

Development of project-based learning electronic student worksheet integrating Ngawi local wisdom to enhance critical thinking skill and environmental caring attitude

Desi Nuzul Agnafia, Qurrotul Anfa *

Study Program of Natural Science Education, STKIP Modern Ngawi, Ngawi, East Java, Indonesia

* Corresponding Author Email: anfaqu@stkipmodernngawi.ac.id

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Abstract

PISA 2022 results show the low critical thinking skills of Indonesian students. Previous research in Ngawi also confirmed similar problems with students' critical thinking test scores below 70. This study aims to develop a project-based electronic learner worksheet (PjBL ESW) that integrates Ngawi local wisdom. This research was conducted using the development method or R&D (Research and Development) model of Borg and Gall. Based on data analysis of the results of validation by experts, it shows that the developed PjBL ESW obtained excellent criteria. The T-test results show that PjBL ESW can improve critical thinking skills, with a significance level of 0.000, which leads to the rejection of H_0 , which means there is a difference in critical thinking skills between the experimental and control classes. The results of the analysis of the environmental care attitude questionnaire showed an n-Gain of 0.3772, which concluded that the application of PjBL ESW in the *Merdeka Belajar* curriculum was effective in increasing students' environmental care attitudes related to ecology and biodiversity. The results of this study have an impact on education, especially the research object school, students are motivated, enthusiastic, and active in learning so that the goal of improving critical abilities can be achieved in each student. Local wisdom-based learning brings a new atmosphere for students in familiarizing themselves in loving the environment and developing sustainable principles in preserving the environment.

Abstrak. Hasil PISA 2022 menunjukkan rendahnya kemampuan berpikir kritis peserta didik Indonesia. Penelitian sebelumnya di Ngawi juga mengonfirmasi masalah serupa dengan skor tes kemampuan berpikir kritis peserta didik di bawah 70. Penelitian ini bertujuan untuk mengembangkan lembar kerja peserta didik elektronik berbasis proyek (e-LKPD PjBL) yang mengintegrasikan kearifan lokal Ngawi. Penelitian ini dilakukan dengan menggunakan metode pengembangan atau R&D (Penelitian dan Pengembangan) model Borg dan Gall. Berdasarkan analisis data terhadap hasil validasi oleh para ahli menunjukkan bahwa e-LKPD PjBL yang dikembangkan memperoleh kriteria sangat baik. Hasil uji T menunjukkan e-LKPD PjBL dapat meningkatkan keterampilan berpikir kritis, dengan tingkat signifikansi 0,000, yang mengarah pada penolakan H_0 , yang berarti ada perbedaan dalam kemampuan berpikir kritis antara kelas eksperimen dan kelas kontrol. Hasil analisis kuesioner sikap peduli lingkungan menunjukkan n-Gain sebesar 0,3772, yang menyimpulkan bahwa penerapan e-LKPD PjBL dalam kurikulum Merdeka Belajar, efektif dalam meningkatkan sikap peduli lingkungan peserta didik terkait ekologi dan keanekaragaman hayati. Hasil penelitian ini membawa dampak bagi pendidikan, khususnya sekolah objek penelitian, peserta didik termotivasi, antusias, dan aktif dalam pembelajaran sehingga tujuan dalam meningkatkan kemampuan kritis dapat tercapai pada setiap peserta didik. Pembelajaran berbasis kearifan lokal membawa suasana baru bagi peserta didik dalam membiasakan diri dalam mencintai lingkungan dan mengembangkan prinsip berkelanjutan dalam melestarikan lingkungan.

A. Introduction

Natural Science plays an important role in improving the quality of education. It consists of product aspects, process aspects, and attitude aspects (Muttaqin et al., 2022). The process is an interaction in the learning process aimed at solving everyday problems through students' success via their thinking skills. 21st-century competencies must be mastered today in preparation for the industrial revolution 4.0, namely critical thinking used to solve problems (Agnafia, 2019). The results of the 2022 PISA (Program for International Student Assessment) study show that Indonesia ranked 71st out of 81 countries participating in the 2022 PISA test with a score of 383, a decrease of 13 points, while the international average score decreased by 12 points (OECD, 2023). The low ability to think critically is also evident in the junior high schools in Ngawi district. In the previous research conducted at the MTs Darul Hikmah Ngawi secondary school, it was found that the results of the critical thinking ability test were still low, below 70 (Lutfiah et al., 2023).

A solution to address the issues of critical thinking skills is to facilitate the learning process in a constructivist and meaningful way. Critical thinking acts as an essential element in individuals because the ability to think critically plays an important role when individuals face a problem (Wardani et al., 2020). One of the models that facilitates this is the project-based learning model. Project-based learning (PjBL) has characteristics that align with 21st-century learning. The PjBL emphasizes solving problems in real-life situations, motivates students, and encourages critical thinking (Noritasari et al., 2024). The PjBL can be supported by the use of learning media sources such as ESW.

