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Development of a Project-Based e-Portfolio for Enhancing Critical and Creative Thinking Skills in Land Pollution and Waste Management Education

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Abstract: Critical and creative thinking skills are the core of 21st century skills that learners must have to face global challenges. The ability to interpret, analyze, evaluate, inference, explanation, self regulation, think fluency, flexibility, originality and elaboration can shows the level of their critical and creative thinking ability. The research aims to develop e-portofolio for enchancing the critical and creative thinking ability of 8th level students at Junior High School by soil pollution and waste management education. The research used a one-group pretest-posttest experimental design. The validity of e-portfolios consists of construct and content validity. The practicality of e-portfolios was assessed based on student response questionnaires. The effectiveness of the e-portfolio was assessed through a test designed to measure their critical and creative thinking skills. After the e-portfolio trial, a test was conducted to enable the improvement of critical and creative thinking skills. This study used the Research and Development (R&D) method with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) which is limited to three stages namely analysis, product design and development. The validity assessment used expert judgement. The design of e-portfolio learning media involves elements that are in accordance with the indicators of critical and creative thinking by providing feedback, self-assessment, peer assessment, self-reflection. The data generated in this study is the validity of e-portfolios to measure critical and creative thinking skills. Based on the profile analysis of critical and creative thinking skills of SMP Negeri 8 Purwosari students, it was found that there was an increase in the percentage of critical thinking skills of grade VIII students from 73.08% in the very low category (19 students) to 88.46% in the very high category (21 students). It was also found that the percentage of creative thinking ability of the largest VIII grade students was 69.23% in the very low category (18 students) to 46.15% in the very high category (12 students) after using e-portfolios. This research developed e-portfolios as an innovative instrument that not only measures critical or creative thinking ability separately, but also learns both critical and creative thinking ability . In its implementation, the e-portfolio is designed to integrate various learning components, such as problem-based assignments, case studies, experiments and self-reflection that are relevant to practising critical and creative thinking skills.

Keywords: critical thinking ability, creative thinking ability, e-portfolio, pancasila student profile.

▪ INTRODUCTION

Critical and creative thinking skills are the core of 21st century skills that learners must have to face global challenges. Critical and creative thinking skills are part of the four main 21st century skills known as the 4Cs, namely critical thinking, creativity, collaboration, and communication (Sari et al., 2021). Problem-solving and creative thinking skills of learners are the core of 21st century skills. Problem-solving skills refer to a set of cognitive-behavioural activities by which a person tries to find or develop effective solutions to real-life problems (Simanjuntak et al., 2021). Critical thinking skills are a process of analysing, finding relationships, evaluating, solving problems, and making decisions (Sari et al., 2021). The importance of the need to improve critical

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thinking skills because it is related to life skills competencies for them after school (Sutiani et al., 2021). According to Facione (2015) critical thinking includes rational, reflective, and purposeful judgements, which aim to guide actions or beliefs. Creativity proposed by Guilford (1987) is the ability to generate new ideas that are original and useful, including the ability to think divergently to find various possible solutions to a problem. The thinking process produces creative products derived from the solution of a problem found previously (Sutiani et al., 2021). Problem solving requires higher-order thinking skills, namely creative thinking, and critical thinking so that individuals are able to answer problems after correctly applying solutions and evaluating answers (Sari et al., 2021). The combination of critical and creative thinking allows students to not only solve problems in depth, but also generate solutions that are relevant in various contexts. The utilisation of relevant technology can develop creative thinking skills, especially fluency and flexibility, and develop constructive critical thinking (Tabieh et al., 2020).

The ability to think critically and creatively is reaffirmed in the learning outcomes of the Pancasila learner profile as stated in the Regulation of the Minister of Education, Culture, Research and Technology Number 22 of 2022. In 2022 the government implemented an independent curriculum to improve the quality of education in schools. One of the most visible in the implementation of the independent curriculum is the implementation of the Pancasila learner profile. According to Hamdi et al. (2022) the independent curriculum has a learning structure that is divided into two main activities, namely learning in each course and a project to strengthen the Pancasila learner profile which refers to the graduate competency standards that students must have. According to Kemdikbud (2022), the important components of this programme are 1) faith, devotion to God Almighty, and noble character, 2) global diversity, 3) mutual cooperation, 4) independence, 5) critical thinking and 6) creativity. The critical and creative thinking skills of learners in the independent curriculum are still relatively low, especially in the project to strengthen the Pancasila Learner Profile (P5). This is supported by research showing that many learners have not been able to demonstrate in-depth critical thinking skills, such as analysing data or evaluating solutions logically, as well as difficulties in coming up with innovative ideas that are relevant to existing problems (Prihantini & Khoirunnisa, 2023). In addition, a survey conducted by (Sabila & Widiyono, 2024) revealed that in the implementation of P5, many schools still face challenges in facilitating the development of students' creative abilities, especially in completing collaboration-based project tasks. Another study conducted by (Faslia et al., 2023) showed that the lack of utilisation of innovative technologies in learning, as well as learning approaches that have not been maximised, is one of the factors that cause the low critical and creative thinking skills of learners in the context of P5 implementation.

Although critical and creative thinking skills are very important in the 21st century and have been integrated in the Merdeka curriculum through the dimensions of the Pancasila Learner Profile, the results of the study show that students still have not reached the expected level of competence in both skills. Previous research such as that conducted by Sarwanto et al. (2020), Lestari et al. (2021), Murtadho (2021) showed that students' critical thinking skills were still low and creative thinking skills by Leasa et al. (2021), Fatmawati et al. (2022), Jumadi et al. (2021). The results of this study indicate that students' critical and creative thinking skills are still not optimal. Some of the factors that cause this problem include Lack of effective learning activities to develop ideas and solve

problems using higher order thinking skills, lack of student interest in learning due to limited teacher facilitation in implementing innovative learning approaches. Such factors need to be identified and addressed to ensure that students have the critical and creative thinking skills needed for success in the 21st century.

This research aims to develop, validate, and implement a project-based e-portfolio as an instrument to improve students' critical and creative thinking skills in Pancasila Student Profile strengthening project activities. E-portfolios can enhance these skills by providing a structured platform for reflection, self-assessment, and problem-solving demonstration (Walland & Shaw, 2022). Using of e-portfolios in education enables students to engage in deeper analysis and innovation when solving real-world problems (Afrilyasanti et al., 2024). Critical and creative thinking are key 21st-century competencies that empower students to evaluate information, generate new ideas, and make informed decisions in various contexts (Simanjuntak et al., 2021). By using e-portfolios into learning, students can actively participate in inquiry-based learning, which fosters conceptual connections and the development of original solutions (Rezai et al., 2022). In the digital era, integrating e-portfolios into education is a step toward optimizing learning strategies to prepare students for 21st-century challenges (Bedel et al., 2024).

