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Original Research Article

Development of electronic portfolios to assess concept mastery and creative thinking on project-based acid-based concepts

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ABSTRACT

The purpose of the study was to develop an electronic portfolio instrument to assess concept mastery and creative thinking on project-based acid-base materials. The research participants are class XI, who will study acid-base materials. This research uses the 4D Research and Development model which are carried out up to stage 3 (Define, Design, and Development). On the define stage, a literature study, a field survey, material analysis, indicator analysis, and task analysis were conducted. The design stage designed grids and assessment rubrics, the preparation tasks consisting of four: making papers, practicum reports, posters, and concept maps. The design stage compiled an electronic portfolio instrument. The developmental stage conducts quality tests: initial development test, expert validity test obtained a CVR value of 1.00, reliability test with inter-rater obtained a Cronbach Alpha value between 0.652 and 1.000. After the electronic portfolio instrument was valid and reliable, a limited trial was conducted with N-Gain scores of task 1, task 2, task 3, and task 4, respectively: 0.17 (low), 0.13 (low), 0.46 (medium), and 0.32 (medium). The overall average of the pretest and posttest N-Gain scores is 0.90, with a higher category. This electronic portfolio instrument based on Project-Based Learning (PjBL) is expected to help teachers assess tasks on concept mastery and students' creative thinking on acid-based materials.

Introduction

Project-based learning assessment is used as the core assessment in the 2013 curriculum. This project-based assessment is designed for the complex problems that students experience in understanding learning. As in acid-base identification materials, project-based assessment can be applied to making acid-base indicators from natural materials. There is 57% completeness of acid-base learning that only involves cognitive assessment, while project-based assessment has 85% learning completeness (Sudibawa and Rina, 2020). Success in the learning process is essential to ensure optimal academic performance. By increasing motivation, improving understanding, developing skills, building confidence, and fostering a more inclusive environment, it is to achieve better academic performance (Solimani and Karim, 2024). Using this student-centered pedagogical approach makes students more interested, so that it can encourage active learning through the application of knowledge of the topic. The approach used is designed to build student knowledge through collaboration, responsibility, effective communication, analytical, and critical thinking so that students will learn science more effectively (McLaughlin et al., 2024).

Assessment is used to reflect six fundamental self-regulatory constructs, such as (1) planning (task analysis and self-motivation beliefs), (2) doing (self-control and self-observation), (3) reflecting (self-assessment and self-reaction), (4) predicting one's success (self-efficacy), (5) reasons to succeed (self-determination), and (6) task value. So this assessment of learning is very important to do to monitor the learning process, improvement, and learning effectiveness (Lysenko et al., 2022). In the research of Asmi et al. (2021), that assessment is not only used to assess learning outcomes; but assessment is also used to develop and train metacognitive skills in students. The use of portfolio assessment can assess learning outcomes and develop and train students' metacognitive skills. This is in line with the research of Lukitasari et al. (2021), that the use of technology in learning, namely electronic portfolios, can improve student skills. The use of this electronic portfolio makes learning more effective because students must be able to think and solve during the learning process.

According to Masluhah and Afifah (2022), providing feedback on the use of electronic portfolio assessments can develop and train student skills. Portfolios used to describe a compact container to convey an unstructured collection of documents and materials, but over time they have evolved from paper to electronic, from local networks to the world wide web (Farrell, 2020). These electronic portfolios are used to provide evidence of the owner's experience, both teacher and learner, and as an instrument to collect assessments (Zhang and Gemma, 2022). In achieving creative thinking skills, the learning process can be assessed by utilizing existing technology The utilization of technology in the form of electronic portfolios can be integrated into project-based learning (Lukitasari et al., 2021).

An educator in the 21st century must keep up with technological developments to be able to improve 21st-century skills, which include (a) critical thinking and problem-solving, (b) communication and collaboration, and (c) creativity and innovation (Radin and Yasin, 2018). Educators really need to understand students in the 21st century, be able to communicate well, and be able to guide students in the learning process (Soylemez, 2023). So that educators in the 21st century need an innovative learning model and are able to improve students' 21st-century competencies, such as project-based learning (PjBL) (Kautsar, 2023). Project-based learning activities aim to make it easy for students to understand the material, especially in learning acid-base chapter chemistry. The application of project-based learning is used to make it easier for students to understand the material. Some concepts in chemistry cause difficulties and different perceptions for students because chemistry is dominated by abstract concepts (Widarti et al., 2025). This PjBL model is one of the learning models that can increase students' creativity by integrating real-world problems into the learning process (Kautsar, 2023). This is in line with research Yustiana et al. (2020), project-based learning can affect the improvement of creative thinking.

