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Development of STEM-Based Performance Assessments to Analyze Students' Creativity

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Abstract

This research aims to develop a STEM-based performance assessment instrument to analyze students' creativity. This research used the Research and Development method referring to the 4D model. The define stage was carried out by conducting preliminary studies which were then analyzed, starting from analysis of initial, student, concept, task and learning objectives. The design stage was an initial design in the form of Draft I. The development stage was carried out to produce draft II, draft III, and final products from performance assessment instruments. Draft II was obtained through the results of expert validation revisions. Draft III was the result of small-scale product trials. The Final Product was from the results of large-scale product trials. STEM-based performance assessment instruments used to analyze students' creativity were developed in the form of 1) Lesson Plan, 2) Student Worksheets, 3) Grid, 4) Performance Assessment Sheet, 5) Assessment Rubric, and 6) Assessment Guidelines. Expert Validation of STEM-based performance assessment instruments used to analyze students' creativity produced valid criteria that was worthy of trial. Based on the results of product trials, both small-scale and large-scale also showed reliable categories. The developed STEM-based performance assessment instrument is valid and reliable so that it can be used to analyze students' creativity. Based on this, it was known the profile of students' creativity in two Public High Schools of Brebes Regency.

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INTRODUCTION

The 21st century is a century marked by major advances in various sectors, especially in the sector of technological development. Education is an important sector that is considered responsible for forming superior human resources to be able to compete in the 21st century (Sofiawati, Rochmiyati, & Haenilah, 2017; Sumarni, Wijayati, & Supanti, 2019).

Currently, the government through the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia is processing a new curriculum called the Merdeka Curriculum which is considered relevant to the current state of the Indonesian nation. The curriculum is still an offering. The 2013 curriculum, at this time, is still the curriculum applied in many educational units. These two curricula, both have an educational paradigm that emphasizes more on the process of building students' attitudes, knowledge and skills (Anggraini & Nurita, 2021). The Merdeka Curriculum emphasizes project-based learning, which means that the Merdeka Curriculum is designed to prepare a generation that can build innovation and creativity as well as critical thinking and also a generation that has good communication and collaboration skills.

In order to improve education in Indonesia, the Ministry of Education and Culture has also carried out various innovative activities to improve the competence of teachers and students in the fields of Science, Technology, Engineering, and Mathematics (STEM) and create learning experiences that prepare students to face the challenges of the 21st century (Sumarni *et al.*, 2019). STEM is a learning approach that has continuity with project-based learning (Erlinawati, Bektiarso, & Maryani, 2019; Izzah & Mulyana, 2021; Lestari, Eraku, & Rusiyah, 2021; Sarwi, Baihaqi, & Ellianawati, 2021; Stohlmann, Moore, & Roehrig, 2012; Vossen, Henze, Rippe, Van Driel, & De Vries, 2021; Wahono, Lin, & Chang, 2020). The STEM approach integrates science, technology, engineering, and mathematics in learning so that it can answer the challenges of the 21st century to be able to improve the 4C (critical thinking, creativity, communication, and collaboration) abilities of students (English, 2016; Martha, Noviliyosi, Jaenudin, & Rafianti, 2021; Shahbazloo & Abdullah Mirzaie, 2023).

Creativity is one aspect of the 4Cs that is still less measurable in learning (Boldt & Strub, 2023; Rindiantika, 2021). This is because there is a trend of written tests as a form of cognitive assessment of learning outcomes that dominate assessments carried out by teachers (Hadzhikoleva, Hadzhikolev, & Kasakliev, 2019). Creativity is part of the learning process that is not precisely measured as a learning outcome (Da'as, 2023). Student creativity can be measured, one of which is by applying project-based learning with a STEM approach which in the process is also applied authentic assessment (Ansori, 2017). One authentic appraisal technique is performance assessment. Performance assessment does not only assess student learning outcomes at the end of learning, but looks at how students were active in the learning process (Budiono, Susilaningsih, & Fatmasari, 2014). Performance assessment is one of the assessment tools that is suitable for use in STEM learning (Septiani, 2014). Performance assessment also has the opportunity to be able to measure student creativity (Irawati, 2021; Rahayu, Handayani, & Mujdalipah, 2019). Therefore, it is necessary to develop STEM-based performance assessments to analyze students' creativity. In this context, the researcher has developed a STEM-based performance assessment to analyze student creativity with the aim of obtaining a STEM-based performance assessment format for analyzing student creativity, analyzing the validity and reliability levels of the developed STEM-based performance assessment for analyzing student creativity, and analyzing student creativity profiles using the developed STEM-based performance assessment.