Recent research shows that the implementation of technology-supported project-based learning, such as e-portfolios, enables students to more actively construct knowledge, collaborate, and develop their creativity in solving complex tasks (Peña-Ayala, 202). In addition, project modules designed to integrate the dimensions of the Pancasila Learner Profile allow students to internalise values such as gotong royong, independence, and critical thinking through collaborative activities and self-reflection (Bayley, 2022). Therefore, the application of e-portfolios in learning projects not only supports students to develop critical thinking skills but also creative thinking skills. This is in line with 21st century learning objectives that emphasise the development of real-world-based problem-solving skills (Peña-Ayala, 2023). Through this approach, students are better able to connect the concepts learnt with daily life practices, thus helping to build their character as smart, innovative, and actively contributing individuals in accordance with the values of Pancasila (Bayley, 2022). In addition, e-portfolios provide a platform for formative assessment that allows teachers to provide constructive feedback, thus enhancing student engagement in project-based learning more holistically (Jaramillo & Chiappe, 2024). However, current research on the assessment of critical and creative thinking is very limited. This suggests that although these two skills are recognised as important in 21st century learning, efforts to develop them through formal assessment are minimal.

A study from the University of Buffalo shows that electronic portfolios allow learners to reflect on their learning in an integrative and creative way through the incorporation of text, multimedia and other artefacts. Using platforms such as Digication, learners are directed to create portfolios that emphasise intrinsic learning and the development of critical thinking skills (Manoban, 2021). Similarly, research conducted by (Anh & Truong, 2023) showed that project-based learning using electronic portfolios improved not only academic outcomes but also skills such as teamwork, problem-solving, and self-reflection. This supports the concept that the use of e-portfolios facilitates more intrinsic learning by engaging learners in activities that promote Pancasila Learner profile values such as critical and creative thinking contextually. Whereas in the context of

creativity, e-portfolios provide space for learners to express their ideas in a more free and innovative way. Research by Rahmawati et al. (2023) shows that e-portfolios allow learners to explore creative solutions in more open-ended tasks, thus improving their creative thinking skills in dealing with problems. Similarly, Tiara Linanti et al. (2021) found that e-portfolios allow learners to explore creative solutions in more open-ended tasks, thus improving their creative thinking skills in dealing with problems. The structured reflection and feedback process embedded in e-portfolios helps student to think critically in their learning and engage in problem solving (Bayley, 2022). Therefore, researchers developed an e-portfolio that can learn both critical and creative thinking skills.

A literature review by Zheng et al. (2024) revealed that although curricula in many countries have started to integrate critical and creative thinking, valid and reliable assessment instruments to assess these skills are still limited. This is compounded by the inability of education systems to adapt to more comprehensive assessment methods, capable of measuring higher cognitive dimensions. Similarly, a study by Bayley (2022) showed that assessment in schools tends to focus on factual knowledge and basic understanding with little attention to the assessment of more complex creative and critical skills. The main challenge is to create assessment tools that can effectively teach and measure learning outcomes that are not only content-based, but also cognitive process-based. This research seeks to add insight into the assessment of critical and creative thinking by exploring the use of e-portfolios as a comprehensive and objective learning and authentic assessment tool in the implementation of Merdeka Curriculum.

Based on research conducted by Chun-Burbank et al. (2023) said that the e-portfolio project learning model deepens learner learning, offers a useful tool for assessing learner learning and provides opportunities for learners to undertake learning and development. Project e-portfolios are used as instruments for learner assessment and learning deepening that serve as valuable tools for learner learning progress. Prokopetz (2022) says that e-portfolios make learner learning in Canada more active and help make learner engagement visible during feedback interactions between learners leading to critical reflection during learning using e-portfolios.

Shaw et al. (2019) state that the design of e-assisted portfolios for learners in secondary schools can reflect the process of creating textile projects. Kır (2023) stated that the skill of finding solutions to problems at hand is one of the critical thinking skills that can be developed through portfolios. Khafah et al. (2023) suggested that the PjBL model has a significant effect on students' critical and creative thinking skills on the concept of ecosystems. The PjBL model can be used as a learning alternative to empower 21st century skills. E-portfolios have proven to be an effective tool for developing and measuring students' critical and creative thinking skills. A study showed that the integration of e-portfolios allows students to develop skills of critical analysis, evaluation, and reflection, while encouraging creativity through the exploration of ideas and the development of innovative solutions in the context of project-based learning (Park et al., 2021). E-portfolios have also proven effective for measuring and training students' creative thinking skills. Research shows that e-portfolio-based approaches encourage students to develop skills such as flexibility, originality and elaboration through interdisciplinary projects that utilise digital technology (Samaniego et al., 2024).

Self-assessment, peer assessment and feedback are essential components of authentic learning and assessment that encourage deep reflection and skill development. Self-assessment allows students to evaluate their own performance and learning process, which can enhance self-awareness and reflection skills (Andrade, 2019). Peer assessment involves students assessing their peers, which can strengthen understanding and communication between students and introduce new perspectives in evaluation (Topping, 2023). Constructive feedback from teachers and fellow students is also very important in authentic assessment as it can provide direction for improvement and further development (Wisniewski et al., 2020). By using these three components, authentic assessment not only measures learning outcomes, but also facilitates the development of critical and reflective thinking skills. Assessment portfolios are one of the five types of portfolios that can be used in education, in addition to showcase portfolios, learning portfolios, development portfolios and professional portfolios. Assessment portfolios are effective for measuring students' critical and creative thinking skills. This type of portfolio allows learners to reflect and evaluate their understanding through self-analysis and continuous feedback (Nelly et al., 2023). Sulistyo et al. (2020) emphasises that assessment portfolios encourage the development of critical thinking skills and creativity, as learners select and evaluate works that reflect their understanding and innovative ideas. Thus, assessment portfolios serve not only as an assessment tool, but also as a means to develop critical and creative thinking skills.

Electronic portfolios take a more interactive and reflective approach, allowing learners to document and reflect on their learning process continuously so that assessment focuses not only on the end result, but also the learning process. By utilising digital technology, e-portfolios support more thorough assessment, providing opportunities for teachers to measure critical and creative thinking skills more accurately and in line with the values of the Pancasila Learner Profile. This approach has not been widely explored in the context of an independent curriculum, especially in relation to the integration of learner profile strengthening (P5) projects, which rely heavily on the assessment of 21st century skills. Therefore, this research aims to develop an e-portfolio to measure learners' critical thinking and creative thinking abilities which are critical 21st century skills. These abilities are affirmed in the learning outcomes of the Pancasila Learner Profile stipulated in the Minister of Education and Culture Regulation Number 22 of 2022. As an authentic and comprehensive assessment tool, e-portfolios are used to measure both abilities in a more structured and reflective manner.