Portfolios are used to evaluate students' learning processes. In addition, the use of portfolios refers to academic performance and the main factor that drives interest in evaluation through portfolios (Salarirche, 2016). There are several studies that discuss electronic portfolio assessments, such as Nurhayati's research (2023), developing electronic portfolio assessments can improve creative thinking skills by giving assignments to students. Another research project is developing electronic portfolios by providing assignments that can improve concept mastery and creative thinking with N-gain results of 0.71, with a high category and 0.77 high category respectively (Apriani, 2023). As well as in the research of Lukitasari et al. (2021), that the use of electronic portfolio assessment in project-based learning can develop metacognitive abilities in the three phases of planning, application and evaluation with scores of 69.08 to 69.31, 66.78 to 69.42, and 56.20 to 72.41, respectively.

The result of the analysis of previous research Lukitasari et al. (2021), developed electronic portfolio assessments that were linked to project-based learning which were out in mathematics, biology and physical education study programs. Meanwhile, there is no research that develops electronic portfolio assessment in project-based chemistry learning. In addition, Apriani's research (2023) found that electronic portfolios can improve students' conceptual understanding and creative thinking. Research conducted by Mahardika et al. (2024) is to implement an assessment using an electronic portfolio that can improve habits of mind and concept mastery. In Nuryanto's research (2024), linking the use of electronic portfolios to using Google Classroom can improve 21st-century skills. Therefore, this research was conducted to develop an electronic portfolio assessment linked to project-based chemistry learning. With the electronic portfolio assessment instrument associated with project-based chemistry learning, it is expected to facilitate teachers in assessing the assignments given.

Methods

This research was conducted in one of the high schools in Cimahi class XI, who was studying acid-base identification. The participants of this study amounted to 23 students in class XI. The method used in this research is the Research and Development (R&D) model carried out with the 4D model developed by Thiagarajan et al. In Maydiantoro (2021). The 4D research model is carried out up to stage 3: (i) Define, at this stage a literature study is carried out to analyze previous research, then a field survey is carried out in order to find out the problems that exist in the research school. In addition, material analysis was carried out based on the 2013 curriculum, analyzing indicators of concept mastery and creative thinking skills, and analyzing the tasks that would be given to students. (ii) Design. At this stage, the preparation of grids and assessment rubrics, the preparation tasks consisting of 4 tasks: making papers, practicum reports, posters and concept maps. Furthermore, the preparation of electronic portfolio instruments. (iii) At the development stage, the instrument quality test is carried out, namely the validity test and reliability test. The revised results from the expert became the basis for the limited trial. The limited trial was conducted with 24 students in the same school and different classes. After the electronic portfolio instrument is valid and reliable and a limited trial is conducted, the implementation of the developed electronic portfolio instrument is carried out.

The validity test was carried out by asking for expert judgment as many as five validators. The results obtained from the experts' consideration were then analyzed using the Content Validity Ratio (CVR), using the following equation:

$$CVR = \frac{N_e - \frac{N}{2}}{\frac{N}{2}}$$

Description: Ne = Number of validators who stated valid; N = Number of validators

The results of the Content Validity Ratio (CVR) were compared with the minimum value of CVR one-tail significance of 0.05 (Lawshe, 1975). With the number of validators, 5 people obtained a CVR calculated value of 0.99. After the electronic portfolio instrument was valid, the reliability test was carried out using the inter-rater method with three raters, and the Cronbach Alpha value was calculated.

