. In addition, students are also asked to explain the relationship between natural disasters and climate change. This activity introduces computational thinking skills such as problem-solving and abstraction, which are necessary to understand and detail more significant problems (Bilbao et al., 2021b; Li et al., 2020d, 2020b). In explaining such relationships, students use algorithmic skills and generalizations, which are the foundation of computational thinking (Li et al., 2020b; Ortiz & Pereira, 2020b). At the same time, this activity also encourages students to look up facts and interpret them, which is an essential part of computational thinking and creative problem-solving skills (Demir & Açıkgül, 2021b; Khalid et al., 2020b; Utari et al., 2023b).

In the explore stage, students are invited to explain the definition of climate change and the causes of climate change. This activity requires problem-solving skills and abstraction because students must break down complex concepts into simpler components. It involves computational thinking skills such as problem-solving and abstraction (Bilbao et al., 2021b; Li et al., 2020d). In addition, students are invited to find alternative solutions to address climate change, involving algorithm and automation skills. At this stage, they are also given the task of determining the most effective solution, which requires generalization ability (Bilbao et al., 2021b; Kelly & Gero, 2021b; Li et al., 2020d, 2020b; Ortiz & Pereira, 2020b).

In the explain stage, students are asked to present their findings from the exploration stage. It is an essential step in developing speaking and communication skills, which are also important aspects of computational thinking and creative problem-solving. This activity encourages students to develop ideas and articulate their ideas effectively(Bilbao et al., 2021b; Demir & Açıkgül, 2021b; Kartikasari et al., 2022b; Khalid et al., 2020b; Li et al., 2020d; Utari et al., 2023b). It contributes to idea-finding and idea-developing skills that become important to creative problem-solving.

At the elaboration stage, students will be experts in efforts to deal with natural disasters caused by climate change. These role-play activities involve problem-solving, abstraction, algorithmic, automation, and generalization skills, all of which are computational thinking skills (Bilbao et al., 2021b; Kelly & Gero, 2021b; Li et al., 2020d, 2020b; Ortiz & Pereira, 2020b). They were also asked to create sensors to address natural disasters caused by climate change using Micro: bit, which involves algorithmic, automation, and generalization skills (Bilbao et al., 2021b; Li et al., 2020d, 2020b). At this stage, students are invited to develop creative solution ideas and the ability to generate solutions (Demir & Açıkgül, 2021b; Khalid et al., 2020b; Maliakkal & Reiter-Palmon, 2023b). This activity also involves interpreting facts and information needed to solve problems (Khalid et al., 2020b; Kovari & Rajcsanyi-Molnar, 2020b; Utari et al., 2023b).

Lastly, the evaluation phase involves testing the sensors that the student has created. It requires algorithmic, automation, and generalization skills in testing and evaluating the effectiveness of sensors that have been created (Kemal & Altan, 2021b; Lemarchand et al., 2023b). Thus, this activity contributes to students' ability to evaluate the solutions they develop (Demir & Açıkgül, 2021b; Maliakkal & Reiter-Palmon, 2023b).

After the worksheet is developed according to the purpose, which is to improve computational thinking skills and creative problem solving, the worksheet is then tested for validity by three experts using a validity test scale. The validity test results in Table 4 show that the worksheet developed has aspects of content that are very appropriate and relevant, support social solid interaction and provide good support for the learning process. Although aspects of reaction principles require further attention to encourage active student participation and instructional and pedagogical effects can be improved, average percentages of all aspects still indicate that this worksheet is appropriate and relevant to climate change-related learning objectives (Jusmawati et al., 2021; Mulyani, 2021; Suryanto et al., 2022).

Furthermore, the results of the construct validity test in Table 5 show that the worksheet developed has several aspects that require further attention to improve its quality. The social system and instructional and nurturant effect aspects received very appropriate and relevant assessments, but the support system and reaction principal aspects scored lower, indicating the need to increase support for students and encourage positive reactions from them. The average percentage of all aspects is 79.17%, categorized as "Suitable." With this understanding, there must be efforts to improve aspects to ensure that worksheets are more effective in the learning process (Fatmawati et al., 2021; Maharani et al., 2023; Muliyati et al., 2020a, 2020b).