Validation is the process of ensuring that learning instruments consistently measure their intended purpose, with a focus on accuracy, relevance and accuracy of interpretation of results. Validity as an indicator of instrument quality includes content validity (conformity with the material being taught), construct validity (the extent to which the instrument measures the intended theoretical concept) (Kunwar et al., 2023). Research by (Alordiah & Oji, 2024) emphasised the importance of statistical analysis-based validation to ensure valid and reliable results in project-based learning. In addition, (Adom et al., 2020) showed that a thorough validation process, including expert involvement can increase the effectiveness of instruments in measuring critical and creative thinking skills. With strong validation, learning instruments can be used to generate accurate and relevant data to support educational decision-making. Instead of validity, practicality and effectiveness should be conducted of the developed teaching aids (Ainun & Jefriyanto,

2023). This study aims to reveal the validity, practicality, and effectiveness of e-portfolios. Based on the above background, researchers want to develop an e-portfolio of environmental pollution material for students.

▪ METHOD

Participants

The research was conducted by describing student score achievement in critical and creative thinking skills using e-portfolio (Rahmawati et al., 2023). This research was conducted from November 2024 to January 2025 in one of the junior high schools in Purwosari with the research subject of class VIII C students. The population in this study were all students of class VIII C, totalling 26 students. The number of respondents consisted of 17 male students and 9 female students. A total of 24 students were 13 years old, while 2 other students were 14 years old. The entire population was used as a research sample because if the population is less than 100 people, then all of them can be used as research samples (Arikunto, 2019).

Research Design and Procedures

The ADDIE (Analysis, Design, Development, Implementation, Evaluation) model was used as the framework. The Analysis stage involved gap identification through literature review, teacher interviews, and classroom observations. The Design stage designed the structure and content of the e-portfolio, including task types, assessment criteria, format, and appearance. The Development stage created the e-portfolio platform, sample tasks, rubrics, and usage guides. The Implementation stage pilots the e-portfolio in the classroom, collects feedback, and records constraints. Finally, the Evaluation stage analyses data, surveys, and interviews to evaluate the effectiveness of the e-portfolio and improve it.

The validation process was carried out using a construct validity sheet consisting of thinking activity elements, assessment elements, and scoring rubrics. The practicality of e-portfolios is assessed based on student response questionnaires. The effectiveness of the e-portfolio is assessed through a pretest designed to measure their critical and creative thinking abilities. After implementing the e-portfolio, a posttest was carried out to enable improvements in critical and creative thinking skills. The Data were analysed descriptively quantitatively based on the score of each relevant instrument component (Sugiyono, 2019). Content validity focuses on the suitability of critical and creative thinking indicators and the scientific accuracy of the products developed.

Instruments

This research involved five expert validators, lecturers and experts in the field of e-portfolio design, to ensure the validity and feasibility of the design. These experts have expertise in learning technology, instructional design, and e-portfolio development, as well as extensive experience in designing and evaluating e-portfolios. Their involvement aims to obtain a comprehensive and objective assessment of the design, so this instrument is valid and reliable in measuring students' critical and creative thinking skills.

Learning tools are declared valid if each indicator and each criterion has a minimum mode of 3 or valid criteria. Learning tools are declared to fulfil content validity requirements when all content is declared relevant and scientifically correct (no wrong concepts found). The results of the expert assessment were then analysed using ECVT

(Extended Content Validity Technique) which is a development of the content validity approach aimed at measuring the validity of instrument content quantitatively. This technique is often used to assess the relevance, clarity, and coverage of items in research instruments based on input from experts or experts with the formula. The CVR value is compared with the minimum value corresponding to the number of experts based on Lawshe's table. The minimum CVR value that is considered valid is 0.99.

Data collection techniques involved the use of an e-portfolio, observation, and both test and non-test instruments. The test instrument was developed based on established frameworks (Facione's model of critical thinking and Gultford model of creative thinking) comprises a total of 10 items, with 6 items assessing critical thinking and 4 items assessing creative thinking. For the critical thinking section, each of the six indicators (interpretation, analysis, evaluation, inference, explanation, and self-regulation) is measured by one item. Additionally, a non-test instrument in the form of a questionnaire was employed to gather self-reported data on students' critical and creative thinking skills. The questionnaire comprises 20 items, with each indicator represented by 2 items (covering 6 critical thinking indicators and 4 creative thinking indicators), and was also adapted from previous studies; its validity and reliability were established through expert consultation and pilot testing, Together, these instruments provided a robust framework for evaluating the effectiveness of the intervention in enhancing students' critical and creative thinking skills.

Data Analysis

The categories of students' critical and creative thinking skills were determined based on a scale adapted from Lestari et al. (2021). This scale categorized students into five levels of ability. Students scoring between 81.25 and 100 were classified as having "Very High" critical and creative thinking ability. Those with scores between 71.5 and 81.25 were categorized as "High," while scores between 62.5 and 71.5 indicated "Moderate" ability. Students scoring between 43.75 and 62.5 were classified as having "Low" ability, and those with scores below 43.75 were categorized as having "Very Low" critical and creative thinking ability.

▪ RESULT AND DISSCUSSION

The development of e-portfolios to measure critical and creative thinking skills using the ADDIE model begins with the analysis stage. At this stage, the potential, problems, materials, and functional and non-functional needs were identified. Based on pre- research interviews with science teachers, it was found that students' critical and creative thinking skills were still low in Purwosari. In addition, there is no documentation of learning development and learning assessment in accordance with the Pancasila learner profile in the project activities to strengthen the Pancasila learner profile. The contextual problem that needs to be raised in this development is environmental pollution. Schools have limited learning facilities. The number of computers or laptops in the computer laboratory is very limited, which is an obstacle. Therefore, the e- portfolio is made to be accessed efficiently using a mobile phone or smartphone.

Based on the problems that arise, researchers need to develop learning instruments that can measure and train critical and creative thinking skills. Another study by (Pang, 2022) also emphasised that e-portfolios can support the development of 21st century skills, including critical and creative thinking by creating a project-based learning

environment that encourages active student engagement. This stage is in line with research conducted by López-Crespo et al. (2022) who confirmed the importance of e-portfolios as a digital learning tool to encourage reflection, self- assessment, and student engagement. E-portfolios are designed with features that support the learning process, such as feedback, self-assessment, peer- assessment, and self-reflection. According to a study by Syzdykova et al. (2021) these features provide opportunities for students to evaluate their progress, improve understanding, and develop higher order thinking skills. However, the limitations of learning facilities, such as the minimal number of computers, are a challenge that is overcome by creating an e- portfolio that can be accessed through smartphone devices. This solution is supported by research by (Choi-Lundberg et al., 2023) which shows that the use of mobile devices in digital learning increases includes activity diagrams, drawing use case diagrams and interface design. E-portfolio activities include students starting by accessing learning materials in the form of stimulus (text or reading) and learning videos. After that, students conduct learning activities (such as experiments, practices, or projects). Students then upload assignments and complete self-assessment and some provide peer- assessment of their classmates' assignments. The teacher then reviews the students' assignments and provides feedback on the completed assignments.