Based on field observations, students were still using the textbooks provided by the school, and there are no other references besides that. Student activities were limited to just the textbooks. Based on interviews with students, the learning or practical activities conducted are only obtained from information provided by the teacher. Without the teacher's explanation, students have no guidelines for learning activities, so they only receive knowledge from the teacher and cannot explore the learning material on their own. Moreover, in several schools in Ngawi, teaching guidelines like ESW are still minimal in terms of electronic resources, especially regarding student worksheets, which have not yet been developed to foster critical thinking and environmental awareness.

The ESW created must align with the principles of learning and be able to implement the expected skills, one of which is the 21st-century skill of critical thinking, as well as the ESW being able to implement the character values of students (Maor et al., 2023). The implementation of Industry 4.0 has become a government policy agenda, prompting educators and researchers to develop the skills needed to face this

change, one of which involves digital technology (Saleem et al., 2024). ESW can be developed in electronics and needs to be optimally prepared to improve the quality of learning. This electronic form aims to address the environmental crisis in Indonesia by helping to preserve the environment through reduced paper usage (Anindya & Lokita, 2023). This goal aligns with the development of ESW in fostering an environmental awareness that needs to be implemented in education to prevent environmental damage (Sukmawati et al., 2023). ESW infused with local wisdom from Ngawi serves as a solution for students to develop an environmentally caring character in managing the sustainability of the local wisdom of Ngawi. The use of electronic or digital learning devices supports the era of the industrial revolution 4.0, making students creative, innovative, and competitive. Learning is more practical because it can be used anywhere and at any time.

This research has high urgency for lecturers, students, and science teachers in the implementation of science education. The still low 21st-century skills among human resources in Indonesia require improvement, specifically through an education system that fosters a national character, which includes environmental awareness and the ability for students to think critically when facing problems. The issues in the field of learning are carried out with a teacher-centered method, which makes students passive and uncritical learners. There is a need for teaching materials that support student-centered learning so that students become active, critical, and develop a learning character. Through the development of ESW, it is greatly needed by teachers and students to meet the demands of the 21st century, being effective and not limited by time and space, as well as environmentally friendly.

Based on the result of students' need analysis through field observations, the local wisdom of Ngawi has not yet been widely linked to science education. Also, for the level of critical thinking skills in several schools in Ngawi district, data was obtained showing that SMPN 1 Ngawi, SMPN 2 Paron, dan SMPN 3 Paron had an average score of 62. There is a lack of concern regarding the waste generated from the local wisdom sites in Ngawi. The results of the 2022 PISA (Program for International Student Assessment) study show that Indonesia ranked 71st out of 81 countries participating in the 2022 PISA test with a score of 383, a decrease of 13 points, while the international average score decreased by 12 points (OECD, 2023). Therefore, students need knowledge related to the potential of local wisdom in Ngawi, and they should be able to utilize the results or waste from local wisdom in Ngawi into products that have beneficial value. Through this PjBL ESW integrating Ngawi local wisdom, students can develop a critical attitude and environmental awareness in processing the potential or waste present

in the local wisdom of Ngawi. Students will independently become skilled in creating products from waste based on local wisdom in Ngawi and will understand the characteristics of local wisdom potential, so that in the future, the places of local wisdom in Ngawi can grow and thrive. Through an environmentally caring attitude, students become creative and help prevent environmental damage (Agnafia et al., 2022), thus assisting the government and the local area of Ngawi in preserving environmental sustainability.

Based on previous research, learning through local wisdom can shape students' character in accordance with the demands of the 21st century (Septika & Prasetya, 2020). Through ESW, it is more effective in increasing flexibility and improving the quality and speed of student feedback. Students can conduct independent experiments and present independent scientific data so that they can understand the concepts of the material being taught (Bussemaker et al., 2011). The PjBL provides an effective impact for students and is very engaging for them, in addition to preparing them to adapt to changes in life (Maros et al., 2023). The PjBL can stimulate students' thinking in acquiring new knowledge, enhance critical thinking, creative thinking, communication skills, and collaboration skills (Issa & Khataibeh, 2021). Research with a PjBL model can enhance critical thinking. Through collaborative learning, it also impacts the enhancement of critical thinking (Cortázar et al., 2021).