In addition, the results of the validity test in Table 6 showed that aspects of language quality in the worksheet developed received a firm assessment. The language in this worksheet is considered very appropriate, with aspects such as "Straightforward," "Communicative," and "Suitability to the level of development of learners" rated "Very suitable." Although there are some slightly lower ratings on "Dialogical and Interactive" and "Demand ability and cohesiveness of mindsets," the average percentage of all aspects is 85.90%, indicating that this worksheet is very suitable for language quality and communication skills. It supports ease of understanding and effective communication in the learning process (Haerani et al., 2023; Muliyati et al., 2022; Susanti & Wulandari, 2022).

Finally, the results of the validity test in Table 7 show that the design and content aspects of the worksheet developed received a very high rating. The "Design" aspect, including the assessment of the worksheet cover, obtained a very high score of 99.07%, while the "Content" aspect obtained a score of 91.67%. These results show that this worksheet is very suitable in terms of design, including physical appearance and presentation of its content. In addition, the worksheet's content is also very appropriate, showing that the material presented is following learning needs and relevant to the topic of climate change. The average percentage of all aspects is 95.18%, which indicates that this worksheet is very suitable in design and content and meets high-quality standards. It will support the effectiveness and attractiveness of the worksheet in the learning process (Haerani et al., 2023; Marwan Pulungan et al., 2022; Susanti & Wulandari, 2022; Usman Rery & Anwar, 2024).

The percentage of validity tests in Figure 3 shows that the worksheet developed received very positive assessments in various categories. The "Content" dimension obtained a score of 84.33%, with the category "Very Suitable," indicating that the worksheet content is very appropriate and relevant to climate change-related learning objectives. The "Construct" dimension obtained a score of 79.17% with the category "Suitable," indicating that there is potential for improvement in several aspects of worksheet construction. The "Language" dimension achieved a score of 85.90% in the category "Very Suitable," indicating excellent language quality and communication skills. Finally, the "Design" dimension obtained the highest score of 95.18% in the category "Very Suitable," indicating that the worksheet design, including the cover and content presentation, is very adequate. Overall, these results illustrate that this worksheet has high quality standards in terms of content, language, and design, with little room for improvement in the construction aspect. It ensures that this worksheet is ready to be used in the learning process related to climate change.

The findings of this study align with previous research that highlights the potential of UbD and technology integration in enhancing student learning outcomes. Several studies have demonstrated the effectiveness of UbD in fostering deep understanding, critical thinking, and problem-solving skills (Florian & Zimmerman, 2015; Gloria et al., 2018; Neill & Neill, 2019; OZYURT et al., 2021; S. Pertiwi et al., 2019; Rosanti et al., 2019; Setyanto et al., 2018; Young & Young, 2020). Additionally, the integration of technology, particularly in the form of interactive tools like Micro:bit, has been shown to promote student engagement and facilitate the development of computational thinking skills (Bilbao et al., 2021a; Esteve-Mon et al., 2020; Kelly & Gero, 2021a; Li et al., 2020c, 2020a; Ortiz & Pereira, 2020a; Palts & Pedaste, 2020).

The high validation scores obtained in this study for the "ESD-Climate Change" worksheet, particularly in the areas of content, language, and design, further support the efficacy of combining UbD, technology, and a focus on real-world problem-solving to create engaging and effective learning experiences. The identified areas for improvement in the "Construct" dimension provide valuable insights for refining the worksheet and maximizing its impact on student learning.

This study contributes to the growing body of evidence demonstrating the potential of innovative pedagogical approaches and technology integration in promoting ESD and empowering students to address the complex challenges of climate change. It also underscores the importance of continuous evaluation and refinement of educational materials to ensure their alignment with evolving curriculum standards and student needs.

CONCLUSION

This study details the development process of the ESD-Climate Change Worksheet, aimed at enhancing students' computational thinking and creative problem-solving skills. The process began with a curriculum analysis and an assessment of student and teacher needs, providing a solid foundation for the worksheet's design and implementation. The validity test results indicate that the worksheet has highly suitable content, excellent language quality, a very adequate design, and fosters social interaction in learning. While certain aspects like construction and student reactions require further refinement, the overall results demonstrate that this worksheet meets high-quality standards. This conclusion is substantiated by comprehensive research and analysis data, encompassing curriculum analysis, needs surveys, and expert validation assessments. These findings confirm the effectiveness of the approach used in developing this worksheet, resulting in relevant, engaging, and high-quality learning materials. The ESD-Climate Change Worksheet is ready for implementation in climate change-related learning and will contribute to the development of students' computational thinking and creative problem-solving skills.

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