Instruments that have been valid and reliable, the analysis of concept mastery and creative thinking of students using scores before and after giving feedback, then calculated by the N-Gain formula and categorized. The following is the N-Gain equation according to Hake (1998):

$$\text{N-Gain} = \frac{After\ score - Before\ Score}{Maximum\ score - Before\ Score}$$

Description: N-Gain = Normalized gain; After scoring = Student score after giving feedback; Before score = Student score before given feedback; Maximum score = Maximum score

Results and Discussion

The portfolio development in this study is based on the current portfolio collection, which is still done traditionally. According to Chang (2001), traditional portfolio assessment still relies on the manual collection of written assignments. Therefore, the development of this electronic portfolio utilizes technology using the google classroom platform. The use of google classroom in learning is considered to be easier for students. 77.66% agreed with the statement that using the google classroom platform can make it easier for students because they can more quickly access important materials, assignments, and announcements (Utami, 2019).

The preparation of electronic portfolio instruments begins with an analysis of basic competencies (KD) and indicators. From the results of the KD analysis and indicators, four tasks were obtained that will be used in the developed electronic assessment instrument. Table 1 presents the tasks contained in this e-portfolio.

Table 1. Tasks in the electronic portfolio

Basic Competency	Indicators	Task
3.10 Explain the concept of acid-base and its strength and ionizing equilibrium in solution.	3.10.1 Explaining the concept of acids and bases according to Arrhenius, Bronsted-Lowry, and Lewis theories and the strength of acid-base solutions. 3.10.2 Classify the strength of acid-base: strong acid, strong base, weak acid, weak base solutions. 3.10.3 Calculate $[H^+]$ in acidic solutions and $[OH^-]$ in basic solutions, and calculate pH values from molarity data. 3.10.4 Explain how to identify acidic and basic solutions using acid-base indicators.	1. A paper to find information on the impact of using synthetic acid-base indicators, explain the concept of acid-base theory, and acid-base strength. 2. Practicum report on making acid-base indicators from natural materials 3. Poster about the practical results obtained and natural materials that are good to use as natural acid-base indicators.
4.10 Analyze the trajectory of pH changes of several indicators extracted from natural materials through experiments	4.10.1 Apply natural materials that can be used as acid-base indicators. 4.10.2 Carry out an experiment to make a natural-based acid-base indicator.	4. Concept Map on acid-base identification with synthetic or artificial indicators.

Table 2. Content Validity Ratio (CVR) values

Indicators	Aspects assessed	Appropriateness of Indicators and Tasks		Appropriateness of Task and Rubric	
		CVR	Validity	CVR	Validity
Task 1 (Paper on the impact of using synthetic indicators)					
3.10.1	1.1 Identity of the Paper	1	Valid	1	Valid
3.10.2	1.2 Background			1	Valid
3.10.4	1.3 Problem Formulation			1	Valid
	1.4 Purpose of Writing			1	Valid
	1.5 Discussion Points			1	Valid
	1.6 Conclusion			1	Valid
	1.7 Bibliography			1	Valid
Tugas 2 (Practicum Report on Making Acid-Base Indicators form Natural Materials)					
3.10.3	2.1 Practicum Title, Dates, and Objectives	1	Valid	1	Valid
4.10.1	2.2 Theoretical Basis				
4.10.2	2.3 Tools and Materials			1	Valid
	2.4 Work Steps			1	Valid
	2.5 Observation Data			1	Valid
	2.6 Discussion			1	Valid
	2.7 Conclusion			1	Valid
	2.8 Design			1	Valid
				1	Valid
Task 3 (Poster on natural materials used as acid-base indicators)					
3.10.2	3.1 Content/text	1	Valid	1	Valid
4.10.3	3.2 Material content			1	Valid
	3.3 Design			1	Valid
	3.4 Image			1	Valid
Task 4 (Concept Map on acid-base identification)					
3.10.2	4.1 Concept Accuracy	1	Valid	1	Valid
3.10.3	4.2 Concept Hierarchy			1	Valid
	4.3 Connective Words			1	Valid
	4.4 Linkage between Concepts			1	Valid
	4.5 Concept Map Design			1	Valid

The feasibility of the electronic portfolio instrument that has been developed must be tested based on content validity. According to research by Nahadi et al. (2022), if the assessment instrument has high validity, the instrument will obtain good measurement results. Based on the consideration and decision of five experts (expert judgment). In this validity test, a validation sheet was used in the form of a table containing: learning indicators, task instructions, aspects assessed, assessment rubrics, suitability of indicators with tasks, and suitability of tasks with assessment rubrics. The results in Table 2 show the CVR value of the results of the validation test of the electronic portfolio instrument.