Based on previous research, the use of ESW among students through constructivist learning can enhance understanding, thereby improving students' critical thinking skills (Habsyi et al., 2022). Through ESW with problem-based learning, students can also develop a critical attitude towards learning (Nurkhasanah & Rohaeti, 2024). Learning through ESW, if integrated with local wisdom, can make learning effective and enhance higher-order thinking skills (Safirah et al., 2024). In this research, the renewal is carried out through the integration of local wisdom from Ngawi so that students become more familiar with the tourism in the Ngawi area and manage its ecosystem effectively. Through the management of resources in Ngawi tourism, it also enhances environmental awareness. Another novelty through this learning is that students find solutions by creating products from waste generated during observations at the tourist site.

Through PjBL, it can help achieve the goals of the independent curriculum. The PjBL model trains students to tackle real problems and provides appropriate solutions to those issues. PjBL is part of constructivist learning; through the use of PjBL learning tools, students can enhance their critical thinking skills (Anfa et al., 2023). The PjBL will encourage students to think creatively and provide them with the opportunity to enhance their

understanding by deepening the concepts they have already grasped through active student involvement, thereby improving their abilities and enabling them to work both independently and collaboratively in projects to apply the concepts (Al Hanafi et al., 2024). The ESW is also supported by the local wisdom of Ngawi Regency, with the hope that students will become more familiar with the potential of local wisdom and can preserve the environment through an attitude of environmental care without damaging the resources available in the area. The ESW is highly needed because it is effective and easily accessible at any time by both students and teachers. The purpose of this research is to develop the characteristics of PjBL ESW infused with local wisdom from Ngawi to enhance critical thinking skills and environmental awareness, to determine the feasibility of ESW based on PjBL with local wisdom, to assess the effectiveness of ESW based on PjBL, and to understand the dissemination of ESW based on PjBL.

B. Material and method

This research was conducted using the development method or R&D (Research and Development) employing the Borg and Gall development model. The phases of the development research are as follows: 1) research and information collecting, 2) planning, 3) develop initial product design, 4) preliminary field testing, 5) revision of the initial product, 6) limited field testing, 7) product revision, 8) operational field testing, 9) final product revision, and 10) dissemination (see Figure 1).

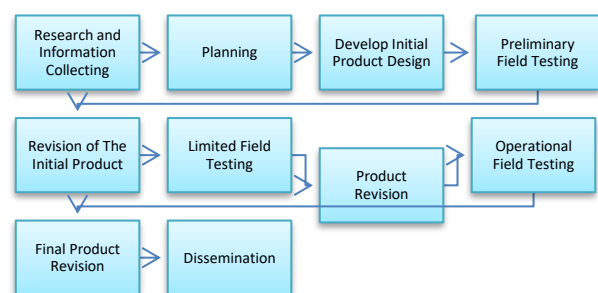


Figure 1
Steps of the research and development (Source: Borg & Gall, 1983)

This research utilizes data analysis methods including: a) Needs analysis data. The data is analyzed using qualitative descriptive techniques, b) Expert assessment data: analyzed using percentage descriptive techniques, c) Small-scale test data in the form of questionnaires analyzed based on qualitative descriptive techniques, d) Operational field trial data. The data collection instruments in this study were created based on the type of data at the phases of the development method. The analysis of needs data was obtained through questionnaires and interviews with students and teachers regarding the learning

conditions in the classroom. The data from expert validation was obtained through the feasibility questionnaire of the ESW and the feasibility questionnaire of the critical thinking and attitude of caring for the environment instrument. The data from the limited test was obtained through the feasibility questionnaire of the ESW by students. The field test data was obtained through the feasibility of the ESW by students and the student response questionnaire. The critical thinking ability was obtained through the post-test, and the data on environmental awareness attitudes was obtained through a questionnaire.

Data needs analysis was conducted using qualitative descriptive techniques. The results of the questionnaire and observations are described for the analysis of development. The results of reviews from experts were analysed using descriptive percentage techniques. The expert validation data processing was conducted using a Likert scale consisting of 4 categories. A limited scale trial was also obtained through student response questionnaires using a Likert scale. The score obtained from the answers is then calculated using the Formula 1.

$$P = (\Sigma x / \Sigma x_i) \times 100\% \dots \dots \dots \text{Formula 1}$$

Description:

P = The percentage of students response

Σx = Score obtained

Σx_i = Maximum score

The final result is obtained from the percentage of the average score of all respondents' answers using the Formula 2.

$$Me = \Sigma x_i / n \dots \dots \dots \text{Formula 2}$$

Description:

Me = Mean of score of all respondents' answers

Σ = Total/ Sigma

x_i = values of x from 1 to n.

n = Number of participants

The percentage obtained will be converted into a qualitative value according to the criteria in Table 1.