For interface design, some of the main screens of the e-portfolio system that include user interaction with important elements are the student dashboard, assignment page, assessment page. On the student dashboard page there is a username menu and navigation menu. On the assignment page consists of its main content in the form of stimulus in the form of text / reading, learning videos, activity commands after that tasks that must be completed that have user access keys, and buttons to upload completed assignments. On each page there is a button to the settings page. On this page there is also a form to upload the assignment (document, image, text), a column to add a link to the learning video (optional) and a button to send the assignment. Meanwhile, on the assessment page, there are assessment rubrics, self-assessment, peer-assessment, self-reflection and feedback from teachers and related parties. On this page, there is a form to provide feedback that includes assessment and suggestions for improvement.

In the use case diagram for e-portfolio, there are two main actors, namely students and teachers. Students are the main users who have a role in accessing learning stimulus, either in the form of reading texts or videos. Students also have the responsibility to upload completed assignments in various formats, such as text, images, or other documents, through fill in assignment feature. Once the assignment is uploaded, students can perform self-assessment, i.e. filling out a form to assess their own understanding or performance. Students can also participate in peer-assessment. Teachers act as actors who provide teacher feedback on assignments that have been uploaded by students.. The following use case diagram in the e-portfolio system is in Figure 1.

At the design stage, the e-portfolio design is designed to support various aspects of learning, including student activities, user interface, and use case diagram. Research by Nelly et al., (2023) shows that a well-designed e-portfolio can serve as an important tool in reflection-based learning and formative assessment. Elements such as self- assessment, peer-assessment, and teacher feedback contribute significantly to students' active learning. In a similar study Hsieh (2024) highlighted the importance of user-friendly interface design to support accessibility and functionality, especially in situations of

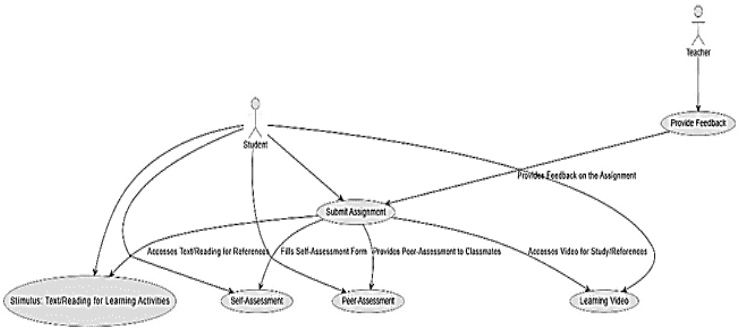


Figure 1. Use case diagram e-portofolio

limited learning facilities. Use case diagrams involving the main actors, i.e. students and teachers, also proved effective to ensure every feature designed is in line with user needs.

In the context of 21st century learning, the integration of features such as assessment rubrics, self-reflection columns, and comprehensive feedback are important elements in supporting the development of students' critical and creative skills. According to the International Journal of New Developments in Education study (2022) e-portfolios with these features can increase student engagement in project-based learning. Overall, the research results support that e-portfolio design that includes student activities, interactive interfaces, and integrated use case diagrams can support the successful implementation of project-based learning.

At the development stage, researchers began developing media based on the results of the design stage. This research uses the flipbook programming language which is converted into an application. The media that has been made will be tested for responsiveness. Furthermore, researchers. Here are some pictures of the appearance of the e- portfolio that has been developed.

The front page contains the title of the e- portfolio along with the project theme and activity title so that students understand the basic things related to the activities to be developed in the e- portfolio. With an attractive and informative display, the front page serves as an initial guide for students to understand the direction and purpose of the project they will document, as well as providing motivation to carry out the activities seriously.The next page is the dashboard containing the activity aspect and student identity. In addition, there is a brief description of the purpose of the activity and instructions for completing the activity. This page becomes one with sequential student activities. In the student activities there are assignments so that students can access and fill them in. Before the activity, there are several references or learning resources in the form of learning videos.

The next page is learning assessment in the form of formative assessment aspects. This assessment contains self-assessment, feedback or peer assessment. Self assessment and peer assessment are in the form of an assessment rubric, then teachers and related parties provide feedback in the form of judgements, criticisms, input or suggestions. Teachers can also assess student work based on assignments uploaded or inputted through google form.

After product design, the next step is responsiveness testing. Responsiveness simulations were conducted using tools such as Chrome Developer Tools to ensure that the app could adjust its layout on various screen resolutions. The results show that the

app is able to adapt from small (360px) to large (1080px) screen sizes perfectly. All features, such as menu navigation, buttons, and animations, functioned seamlessly. User interaction testing was also conducted with a focus on navigation, feature accessibility, and the main functions of the e- portfolio. The results show that navigation between pages can be done easily, either using swipe or navigation buttons. Other buttons, such as menu and zoom, work responsively, ensuring a smooth user experience. Touchscreen interaction on both small and large devices was seamless, supporting user comfort.

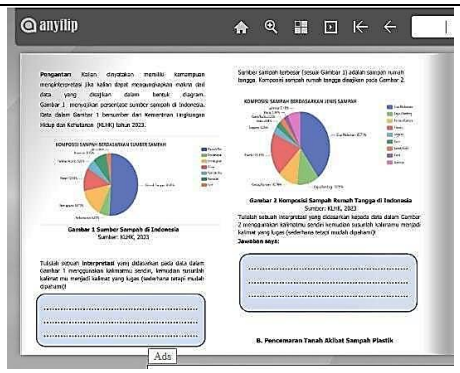
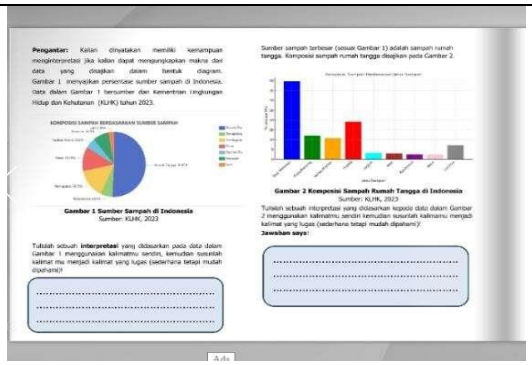
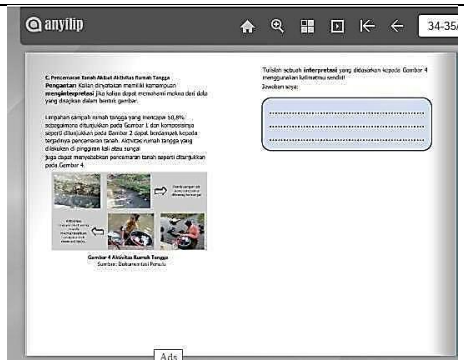
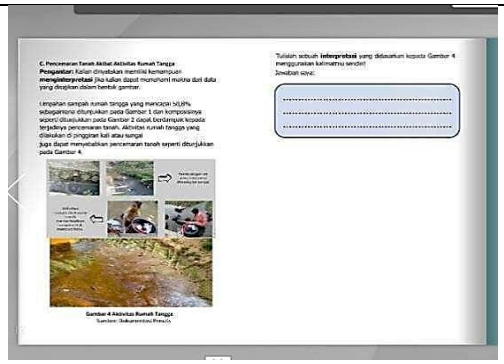
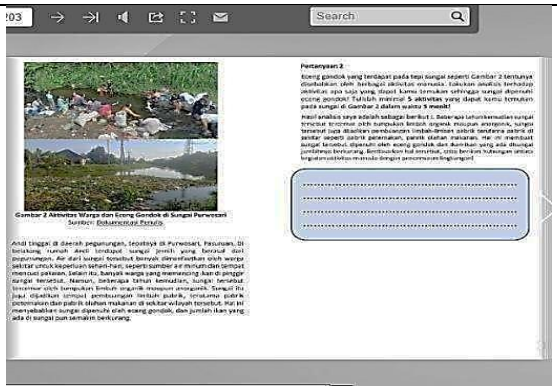
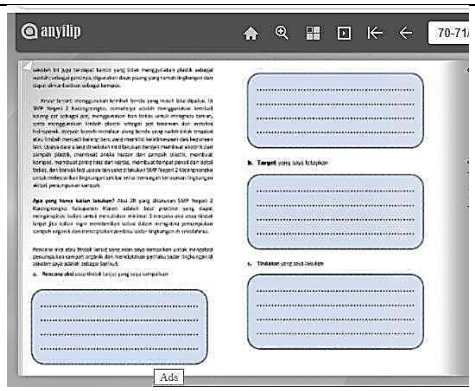
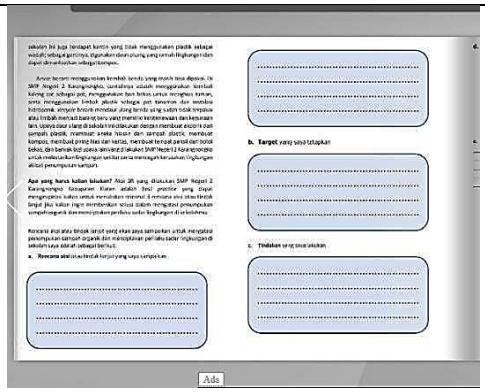
Overall, the e-portfolio application in the form of an application has fulfilled the responsiveness criteria with an adaptive display, smooth user interaction, and stable performance on various devices. With these results, the application is ready to support students in documenting their learning process and results digitally. However, optimising the animations for low-spec devices could be the next development step to improve the user experience.