METHODS

The research method used in this research is research and development. The product developed is a set of STEM-based performance assessment instruments to analyze students' Creativity consisting of 1) Lesson Plan, 2) Student Worksheets, 3) Grid, 4) Performance Appraisal Sheet, 5) Assessment Rubric, and 6) Assessment Guidelines. Research on the development of STEM-based performance assessments to analyze students' Creativity refers to 4D models. This 4D model has four steps, namely: (1) define, (2) design, (3) development, and (4) disseminate as shown in Figure 1.

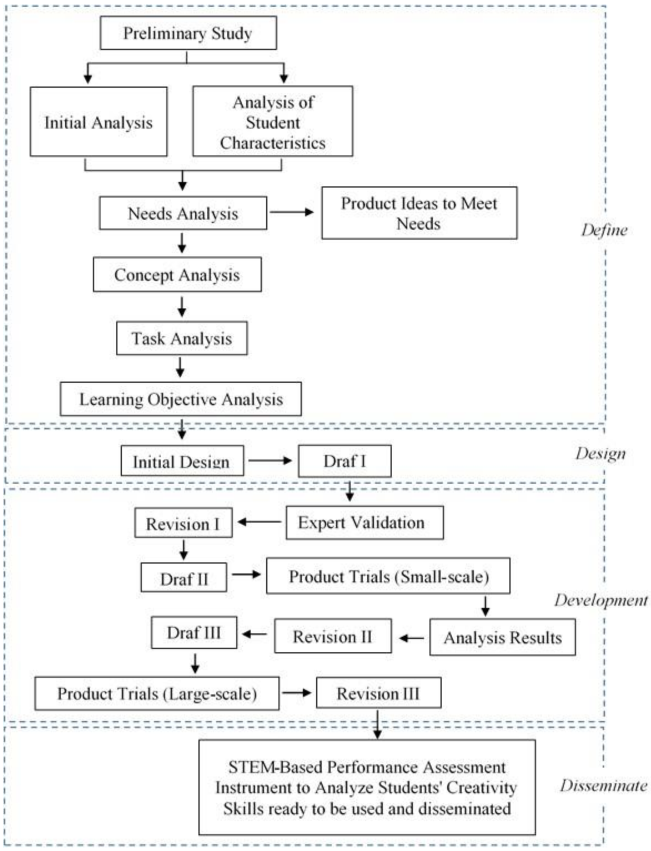

Figure 1. Research Procedure

The define stage is carried out to determine and define the needs in the learning process and collect various information related to the product to be developed. The design phase aims to design a set of STEM-based performance assessment instruments to analyze students' Creativity, hereinafter the design is called draft I. The development stage aims to produce a set of STEM-based performance assessment instruments to analyze students' Creativity that has been revised based on expert input (draft II), small-scale product trials (draft III), and large-scale product trials (final product). The next stage is the dissemination stage, which is the stage of disseminating information on the development of STEM-based performance assessment instruments to analyze students' Creativity, one of which is through scientific publications.

RESULTS AND DISCUSSION

STEM-Based Performance Assessment Development Process to Analyze Students' Creativity

1. Define Stage

A. Initial Analysis

At this stage, several activities were carried out in the form of observation, questionnaires, interviews, and document review to find out the basic problems that exist in the implementation of class XI physics learning in two public high schools in Brebes egency. Based on the initial analysis made, researchers obtained some information about the problems that occurred, including (1) Learning objectives are not by the basic competencies that must be achieved, (2) Learning that is still conventional, and (3) The implementation of assessments that are still not optimal

Based on this initial analysis, it can be known some of the needs required in the implementation of learning, including learning by basic competencies, innovative learning, and alternative implementation of learning assessments that not only measure students' cognitive abilities. So it is necessary to develop products that can answer these needs.

B. Analysis of Student Characteristics

Based on the results of initial analysis, several information were known about student characteristics during learning, including (1) Students who tend to be passive and (2) Low student interest and motivation. Based on the analysis of student characteristics, it is more reinforcing the needs needed in the implementation of learning. Based on these two analyses (initial analysis and student characteristics), researchers chose to develop a STEM-based performance assessment product to analyze students' Creativity. Performance assessment is one of the assessments of the learning process in which the learning process will accompany its application carried out.