Table 1 Data conversion from quantitative to qualitative

No.	Criteria	Score	
		Number	Calculation
1.	Excellent	4	3.51-400
2.	Good	3	2.51-3.50
3.	Poor	2	1.51-2.50
4.	Bad	1	1.00-1.50

Field trial operational data in the form of analysis of critical thinking skills and environmental caring attitudes results. The research conducted aims to determine the effectiveness of learning using PjBL ESW integrated with local wisdom from Ngawi to enhance critical thinking skills and environmental

caring attitudes among junior high school students regarding environmental material. The subject of this research is PjBL ESW integrating Ngawi local wisdom, then the object of this research were 64 students of 7th grade in SMPN 1 Ngawi, divided into two groups experiment and control class,

The analysis technique used is the paired t-test. The conditions for bias in the paired t-test require that the data distribution is normal and homogeneous, so there must be prerequisite tests for normality and homogeneity. The normality test in this study was conducted using the Shapiro-Wilk test with the SPSS program. The hypothesis pairs to be tested to meet the normality assumption are H_0 , which states that the data comes from a normally distributed population, while H_1 states that the data comes from a population that is not normally distributed. The significance level is set at $\alpha = 5\%$. The subsequent test conducted is the T-test to assess the effectiveness of ESW.

Analysis of student environmental awareness attitude data using N-Gain. The criteria for N-Gain are calculated using Formula 3. The N-Gain value is interpreted the following criteria on the Table 2 (Hake, 1999).

$$NGain = \frac{\text{Final score} - \text{initial score}}{\text{Maximum score} - \text{initial score}} \dots \text{Formula 3}$$

Table 2 N-Gain criterion

Interval score	Criteria
$G > 0.70$	High
$0.30 \leq G \leq 0.70$	Medium
$G \leq 0.30$	Low

C. Results and discussion

The result of the literature study is the analysis of the Learning Outcomes. The Learning Outcomes used as a reference in this ELKP are that by the end of phase D, students can identify interactions between living organisms and their environment, and can design efforts to prevent and address pollution and climate change. Based on the literature review, it was also found that the results of the PISA study in 2022 show that Indonesia ranked 71st out of 81 countries participating in the PISA 2022 test with a score of 383, a decrease of 13 points, while the international average score decreased by 12 points. Science learning should be conducted through real activities. Through this learning, students are faced with the challenge of designing investigations on real-world problems.

Field surveys are used to identify problems in the field through critical thinking ability tests, analysis of teaching materials, as well as observations and interviews. The test conducted was an essay test with a total of 10 questions. From several schools that conducted the initial ability test, the following results were obtained. Analysis of the teaching materials used at SMPN 1 Ngawi consists only of textbooks without

student activity sheets; when students have assignments, they are only noted on the blackboard. Observations and interviews were conducted with the curriculum deputy principal, science subject teachers, and students. The results obtained are related to the learning process, namely: 1) the learning process has already used the independent curriculum, 2) the learning applied is mostly still conventional and one-way, with the teacher explaining the material first without providing stimuli for the initial construction of students' knowledge, 3) the teacher only uses government-provided textbooks without accompanying student worksheets, 4) the facilities at the school are quite complete, but the teachers do not use them much, for example, they do not use the LCD when delivering lessons and other teaching media, 5) students learn science by memorizing the material, 6) students are rarely trained in indicators of critical thinking skills, 6) students are rarely trained to have an environmental care attitude, students are rarely trained in the scientific process, explanations of material without any field proof or process, 7) in regular learning, students are only given cognitive assessments, 8) students have never been invited to recognize the wisdom around them as a means of learning, and 9) Not all subjects incorporate character education and nationalism or love related to local culture (local wisdom) in science classes.

The PjBL ESW integrated with Ngawi local wisdom is developed to enhance critical thinking skills and environmental caring attitude. The components of the module consist of an introduction, which includes the title of the ESW, an overview of the ESW, learning outcomes and learning objectives (see Figure 2), usage instructions (see Figure 3), the profile of Pancasila students, and the phases of PjBL related to critical thinking skills and environmental caring attitude.



Figure 2
 Learning outcomes that are presented in ESW (in Indonesian)

The PjBL ESW and integrating local wisdom from Ngawi is developed to enhance critical thinking skills and environmental caring attitude. By using educational innovations and looking for methods that may actively engage students, teaching techniques are improved to increase student learning results (Agnafia et al., 2023). One of them is PjBL methods. The core section consists of the identity of the sub-topic, fundamental questions, designing project planning, creating schedules, monitoring project progress, testing results, and evaluation.

In biology learning, students create products from waste at the tourist sites they visit. There are five tourist attractions in Ngawi, namely Kabun Teh Jamus, Hutan Pinus Seloondo, Taman Wisata Tawun, Benteng van den Bosh, and Waduk Pondok (see Figure 4).