At the development stage, the realisation of the e-portfolio design into program code is a key step to creating a functional and responsive application. Several international studies support this approach. For example, in a study by Meyer et al. (2018) the use of app-based e-portfolios was shown to be able to support technology-based learning by improving accessibility, interactivity, and documentation of student learning processes. This research shows that the development of project-based learning apps requires rigorous functionality testing to ensure compatibility across different devices.

After design development and responsiveness testing, the next step is product validation. According to Sugiyono (2013) before being tested, development research must go through the validity stage first. There are results and discussion of e-portfolios developed on environmental pollution material validly seen from the validation sheet. The validation the e-portfolio consists of construct and content Nieveen (1999). Construct validation is used to measure the level of conformity of critical and creative thinking indicators with the instruments used while content validation is used to measure the suitability of content or substance based on science. The criteria on the validation sheet were analysed descriptively quantitatively with the mode score of each component in accordance with the assessment instrument.

Furthermore, the expert's suggestions became the basis for revisions aimed at improving the quality of the instrument. Research by (Hanh & Huong, 2021) showed that visual changes such as changing pie charts to bars or adding other visual elements can help improve students' understanding of the material. Similarly Oh et al., (2020) emphasised the importance of concise and clear text presentation to improve accessibility for students in understanding their assignments. In this context, e-portfolios designed for project-based learning show effectiveness in helping students reflect on their learning, as found by Marín, (2020). Revisions made based on expert input have also been shown to produce stronger and clearer assessment rubrics. (Kusuma et al., 2021) noted that improved assessments with better visual guidance, such as thickening the font or adding relevant images, were able to improve students' understanding of the assessment criteria and motivate them to contribute more actively to the learning process. Thus, systematic validation and revision are important steps to ensure e-portfolios can be used effectively as digital learning media. Some changes were made according to the suggestions in Table 1.

Table 1. Revision

No	Before Revision	After Revision
1		
2		
3		
4		

Based on the revision table 1, several significant improvements were made to the e-portfolio to improve its validity and reliability. In the indicator of data interpretation on environmental pollution, data visualization was enriched by the addition of images such as bar graphs, which are considered more effective in presenting data by visual (Abdinejad et al., 2020). An answer key was also created to ensure consistent and accurate assessment. In addition, figure 2 was replaced with a bar graph to present the data more clearly.. For the indicator of organic and inorganic waste impact analysis, the stimulus/reading text and discourse sentences were shortened so as not to burden students' cognitive and focus on important information. This will stimulate critical and creative thinking of students (Aguilera & Ortiz-Revilla, 2021). In the indicator of evaluation, more specific feedback was added to the "conclusion" command to help students reflect on their understanding. Activity descriptions were also reduced so that students could focus more on the core of the problem. about the relationship between waste management and soil pollution issue. In the inference indicator, directed instruction was added to guide students in formulating relevant hypotheses. Information about the relationship between soil type/source and soil pH were added to provide a strong scientific basis, and the reading text was shortened. For the action plan writing indicator, a command to write actions that can be taken was added to encourage students activity for solving problems. Finally, in self regulation indicator, the number of ideas that must be entered was added to ensure that students produce comprehensive solutions (Suwistika et al., 2024). E-Portfolio contains self-assessment and peer assessment which make the assessment more objective. Feedback encourages self-reflection for students' critical thinking.

The study by Fathi & Rahimi (2022) highlights the importance of self-assessment and peer-assessment to encourage collaborative learning and the development of students' reflective skills. In the context of e- portfolios, these features can facilitate active learning and support digital documentation of student progress. In addition, research by Kihwele et al. (2024) supports the use of feedback features to improve student engagement and their learning outcomes, especially in technology-based learning environments. On the aspect of responsiveness, research by Villamil et al. (2023) emphasises the importance of adaptive interface design to ensure optimal user experience across different devices, including smartphones and tablets. The study underlines that responsiveness testing using tools such as Chrome Developer Tools or emulators is essential to ensure application stability and user comfort.

The validity of e-portfolio media can be known based on the results of validation by five experts. Experts provide an assessment on the validation sheet. The e-portfolio media can be said to be valid if the percentage of expert assessments reaches a mode ≥ 3. The validation results data also need to be analysed to support the validity of this e-portfolio product. The score obtained from each expert is determined mode per indicator. Based on Sugiono's Likert scale category (2019) with validity categories 1-4, scores 3 and 4 as "valid". The following are the assessment results for several aspects that have been assessed by experts.