C. Concept Analysis

Concept analysis aims to identify, detail, and systematically compile relevant concepts to be taught based on initial analysis. The material chosen by the researcher was static fluid material for the 2013 curriculum. Researchers analyze static fluid materials to be implemented with STEM learning. The first step researchers took in analyzed the concept of static fluid matter that researchers limit to the sub-material of Hydrostatic Law and Archimedes' Law is to find information on the application of technology closely related to the material. The researcher then chose hot air balloon technology which will be represented in principle more simply using air lanterns. So, the learning design was that students will be invited to make air lanterns creatively. Making air lanterns as learning will be integrated with STEM learning with analysis as shown in Table 1.

Table 1. STEM Components in Air Lantern Making Learning

<table>
<tr><th></th><th>Science</th><th>Technology</th><th></th><th>Engineering</th><th>Mathematics</th></tr>
<tr><td>Factual</td><td>• Observation of the surrounding environment related to the phenomenon of Hydrostatic Law & Archimedes' Law
• Demonstration of phenomena related to Hydrostatic Law & Archimedes' Law</td><td rowspan="3">• Utilization of devices and internet connections as learning resources
• Use of tools in making lanterns
• Use of devices, laptops / PCs and video editing software in making product presentations</td><td rowspan="3">Procedural</td><td rowspan="3">• Design creative, effective, and efficient lantern designs based on the application of Archimedes' Law.
• Selection of tools and materials in making lanterns that pay attention to Archimedes' Law
• Make lantern products according to the design that has been made by taking into account the size scale that has been designed and testing the products that have been made.
• Test the lantern products that have been made</td><td rowspan="3">• Calculation of product design scale into product
• Calculation of the cost of manufacturing products
• Mathematical proof of the working principle of lanterns.</td></tr>
<tr><td>Conceptual</td><td>• Static fluid concept
• The concept of sinking, drifting, and floating
• The concept of density and buoyancy force
• The concept of substance expansion</td></tr>
<tr><td>Principle/ law</td><td>• Hydrostatic Law
• Archimedes' Law
• Charles Law</td></tr>
</table>

D. Task Analysis

In this step, researchers analyzed tasks in the form of skills that will be developed in the learning process and will be analyzed using STEM-based performance assessments. Based on the concept analysis that has been carried out on static fluid material, the tasks or student performance during expected learning are presented in Table 2.

Table 2. Expected Student Performance Emerges During Learning

Component	Sub Component	Expected Performance
Work Preparation	Bring up ideas/responses in learning discussions	Students can respond to demonstrations made by their friends in front of the class regarding floating and sinking phenomena by answering the questions that have been provided correctly. 1. What is density? 2. What phenomena occur in wooden objects? 3. Why can the phenomenon of wooden objects occur? 4. What phenomena occur in aluminum objects? 5. Why can the phenomenon of aluminum objects occur? 6. Why can different phenomena occur between wooden objects and aluminum objects when they are put into a pool filled with water?
		Students can apply concepts they have built themselves to the task of correctly grouping objects that fall into the category of floating or sinking
		Students actively discuss questions and answers in the learning process
	Make lantern designs according to the concept of Archimedes' Law	Students can create detailed, effective, efficient, and attractive lantern designs that are different from their peers
	Write down how it works and flow charts for making lantern products.	Students can make a way of working in the form of a flow chart that is detailed, effective, efficient, and interesting
Work Process	Choose materials and prepare tools that will be used to make lantern products according to the concept of Archimedes' Law	Students can choose materials and prepare tools to be used according to the design they have made
		Students can explain the reasons for choosing materials and prepare tools to be used according to the concept of Archimedes' Law
	Make lantern products using simple technology/tools by the concept of Archimedes' Law by take into account the measurement scale.	Students can make products according to the stages they have designed well, concentrate, and are full of focus as well as effective and efficient in their work
Work Result	Produce lantern products that are different from other student lantern products	Students can produce original products according to the initial design attractively (have neatness and suitable colors) and by the concept of Archimedes' Law so that lanterns can fly
Work Attitude	Present the result lantern products	Students can present products completely and fluently in their delivery
Time	Students can complete the tasks of making lantern products	Students can complete all project assignments for making lantern products

E. Learning Objective Analysis

At this stage, researchers formulated the results of task analysis and analysis of the above concepts into learning achievement goals. The details of the learning objectives began from the analysis of Basic Competencies into Competency Achievement Indicators which was then compiled into learning objectives presented in Table 3.