Based on the Content Validity Ratio (CVR) value in Table 2 compared to the minimum CVR value, in Task 1, all aspects of the assessment have a CVR value of 1 or greater than the minimum CVR value. In task 2, all assessment aspects have a CVR value of 1 or greater than the minimum CVR value. In Task 3, all aspects of the assessment have a CVR value of 1 or greater than the minimum CVR value. And in task 4, all aspects of the assessment have a CVR value of 1 or greater than the minimum CVR value. So based on the results of the CVR value, it can be concluded that the instrument is valid.

After the instrument was valid, reliability was determined on the electronic portfolio instrument developed using the inter-rater method, which determines the consistency of different assessors in assessing student work. There were 3 raters who assessed using the electronic portfolio instrument in this study. Inter-rater reliability was determined by calculating the Cronbach Alpha value using IBM SPSS 25. The results of the calculation of the Cronbach Alpha value and its categories are presented in Table 3. Based on Table 3, the Cronbach Alpha value of the developed assessment instrument ranges from 0.652 to 1.000. There are 24 aspects assessed with different reliability categories, namely: 13 aspects assessed as having excellent reliability categories, 8 aspects assessed as having good reliability categories, and 3 aspects assessed as having acceptable reliability categories.

Table 3. Cronbach alpha value

Indicators	Task	Aspects assessed	Cronbach alpha	Reliability category
3.10.1	1. Paper on the impact of using synthetic	1.1	1.000	SB
3.10.2	indicators	1.2	0.867	B
3.10.4		1.3	0.951	SB
		1.4	0.920	SB
		1.5	1.000	SB
		1.6	0.970	SB
		1.7	0.969	SB
3.10.3	2. Practicum report on making acid-base	2.1	0.926	SB
4.10.1	indicators from natural materials	2.2	0.937	SB
4.10.2		2.3	0.906	SB
		2.4	0.886	B
		2.5	0.750	B
		2.6	0.866	B
		2.7	0.888	B
		2.8	1.000	SB
3.10.2	3. Poster on natural materials used as acid-base	3.1	0.656	DD
4.10.3	indicators	3.2	0.750	B
		3.3	0.903	SB
		3.4	0.652	DD
3.10.2	4. Concept Map on acid-base identification	4.1	0.865	B
3.10.3		4.2	0.811	B
		4.3	0.991	SB
		4.4	0.924	SB
		4.5	0.666	DD

* Notes: SB = Excellent, B = Good, DD = Acceptable

The results of the limited trial on task 1, a paper on the impact of using synthetic acid-base indicators, showed an increase in the average student score before and after feedback. The average student scores and N-Gain scores are presented in Fig-1. Based on the N-Gain value in Fig-1, according to the N-Gain category (Hake, 1998), student improvement occurs in the low to medium category group. The student has corrected the errors that occurred in the initial assignment results. This can be seen from the average score after giving feedback, which has increased.

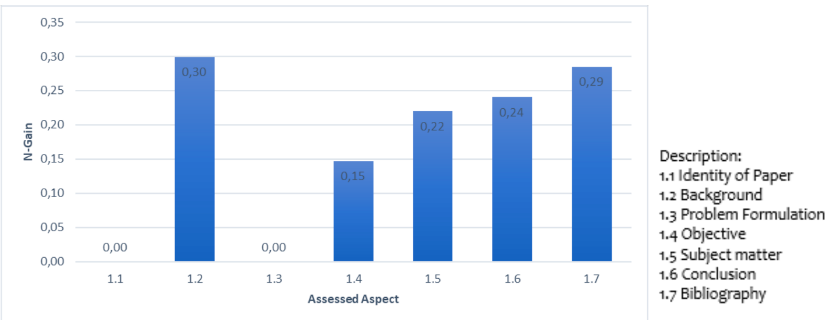

Fig-1. N-Gain score of task 1 paper

In Task 2, which is a practicum report on making acid-base indicators from natural materials, the assessment results show an increase in the average student score before and after being given feedback. Students' average scores and N-Gain scores can be seen in Fig-2. Based on Fig-2, aspects 1.6 and 1.7 experienced a high increase due to the practicum report conducted by students after being given feedback on these aspects, which showed significant improvement. As for aspects with low improvement, the results of student improvement are less significant.