Based on Figure 1, the e-portfolio obtained mode 4 including in the highly valid category. The results of the study are supported by Riduwan (2016) which states that construct validation which obtains a mode value of 4 is included in the highly valid criteria, so it is included in the highly valid category. Based on the data above, each aspect has a mode of 4. A mode is the value that appears most often. These results are then

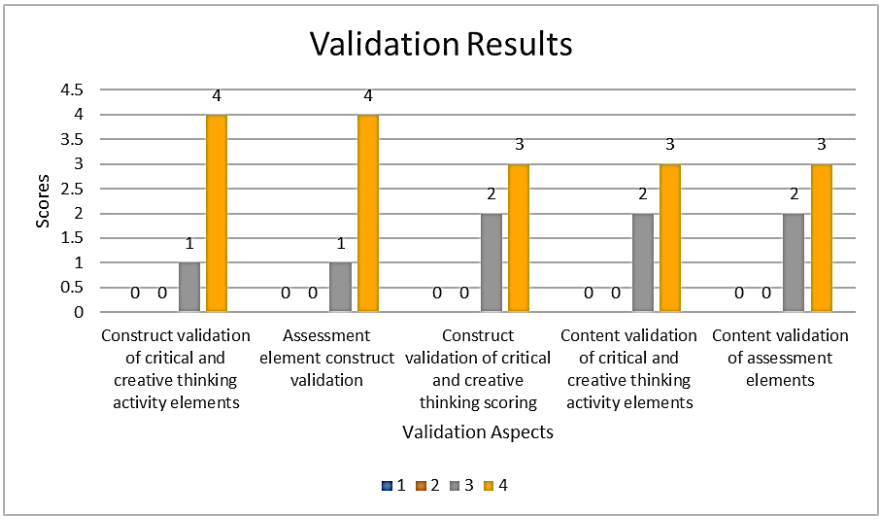


Figure 1. Validation results

categorised as values 3 and 4 as "valid". The number of experts who stated valid was 5 (ne=5), namely experts 1,2,3,4, and 5). The number of experts who stated "valid" was 5 with a total of 5 experts. From this data, it was then calculated using Lawshe's formula. From the calculation using Lawshe's formula, a value of 1 was obtained for each aspect. CVR values range from -1 to +1. A positive value indicates that the item is considered valid by all experts. With a CVR value of +1, this item is considered valid. This indicates that the experts agreed that each aspect in this validation instrument is essential. There were no items that required revision or deletion based on the content validity criteria. Thus, the validation instruments covering critical and creative thinking activity elements, assessment elements, and scoring rubrics were declared highly valid.

Previous research e-portfolio by Purnama et al. (2021), Zhang et al. (2022), Dalton (2022) who did not use self-assessment and peer assessment to maximize the potential of 21st century skills, namely critical and creative thinking (Meletiadou, 2021). This e-portfolio considers the use of self-assessment and peer assessment together not only to improve academic performance but also to improve students' critical thinking skills (Chang et al., 2021). Therefore, this instrument can be used for further research without requiring significant modifications. In conclusion, the developed e-portfolio has excellent content validity to train students' critical and creative thinking skills. On the overall validation results, the e-portfolio falls into the highly valid and highly valid categories.

Other research that supports this is a study by (Bearman et al., 2023) which states that instrument validation is an important step in the development research process to ensure the reliability and accuracy of the data obtained. This validation stage includes testing of content, construct, and criterion validity to ensure that the tools used are in accordance with the research objectives. In addition, research by Nieven (2019) also emphasises that validation in the context of development research involves the participation of experts or experts to evaluate the suitability of the design and substance of the instrument to the research needs.

The results of research by Topping (2023) and Wahyuni et al. (2021) who developed an e- portfolio for 21st century skills assessment also showed that validation by experts should include an assessment of the clarity of content and relevance to learning

objectives. The study found that e-portfolios validated with highly valid and highly valid categories were able to increase the effectiveness of assessment in project-based learning. Thus, adequate validation not only ensures the validity of e-portfolios but also improves their quality and effectiveness in supporting the measurement of learners' abilities.

The critical thinking test aims to determine the extent to which students are able to interpret, analyse, evaluate, infer, explain and create solutions to problems given in the learning context. While the creative thinking test is to determine the extent to which students are able to think fluently, flexibly, original and elaborate. Before the test is given, it is ensured that students have understood the material that is the basis for testing. This study aims to interpret students' critical and creative thinking skills based on predetermined categories.

Before categorisation based on critical and creative thinking indicators, the results of the overall pretest score analysis will be presented. The scores obtained by students varied, with the highest critical thinking test score reaching 78.57 and the lowest score of 10.71. The results of descriptive statistical analysis show that the mean (M) value is 38.87, the median (Me) is 37.50, and the mode (Mo) is 25.00. Based on the assessment category, the average critical thinking ability of students is in the range of 0 -43.75 which is included in the very low category. Then after using e-portfolio the result obtained by students varied, with the highest critical thinking test score reaching 100 and the lowest score of 21.43. The results of descriptive statistical analysis show that the mean (M) value is 38.87, the median (Me) is 96.43, and the mode (Mo) is 96.43.

The results of the categorisation analysis of students' critical ability scores based on the overall final score reveal before (pretest) and after (postest) using e-portfolio. The differences between the pretest and posttest was significantly. In the very high category (scores greater than 81.25 up to 100), no students achieved such scores in the pretest, whereas 21 students reached this level in the posttest. In the High category (scores greater than 71.5 up to 81.25), 1 student was recorded in both the pretest and posttest. In the Moderate category (scores greater than 62.5 up to 71.5), there was 1 student in the pretest, but no students were identified in the posttest. In the Low category (scores greater than 43.75 up to 62.5), 5 students were observed in the pretest, which decreased to 2 students in the posttest. Lastly, in the Very Low category (scores between 0 and 43.75), 19 students were classified during the pretest, and this number declined to 2 in the posttest. Overall, both the pretest and posttest evaluations involved a total of 26 students.

Based on the result of data, it can be seen that most students have critical thinking skills in the very low category. A total of 5 out of 26 students or 19.23% of students have critical thinking skills in the low category. The largest percentage in the very low category is 19 out of 26 students or 73.08% of students have critical thinking skills in the very low category. The rest are in the moderate and good categories at 3.85% each. Many studies have been conducted to analyse critical thinking skills. Arisoy & Aybek (2021) in their research concluded the levels of students' critical thinking are at insufficient levels. Students' critical thinking skills are dominated by certain indicators (Azizah et al., 2018). From five indicators of critical thinking skills above, three indicators, namely analysis, evaluation and inference are lowest (Fernando et al., 2021). Itis needed tools was an impact on increasing critical thinking skills (Sari & Prasetyo, 2021). Therefore, this study will also (Prameswari & Suharno, 2018). Therefore, this study will also present the results of the analysis of critical thinking skills on each indicator based on its category. Through