Figure 3 Instruction for ESW (in Indonesian)



Figure 4
 Teaching and learning integrated with local wisdom of Ngawi in Jamus Tea Garden, Ngawi



Figure 5 The stages of PjBL (in Indonesian)

The stages of PJBL (see Figure 5) that are carried out included introduction to problems or fundamental questions, at this stage the student learning process is carried out through several challenging questions. In the ESW, several videos related to the local wisdom of Ngawi and photos related to existing problems are presented. The theme taken is related to ecosystems and environmental management. Students are invited to conduct a real investigation at Ngawi tourist attractions. Each group conducts an investigation at one tourist spot in Ngawi. Each group conducts observations at different tourist attractions in Ngawi. Through the introduction of Ngawi tourism activities, it is hoped that students can manage waste by producing beneficial products. The research found that the implementation of environmental education based on local potential is very effective in increasing environmental awareness (Wulandari et al., 2019). To achieve this goal, students were divided into several groups. Group 1 to the tea garden: Jamus, Group 2 to the pine forest tour: Seloondo, Group 3 to the pond and bamboo forest tour: Tawun. Then Group 4 to the "Beteng Van den Bosch" tour, and group 5 to the "Waduk Pondok" tour. In each of these tourist sites, there are resources generated from tourism that have not yet been managed and utilized by the surrounding community.

At this stage, students also formulate problem statements and hypotheses related to the presented issues. Introducing problems through learning is very effective in enhancing critical thinking skills (Darmawati & Mustadi, 2023). The assignment of observation tasks in the environment, understanding and concern for the natural environment will increase (Permata, 2021). In their research found that problem-based learning can enhance students' critical thinking skills.

Designing Project Planning, at this stage, students create project designs based on field investigations. Each group creates a different plan based on the underutilized resources found in the local wisdom of Ngawi. Project planning is carried out

collaboratively among students. Through this stage, the active role of students can emerge. Students analyze the problem and then solve it. The explanation indicator can emerge at this stage through group members explaining the relationship between the problem-solving solution and the planning that has been made. Through critical thinking skills, one can find solutions to problems (Kurniasari et al., 2023).

Project Schedule Preparation. At this stage, students work collaboratively with their group. Preparing a schedule of activities to complete the project. The schedule is targeted with the determination of dates. Each target is carried out in groups during its completion. The schedule preparation is carried out by conducting collaborative discussion activities. The collaboration among students in project creation can be completed. Through collaborative learning, students' critical thinking skills can also be enhanced (De Klerk et al., 2024).

Implementation and monitoring of the project, at this stage the students have carried out the project according to the plan and scheduling targets. The teacher at this stage acts as a guide and monitors the activities that the students have carried out. The projects created by the students include tea soap as a product from the Jamus tour, pine briquettes as a product from the Seloondo tour, Ecoenzym as a product from the Van the Bosh tour, corn paper as a product from the Tawun tour, and candles as a product from the Pondok reservoir tour. The project activities carried out by the students were done collaboratively in pursuit of completion targets. Through project assignments in the learning process, 21st-century skills are developed in students, including communication, collaboration, creativity, and critical thinking (Budiarti et al., 2021).

Then, stage of testing results. At this stage, students present the results of the projects that have been carried out in groups. The project results include tea soap, pine flower briquettes, corn paper, recycled oil candles, and Eco-enzymes. The project results are evaluated by the teacher based on. At this stage, students actively express their opinions and show enthusiasm in presenting the results of the products they have produced.

Based on the description above, in summary, the core part consists of the developed PjBL ESW including subtopic identity, fundamental questions, designing a project plan, creating a schedule, monitoring project progress, testing results, and evaluating. The final section consists of a bibliography and glossary.

The initial trial was conducted through expert validation, which included material experts, design and readability, development experts for teaching materials, and learning device experts. The validation results from the material expert can be seen in Table 3. The final product revision results in feedback or suggestions based on expert validation, these suggestions or feedback can be seen in Tabel 4.

Table 3 Result review from expert validation

Expert validator	Aspect	Result	Qualification
Media development of teaching materials	Content of ESW	4	Good
	Overall presentation organization	3.8	Excellent
	Presentation of activities in ESW	3.6	Excellent
	Student engagement	4	Excellent
	Overall appearance	3	Good
	Clarity of ESW	4	Excellent
	Attention to ethics and copyright	4	Excellent
Design and readability	Overall presentation organization	3.5	Excellent
	Meaningfulness and benefits	4	Excellent
	General appearance	4	Excellent
	Variations in information delivery	3.3	Good
	Anatomy of a book	4	Excellent
	Proper and correct Indonesian Language	4	Excellent
	Code of ethics and copyright	3	Good
Content material	Completeness of the ESW according to the phases	4	Excellent
	The accuracy of the context of the questions in accordance with the material	4	Excellent
	Activities that support learning	4	Excellent
	Systematics of phases according to the learning model	3	Good
	Enhancing critical thinking skills	4	Excellent
	Material designed for developing problem solving	3	Good
Learning device	Formulation of learning objective	4	Excellent
	Selection and organization of teaching materials	3.7	Good
	Selection of learning resources and teaching media	3.6	Excellent
	Approaches and learning methods	3.6	Excellent
	Learning scenarios	4	Good
	Assessment of learning outcomes	3.7	Excellent
	Aspects of critical thinking	3.8	Good
	Aspects of environmental caring attitude	3.6	Excellent
Average total score		3,74	Excellent