In task 3, namely making a poster summarizing the results of the practicum report, this poster has the aim of providing information on natural materials that are good for use as acid-base indicators. The assessment results show an increase in the average score of students before and after feedback. The average value and N-Gain score of students can be seen in Fig-3. Based on Fig-3, the aspects assessed in task 3 have increased in average score. After calculating the N-Gain value, there was a significant increase in the assessed aspect 1.1 after being given feedback to a higher category. In the assessed aspect 1.3 there was also a significant increase with a moderate category, and in the assessed aspects 1.2 and 1.4 there was a less significant increase with a lower category.

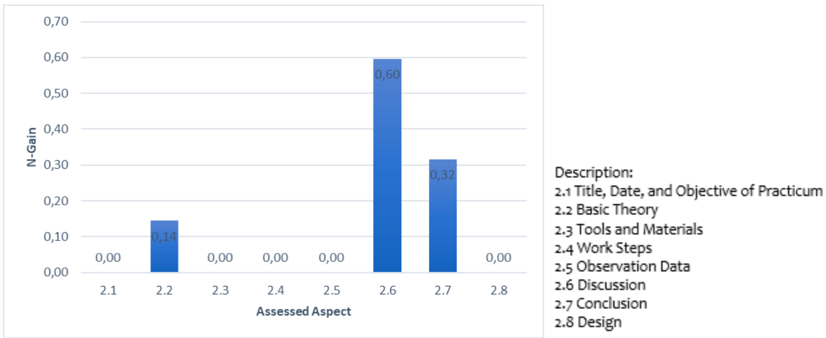

Fig-2. N-Gain score of task 2 practicum report

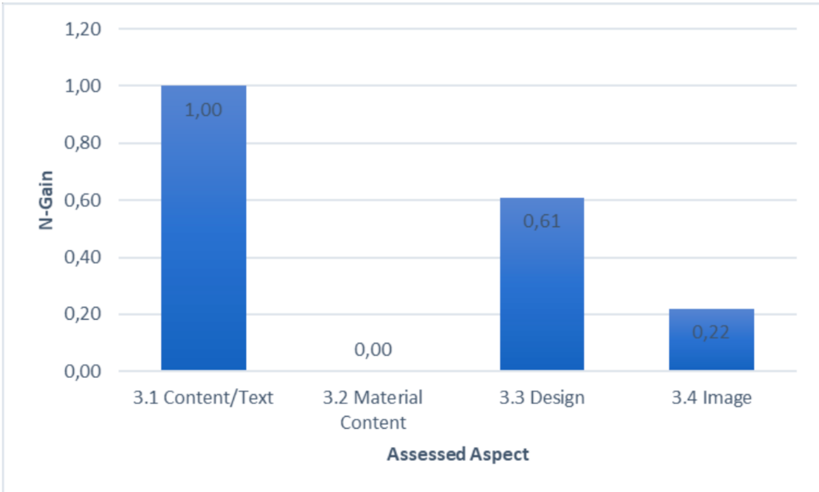

Fig-3. Poster task 3 N-gain score

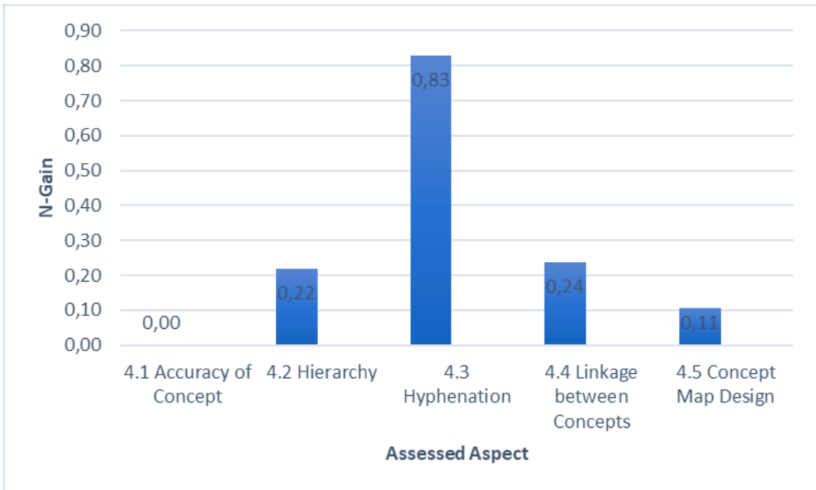

Fig-4. N-Gain score of task 4 concept map

In task 4, making a concept map of the identification of acid-base solutions, the assessment results show an increase in the average score of students before and after being given feedback. The average value and N-Gain score of students can be seen in Fig-4. Based on Fig-4, the aspects assessed in Task 4 have increased in average score. After calculating the N-Gain assessment, there was a significant increase in the assessed aspect 1.3 after being given feedback to a higher category. While in the aspects assessed, 1.1, 1.2, 1.4, and 1.5, there was a less significant increase in a lower category.

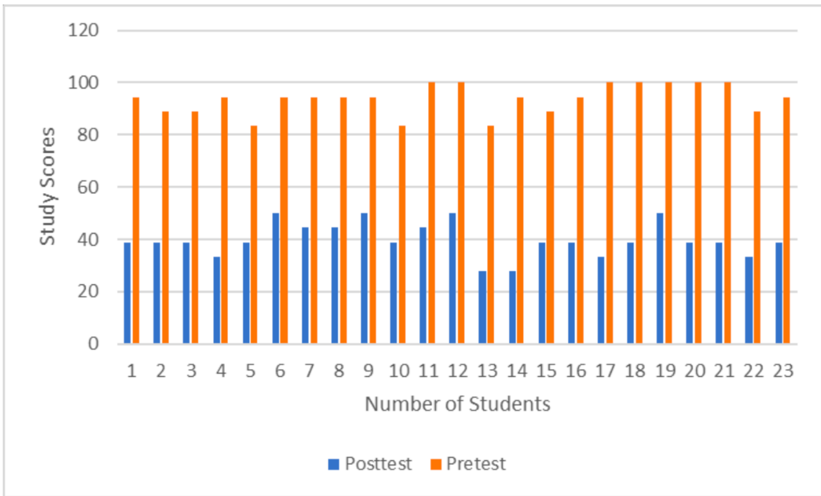

Fig-5. N-Gain score of concept mastery and creative thinking