interviews with educators at the school, it is known that students are still confused in making decisions or the most appropriate actions when faced with the problem of pollution and waste management around them. The educator said Grade 8th students mostly lack learning motivation and learning activities stimulating critical thinking, most of them usually think memorize things, even science phenomena. They also do not understand how to manage waste that is more efficient, effective to solve promblems because most of them lack of awareness of environment. The school facilities are lack for experiment activities. This is a challenge for teachers to teach student think critically related to scientific instrument in preserving the soiil and waste management education. Based on result , contextual questions based on the issue of soil pollution and waste management that are integrated with critical thinking skills show the existence of a relationship with each other and working on improve critical thinking ability. All of the critical thinking indicators have similiar score that indicate they have relationship each others. The average total score obtained by students at Purwosari Junior High School is 38.87 which shows a very low category. Educators at the school also said that 'In doing contextual activities, some students still have difficulty representing the results of observations, experiments on the phenomena around them'. It is known that the use of e-portfolio that provides academic advice and feedback used as a tool for reflection on learning can encourage critical thinking ability student (Syzdykova et al., 2021). Stančić (2021) said that providing self assessment and peer assessment (peer feedback) enhance student awareness and critical thinking ability. It is also known that the use of questions that contain phenomena in everyday life can encourage students to reason critically (Cahyani et al., 2022). Science is closely related to critical, creative, and constructive thinking activities so that it can affect their understanding and learning outcomes (Aditomo, 2019). In detail, the achievement of scores working on contextual questions based on the issue of soil pollution and waste management shows the qualifications of each different learner. There are 6 indicators of critical thinking that show the ability of students in each indicator that varies. The results of the achievement of each learner on each critical thinking indicator can be seen in Figure 2 below.

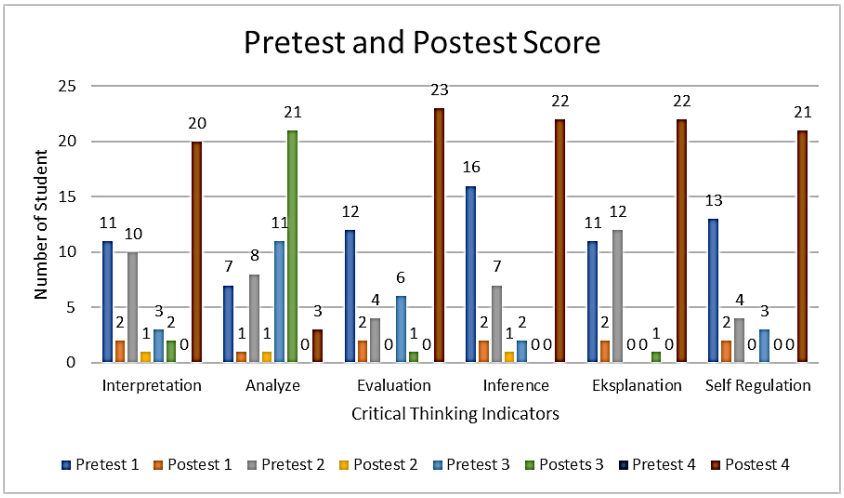


Figure 2. Graph of the achievement of students' critical thinking scores

Based on Figure 2, most students exhibited very low critical thinking scores across nearly all indicators before using the e-portfolio, particularly in self-regulation (18 students) and inference (17 students). This initial weakness in self-regulation, the ability need to students can learn at their own pace, are responsible for their own decisions, can choose and communicate regarding student self-regulation during learning (Eggers & Voogt, 2021). Eggers & Voogt (2021) emphasized the crucial role of self-regulation in effective learning, noting that students who struggle with these metacognitive processes may find it difficult to plan, monitor, and evaluate their learning strategies. On the other hand, the low scores in inference, the ability in their reasoning abilities is leading to better performance to draw logical conclusions, corroborate findings that students frequently encounter difficulties in making sound inferences due to various factors, including limited prior knowledge and cognitive biases (Cromley et al., 2021). Van Dijke-Droogers et al. (2024) suggest that explicit instruction and practice are essential for developing strong inferential reasoning skills. The explanation indicator showed a more balanced distribution between the "very low" (13 students) and "low" (12 students) categories, suggesting that while some students possessed a foundational ability to explain concepts, understanding and articulating these concepts remained a significant hurdle for many. After using the e-portfolio, a substantial shift occurred, most students achieve very high critical thinking scores across almost all indicators, most notably in evaluation (23 students). The inference and explanation indicators also showed significant improvement, with 22 students achieving "very high" scores in both. Interpretation skills also saw considerable gains, with 20 students reaching the "very high" category. While analysis skills improved, they reached a "high" rather than "very high" category (21 students), indicating e-portfolio has made improvement critical thinking ability students. Most of them have improve from very low to very high score. In detail, each student's ability to work on critical thinking activities to solve contextual problems based on soil pollution and waste management issues easily. Therefore indicators of student's critical thinking ability can improve, it is also known by Ait Mama (2023) which students enjoy by virtue of e-portfolio assessment.

Besides critical thinking ability, the test is also measure creative thinking. The test aims to determine the extent to which students are able to think fluency, flexibility, originality, and ellaborate in the learning context. This study aims to interpret students' creative thinking ability based on predetermined categories. Before categorisation based on creative thinking indicators, the results of the overall pretest score analysis will be presented. The scores obtained by students varied, with the highest creative thinking test score reaching 70 and the lowest score of 0. The results of descriptive statistical analysis show that the mean (M) value is 33.46, the median (Me) is 35, and the mode (Mo) is 50. Based on the assessment category, the average student's creative thinking ability is in the range of 0 -43.75 which is included in the very low category. The number of students who scored above the very low category was 8 students. This data shows that more than half of the students are still in the very low category, with a difference of 30.77%. After using e-portfolio students obtained scores varied, with the highest score 100 and the lowest score of 5. The results of descriptive statistical analysis show that the mean (M) value is 80,58, the median (Me) is 80, and the mode (Mo) is 80. Based on the assessment category, the average student's creative thinking ability is very high category.

The categorization analysis of students' critical thinking scores based on their overall final scores reveals significant changes from the pretest to the posttest. In the Very High category (scores between 81.25 and 100), no students achieved such scores in the pretest, while 12 students reached this level in the posttest. Similarly, in the High category (scores between 71.5 and 81.25), there were no students in the pretest, but 8 students attained this score range in the posttest. In the Moderate category (scores between 62.5 and 71.5), both the pretest and posttest had 2 students each. For the Low category (scores between 43.75 and 62.5), no students were observed in the pretest, whereas 3 students fell into this category during the posttest. Lastly, in the Very Low category (scores between 0 and 43.75), 24 students were recorded in the pretest, which dramatically decreased to only 1 student in the posttest. Overall, the total number of students assessed remained constant at 26 for both the pretest and posttest, indicating a notable improvement in the distribution of critical thinking skills following the intervention. .

Based on the result data, it can be seen that most students have creative thinking skills in the very low category. A total of 6 out of 26 students or 23.08% of students have creative thinking skills in the low category. The largest percentage in the very low category is 18 out of 26 students or 69.23% of students have critical thinking skills in the very low category. The rest are in the sufficient category of 7.69%. Learning to improve creative thinking skills in schools at the next level needs to be integrated in every subject, including science subjects regardless of the topic. A research studied positive significant relationship between the children's creative thinking and scientific process skills scores that tendencies to the creative thinking, problem-solving skills students(Yildiz & Guler Yildiz, 2021).