Table 4 Suggestions from expert validation

Expert validation	Recommended results for ESW
Media development of teaching materials	The answer column in one of the phases needs to be enlarged so that students can explain their answers according to their arguments. The image resolution can be increased. ESW needs to include videos or images that provide an overview of the local wisdom being visited.
Design and readability	Some writings still have errors that can be adjusted according to the general guidelines of Indonesian spelling. A simplification of the layout is needed to avoid excessive use of color.
Material	Observations or traces of nature that are conducted need to be clarified in order to observe the components of the ecosystem. The ESW needs to include literacy from the information at the end of the phases according to the subtopics.
Learning devices	Indicators of critical thinking skills need to be displayed in several questions, as a characteristic of this ESW. This ESW is also part of enhancing environmental awareness; it would be best to include a slogan for students to read in order to preserve the environment.

Table 3 shows that the validation conducted by the experts in the qualifications is Excellent. This means that the ESW has met the eligibility requirements and can be used as a learning tool. The ESW can proceed to the next phase of development. Nevertheless, there are some revisions from the experts. The results of a similar study conducted by (Yetti & Afryani, 2021) attempted to develop ESW based on Metaphorical Thinking with valid results.

The ESW had been revised to be used perfectly by the students. ESW plays an important role for students; it can facilitate students in the process of

constructing knowledge through self-directed learning and can help students to be creative according to their abilities in an effort to create enjoyable and meaningful learning experiences. In addition to impacting the students (Nadhiroh & Ahmadi, 2024). Based on the Table 4, the revised results have been corrected according to the feedback provided by each expert validator. The revised ESW results will be used in the next phase, which is a limited field trial.

The phases of the limited field trial were conducted using 10 students with the aim of obtaining feedback on the developed ESW. The learning activities

are carried out according to the learning activities in the ESW phases with the material on Ecology and Biodiversity. The aspects responded for students include learning by participating in fundamental question activities, designing project plans, creating project schedules, monitoring projects, testing results, and evaluating. The results of the limited field trials can be seen in the Table 5. Here is the table of results from the limited scale tests conducted by the students:

Table 5 Results of descriptive analysis of limited-scale trial

	N	Min	Max	Σ	Std. Dev
N-Gain score	10	3.30	3.68	3.517	0.14119

Based on the table 5 above, the results show that the average outcome of the limited-scale trial is 3.517 categorized as excellent. This indicates that ESW is suitable for further application in the next phase of learning, which is the operational field test. Although it can be continued to the next development phase, there are several inputs provided by the students that were discussed in the revision of product phase II.

After conducting a limited-scale trial, a second revision is necessary. The revisions made include enlarging and clarifying some small texts. In the table for interaction between components, an additional column needs to be added, as some students found interactions exceeding the provided columns. The revisions have been made and corrected according to the feedback received.

The operational field test phases are conducted to determine the effectiveness of the PjBL ESW integrating Ngawi local wisdom for enhancing critical thinking skills and environmental caring attitude. The operational field test was conducted at SMPN 1 Ngawi, using two classes: a control class and an experimental class. The control class for learning used the methods typically employed by science teachers in the seventh grade at SMPN 1 Ngawi. Meanwhile, the experimental class utilized the PjBL model infused with local wisdom. Local wisdom is manifested in its implementation by inviting students to the field at the Ngawi tourist site. Through observation or direct practice conducted in the field, students will gain a high learning experience through field study activities as they interact directly with the objects. In addition, students can learn more deeply through field activities than by studying textually through books (Ahmad & Laha, 2020). Here is the documentation of the learning activities in the control class through the implementation of PjBL ESW integrating with Local Wisdom from Ngawi.

The results of the research conducted on the subject of science with a focus on biology show that ESW can provide references for teachers and other researchers in implementing science education in accordance with the independent curriculum. In

science education, especially biology, students must be presented with real examples and must showcase scientific process activities in their learning. The research conducted with states that science education should be carried out through real activities (Abdullah et al., 2024). Through this learning, students are faced with the challenge of designing investigations on real-world problems. Because science learning is inseparable from the surrounding environment. The problems were directly obtained from field observations of local wisdom in Ngawi. Through the learning of local wisdom, it can also foster students' environmental awareness. Students become accustomed to loving the environment through local wisdom (Constantinus et al., 2021). Students need to be involved in preserving local wisdom because they are the next generation responsible for maintaining environmental sustainability. The role of local wisdom is the main form of developing environmental sustainability principles, and the way to address the problem is through product creation, which can also be applied by the community living around the tourist area, thereby managing waste (Nurhasan, 2023). Another implication of PjBL is that it enhances students' creativity through project creation.