The results of the analysis in the concept mastery and creative thinking categories show an increase; this is known from the average score obtained by students from the pretest and posttest scores presented in Fig-5. Based on Fig-5, the results of the electronic portfolio assessment increased in the pretest and posttest results, with an average pretest score of 39.83 and an average posttest score of 93,52. The N-Gain value obtained from the pretest and posttest scores is 0.90, with a high category (Hake, 1998). The application of electronic portfolios has been proven to be able to improve concept mastery and creative thinking, with N-Gain values of 0.71 in the high category and 0.77 in the high category, respectively (Apriani, 2022). In addition, research by Firmansyah et al. (2019) shows that the application of electronic portfolios can improve students' mastery of concepts, resulting in an N-Gain of 0.49 in the moderate category. Therefore, the use of this electronic portfolio contributes to the improvement of students' concept mastery and creative thinking.

Conclusion

Based on the results of the development of electronic portfolio assessment instruments based on Project-Based Learning (PjBL), the results of the feasibility test on electronic portfolio instruments were obtained with a Content Validity Ratio (CVR) valid value of 1.00 and a Cronbach Alpha reliability value between 0.652 to 1.000. The results of the limited trial of N-Gain values in task 1, task 2, task 3, and task 4 are: 0.17 (lowest), 0.13 (lowest), 0.46 (medium), and 0.32 (medium). The average pretest and posttest N-Gain score is 0.90, with a higher category. The data above shows that this electronic portfolio assessment instrument based on Project-Based Learning (PjBL) can assess students' concept mastery and creative thinking on acid-based materials.

Conflict of Interests

The author declares that there is no conflict of interest in this research and manuscript.

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