According to previous research, low or unsatisfactory achievements in the other three criteria include the ability to generate new ideas easily (fluency), the ability to generate varied ideas (flexibility) and the activity task for originality includes new creation (Weiss & Wilhelm, 2022). Therefore, this study will also present the results of the analysis of creative thinking ability on each indicator based on its category. Through interviews with educators at the school, it is known that students are still confused in finding novelty or innovation of ideas as a solution to the problem of pollution and waste management around them. The educator said Grade 8th students mostly do not have the thinking skills to create ideas or new things because of their convergent way of thinking. This is a challenge for teachers to provide stimulus or learning activities in creating new policies or ideas related to scientific attitudes in maintaining soil sustainability'. The third low critical thinking ability shows that the results of working on contextual questions based on the issue of soil pollution and waste management that are integrated with creative thinking skills show a connection with each other. If one of the creative thinking indicators cannot be mastered well, then this can have an impact on other creative thinking indicators such as thinking fluently, flexibly, originality and elaboration. The average total score obtained by students at Purwosari Junior High School is 33.46 which shows a very low category. Educators at the school also said that 'Students have lack of ability to generate new ideas and create them al into a new activities plan'. It is known that the use of problems is known that the use of texts or readings that contain examples of problem solutions and can be used as material for creative thinking ideas but more effectively for guiding students to explore, elaborate, and evaluate story ideas, rather than generating ideas (Yang et al., 2022). Making a new product comes from environmet issue make

student explore, elaborate and evaluate their ideas This divergent thinking activity can affect their science understanding. It comes from one problem then solve it (Mursid et al., 2022). In detail, the achievement of scores working on contextual questions based on soil pollution and waste management issues shows the qualifications of each different learner. There are 4 indicators of creative thinking that show the ability of students in each indicator that varies. The results of the achievement of each learner on each indicator of creative thinking can be seen in Figure 3 below.

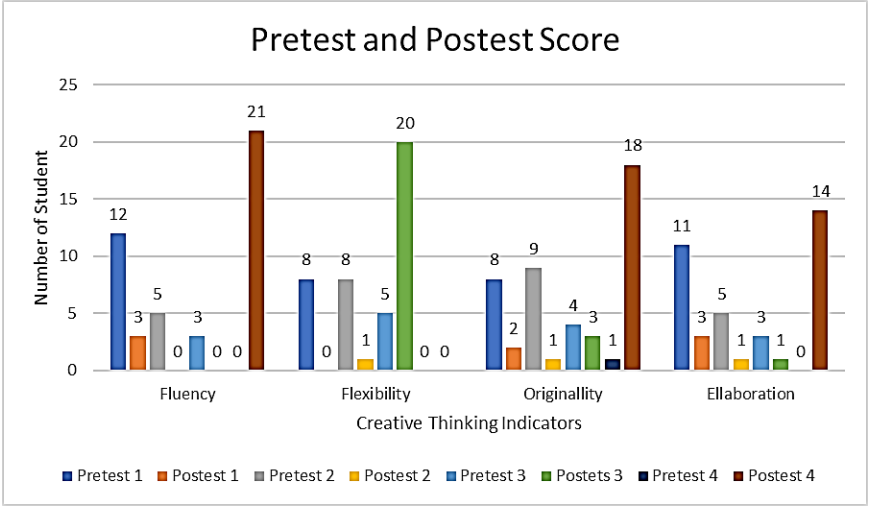


Figure 3. Graph of the achievement of students' creative thinking scores

Based on Figure 3, most students have very low critical thinking scores on almost all indicators, especially on fluency (12 students) and ellaboration (11 students). The explanation indicator has a more balanced distribution between the very low (12 students) and low (9 students) categories, indicating that understanding and explaining concepts is still a challenge. After using e-portfolio Meanwhile, most students have very high critical thinking scores on almost all indicators, especially on fluency (21 students). The inference have same score with originality (18 students) and ellaboration (14 students). It is indicate that e-portofolio has made improvement critical thinking ability students. Most of them have improve from very low to very high score. In detail, each student's ability to work on creative thinking activities to solve contextual problems based on soil pollution and waste management issues easily. Students can enhance their ideas to make a product from ecoenzyme. Many types of research and studies have been conducted to identify the importance and how to improve of creative thinking. Jawad et al (2021) in their research concluded that most students have sufficient creative thinking skills. Students' creative thinking skills are dominated by certain indicators of creativity (Forte-Celaya et al., 2021). The development of creative thinking skills that are trained on indicators gradually will be more focused and optimal by using learning activities that made student made their ideas generate and develop it, it can be used by e-portfolio (Bedel et al., 2024) . Therefore, this study will also present the results of the analysis of creative thinking that is considering indicators of creativity thinking (Mursid et al., 2022) and showed the improvement made from using e-portfolio. By using e-portfolio student have improve creative score from very low category to very high category. The third low critical

thinking ability shows that the results of working on contextual questions based on the issue of soil pollution and waste management that are integrated with critical thinking skills show the existence of a relationship with each other. If one of the critical thinking indicators cannot be mastered properly, then this can have an impact on other critical thinking indicators. The average total score obtained by students at Purwosari Junior High School is 38.87 which shows a very low category then improve to 80,57 which is very high category. Educators at the school also said that 'in doing contextual activities, some students still have difficulty representing the results of observations, experiments on the phenomena around them'. It is known that the use of open questions, self assessment, peer assessment that contain phenomena in everyday life can encourage students to reason critically (Stančić, 2021). The result of the investigation on the students' e-portfolio was improve students' critical, reflective and creative thinking students (Afrilyasanti et al., 2024).

▪ CONCLUSION

This study investigated the effectiveness of an e-portfolio in enhancing critical and creative thinking ability of 8th-grade students at a junior high school in Purwosari. The e-portfolio's construct and content validity were established with a mode of 4 and a Content Validity Ratio (CVR) value of 1. Analysis of student performance revealed a positive shift in critical thinking abilities. The most of students 73.08% (19 students) were categorized as having "very low" critical thinking skills. After using the e-portfolio, improve significantly most of students 88.46% (21 students) achive "very high" critical thinking ability. While most of students 69.23% (18 students) were categorized as "very low" creative thinking ability after the intervention, 46.15% (12 students) reached the "very high" category.

The study concluded that e-portfolio improve students' critical and creative thinking ability in the context of environmental issues like soil pollution and waste management still require further development. Observations and interviews with science educators highlighted the critical role of teachers' ability to design and implement effective learning activities in fostering these essential skills. Therefore, this study recommends for educators to implement learning strategies that improve critical and creative thinking, supported by appropriate resources. Recognizing the increasing importance of these skills in the 21st century, this research offers valuable insights for future studies exploring the development of critical thinking and creativity, specifically within the context of soil pollution and waste management. A limitation of this study is the relatively small sample size. Future research should consider expanding the sample to obtain more robust and generalizable findings.

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