At the four stages of PjBL, after students explored the environment of Ngawi local wisdom, they did a project in class using ESW. The ESW can be used by students as independent learning in the process of science. Student worksheets are utilized by students as independent learners and are not dependent on the presence of a teacher (Astuti & Sari, 2017).

The collaboration among students in project creation can be completed. Through collaborative learning, students' critical thinking skills can also be enhanced. The teacher at this stage acts as a guide and monitors the activities that have been carried out by the students. The projects created by the students include tea soap as a result of the Jamus tour, pine briquettes as a result of the Seloondo tour, Ecoenzym as a result of the Van the Bosh tour, corn paper as a result of the Tawun tour, and candles as a result of the Pondok reservoir tour. The project activities carried-out by the students were done collaboratively to achieve the completion targets.

The implementation of this learning requires a recommendation for team teaching because students go directly to the field and need a lot of equipment that must be prepared. The collaboration among students in project creation can be completed. Through collaborative learning, students' critical thinking skills can also be enhanced. The teacher at this stage acts as a guide and monitors the activities that have been carried out by the students. The projects created by the students include tea soap as a result of the Jamus tour, pine briquettes as a result of the Seloondo tour, Ecoenzym as a result of the Van the Bosh tour, corn paper as a result of the Tawun tour, and candles as a result of the Pondok reservoir tour. The project

activities carried-out by the students were done collaboratively to achieve the completion targets. The project monitoring is can be seen in Figure 6.

In the operational field test, data was obtained regarding critical thinking skills and environmental caring attitude, which had previously been validated by the results of the learning instrument. Therefore, the test instrument for critical thinking skills and the questionnaire on environmental caring attitude can be applied to students. After the learning process using PjBL ESW integrated with local wisdom from Ngawi, students were given an evaluation in the form of a test on critical thinking skills and the completion of a questionnaire on environmental caring attitude. Essay questions that assess critical thinking skills based on Facione's list of indicators, which includes self-regulation, interpretation, analysis, evaluation, explanation, conclusion, and self-analysis.

At this stage, the teacher and students conduct a reflection on the learning that has been carried out. The teacher invites the students to write down their feelings during the project activities and to discuss the factors that hindered the implementation of the activities. Some students experienced obstacles related to unfavourable weather conditions during the project.

Some projects need to be dried under the sun, but sometimes the weather is cloudy and rainy, causing the product refinement process to take a long time. The materials used include some that are sensitive to the skin, such as NaOH, so gloves are necessary when making the product. The students were very happy and enthusiastic about making the product, and they hope that the PjBL activities will be conducted again in the next meeting. Students gain knowledge that can be applied in everyday life. Through PjBL, a process of knowledge creation occurs that allows students to test and achieve ideas with the solutions they propose, and can also foster creative innovation competencies for students (Guo et al., 2020).

The experimental class had an average score of 80 on the critical thinking skill exam, whereas the control group received an average of 52. The following tests for homogeneity and normalcy were run on the test findings. Table 6 shows that the control class's average critical thinking skill score is 52, with a minimum score of 40 and a maximum score of 67. Meanwhile the experimental class utilizing ESW got a maximum score of 93 and a minimum score of 70, which is based on PjBL and integrated with local wisdom from Ngawi, has an average of 80.1.



Figure 6

Part of monitoring the project: (A) students made a project of briket from *Pinus merkusii* flower from Seloondo tour; (B) students made a project of Eco-enzyme from leaf and bark waste from the *Samanea saman* in Benteng Van Den Bosch; and (C) students made a project of paper from corn husks in Tawun tour

Table 6 The data of critical thinking skill

	Class	Number of students	Average	Score	
				Highest	Lowest
Post-Test	Control	35	52	67	40
	Experiment	35	80.1	93	70

Table 7 Results of inferential analysis of posttest critical thinking skills

Test	Type of test	Result	Interpretation	Conclusion
Normality	Kolmogorov-Smirnov	Control: 0,119	H ₀ accepted	Data is normal
		Experiment: 0,209	H ₀ accepted	Data is normal
Homogeneity	Levene's test	0.467	H ₀ accepted	Data is homogeneous
Result of post-test control and experiment	Paired sample t-test	0.000	H ₀ rejected	Significantly difference

Table 8 Results of descriptive analysis of the environmental care attitude questionnaire of N-Gain scores

	N	Min	Max	Σ	Std. Dev
N-Gain score	35	0.23	0.63	0.3772	0.08465

Table 9 The third revision phase

Suggestion	The third revision phase's explanation
Observations are requested to use images so that there is no need to visit the observation source (tourist attractions) due to the distance being too far.	A video has been exist because it used to teaching and learning.
Adding explanations of the material into the ESW	Material is indeed not explained in the ESW because the nature of ESW is merely as a supporting sheet for student activities, and this learning is based on constructivism, so students seek concepts and process information first.
Project guidelines can be written into the ESW	The instructions for the project are not written down because the answers regarding how to create the project are part of assessing critical thinking skills (solutions to waste management), as well as training students to be creative and critical.

Based on the Table 7, the normality of the data tested using the Kolmogorov-Smirnov test showed a significance level of 0.119 for the control class posttest and 0.209 for the experimental class post-test. The value indicates that it is greater than $\alpha = 0.05$, so H_0 is accepted, which means that the post-test scores of the control class and the post-test scores of the experimental class are normally distributed. The homogeneity test yielded a significance level of 0.467, which means the significance is greater than 0.05, thus the null hypothesis (H_0) is accepted, it means indicating that the variances of each sample are the same (homogeneous).

The pre-test and post-test scores, which have been normally distributed and homogeneous, were then it was analyzed using the Paired Sample t-test. Based on the calculations, a significance level of 0.000 was obtained, leading to the rejection of H_0 , which means there is a difference in students' critical thinking skills using PjBL ESW integrated with local wisdom from Ngawi. The analysis concludes that the implementation of PjBL ESW with local wisdom content from Ngawi can enhance students' critical thinking skills.

The data on environmental awareness was obtained from the questionnaires filled out by students after the lessons, both in the control class and the experimental class. In the Table 8, it can be seen that the value of n Gain is 0.3772, which indicates that the score falls into the moderate category. The results of the questionnaire indicate that the average score in the control class is 61.14, while in the experimental class it is 75.54. The experimental class shows that the average score is higher compared to the control class. It can be concluded that the implementation of PjBL ESW, which integrates local wisdom, is effective in enhancing students' environmental caring attitude regarding ecology and biodiversity. In this third revision phase, it was the revision phase following the operational field test. After the implementation of the PjBL ESW that integrates local wisdom from Ngawi,

students filled out a response questionnaire regarding the learning experience. The results of the operational field test suggestions yielded recommendations and inputs that can be seen in the Table 9.

Irhasyuarna et al. (2022) also proved that the integration of material with local wisdom can improve students' critical thinking skills. In addition to PjBL-based, Safitri et al. (2024) also proved that PBL-based ESW is also able to improve critical thinking skills. Electronic learning device development products in other forms such as Nabila et al. (2023) also prove their effectiveness in training critical thinking skills. Some of these previous studies and this study show that there is an opportunity for a more in-depth analysis of effectiveness, because both with different products and approaches, learning implemented with problem solving characteristics and based on local wisdom has a positive impact on students' critical thinking skills.

The last phase is the dissemination phase, which is the final phase of the development research of PjBL ESW aimed at enhancing critical thinking skills and environmental awareness. The dissemination phase involves socializing with science teachers, providing materials and guidance on how to use the PjBL ESW that integrates local wisdom from Ngawi to improve critical thinking skills and environmental awareness.

In the dissemination phase, the ESW product is being distributed to both public and private junior high schools in Ngawi Regency, and this dissemination phase is currently in progress. The schools that were involved in the dissemination were SMPN 1 Ngawi, SMPN 3 Ngawi, SMPN 4 Ngawi, SMPN 1 Pangkur and SMP Al-Azar Paron Ngawi.

D. Conclusion

Based on data analysis towards the validation results by experts in media and teaching materials development, design and readability, content, and teaching devices, it shows that PjBL ESW integrating

Ngawi local wisdom is excellent. This means that the ESW has met the eligibility criteria and can be used as a teaching device. In addition, based on the results of the T-test, the ESW PjBL infused with Local Wisdom from Ngawi can enhance critical thinking skills, with a significance level of 0.000, leading to the rejection of H_0 , which means there is a difference in critical thinking abilities between the experimental and control classes. Meanwhile, the results of the analysis of the environmental awareness questionnaire showed an n-Gain of 0.3772, which concludes that the implementation of PjBL ESW, infused with local wisdom, is effective in enhancing students' environmental awareness regarding ecology and biodiversity. The results of this research have an impact on education, especially at the school where the research was conducted. Students are highly motivated, enthusiastic, and active in learning, so the goal of enhancing critical thinking skills can be achieved by every student. Learning based on local wisdom brings a new atmosphere for students to get used to loving the environment and developing sustainable principles to preserve it.

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