Table 3. Learn Objective Analysis

Basic Competence	Competency Achievement Indicators	Learn Objectives
3.9 Apply (C3) the laws of static fluid in everyday life	1. Conceptualize (C3) Archimedes' Law regarding floating and sinking phenomena based on demonstrations carried out. 2. Implement (C3) Archimedes' Law in considering the selection of materials for the manufacture of lanterns. 3. Prove (C3) with a mathematical approach to the lantern principle as an application of Archimedes' Law.	Through learning with the Project Based Learning-STEM model, students can: 1. Conceptualize Archimedes' Law regarding floating and sinking phenomena based on properly conducted demonstrations, 2. Designing a simple technology in the form of lanterns that utilizes the principle of hot air balloons as a technology that applies Archimedes' Law in as much detail and creativity as possible, 3. Implement Archimedes' Law in considering the proper selection of materials for the manufacture of lanterns, 4. Making a simple technology in the form of lanterns that utilize the principle of hot air balloons as a technology that applies Archimedes' Law by the design that has been made as well, neatly, and creatively as possible, 5. Prove with a mathematical approach the principle of lanterns as a proper application of Archimedes' Law, 6. Presenting a simple technology product in the form of a lantern that utilizes the principle of hot air balloons as a technology that applies Archimedes' Law in good, fluent, clear, and communicative language.
4.9 Designing (C6) and conducting experiments that utilize the properties of static fluids, along with the presentation of experimental results and their utilization	1. Design (C6) a simple technology in the form of lanterns that utilize the principle of hot air balloons as technology that applies Archimedes' Law. 2. Make (C6) a simple technology in the form of lanterns that utilize the principle of hot air balloons as a technology that applies Archimedes' Law by the design that has been made. 3. Presenting (C6) a simple technology product in the form of a lantern that utilizes the principle of hot air balloons as a technology that applies Archimedes' Law.	

2. Design Stage

A. Initial Design

1) Initial Design of Lesson Plan

A Lesson Plan is prepared as a guideline for teachers to carry out classroom learning. The composition of the Lesson Plan is oriented toward STEM-based learning which contains the identity of the Lesson Plan, time allocation, core competencies, basic competencies and indicators of competency achievement, learning objectives, learning materials, approaches, methods, and learning models, learning media, learning resources, learning activities, and assessment.

2) Initial Design of Student Worksheets

The Student Worksheets developed in this study contain the performances that students need to show to be able to train and demonstrate their Creativity.

3) The Initial Design of The Grid

In this study, the developed grid contains indicators of competency achievement, STEM content raised, indicators of creativity used, and performance indicators as expected performance appears in students during learning.

4) Initial Design of Assessment Rubric

After the grid is arranged, the researcher obtains a general idea of the performance indicators expected to appear to students during learning. The general description is further detailed in the form of scoring on the actual performance raised by students in the learning written in the assessment rubric.

5) Initial Design of Performance Assessment Sheet

Performance Assessment Sheets are made to collect scores that are by the performance of students shown based on the assessment rubric as a whole during the learning process.

6) Initial Design of Assessment Guidelines

The assessment guidelines are created as a tool to describe the performance scores that students have shown during learning into four criteria of Creativity, namely: less creative, quite creative, creative, and very creative

3. Development Stage

1. Expert Validation

The purpose of holding validation activities in this research is to obtain valid status from experts. After the validation process by the validator, the researcher revises several parts of the instrument with suggestions and input from the validator.

2. Product Trials

In this product trial activity, two trials were carried out in the form of small-scale trials involving 36 students at High School A in Brebes Regency and large-scale trials involving 72 students at High School B in Brebes Regency. At this stage, data on the reliability of the instrument and data on students' Creativity are obtained. In the implementation of small-scale product trials, several notes were obtained related to the use of a set of STEM-based performance assessment instruments to analyze students' Creativity, so some revisions or improvements are still needed. The following is a list of revisions made, presented in Table 4.

Table 4. List of Revised Research Instruments at the Small-Scale Product Trial Stage

No	Note	Revisions made
1	Students have not linked the material of the kinetic theory of gases with the working principle of lanterns	The use of an easier concept is the expansion of substances and density on the working principle of lanterns
2	Students still ask a lot about performance instructions that must be done at the product presentation stage.	Complete performance instruction at the product presentation stage to make it easier for students to understand
3	Some sentences are less effective in the assessment rubric so it is still difficult for other observers to understand	Improve sentences to be more effective to make them easier to understand

4. Disseminate Stage

After product and instrument trials have been revised, the next stage is the dissemination stage. The purpose of this stage is to disseminate information on the development of STEM-based performance assessment instruments to analyze students' Creativity in the form of scientific publications.

Description and Data Analysis of the Results of the Development of STEM-Based Performance Assessment Instruments to Analyze Student Creativity

1. Product Validity

The product validity of a set of STEM-based performance assessment instruments to analyze students' Creativity is divided into three, namely: 1) Lesson Plan, 2) Student Worksheets, and 3) Assessment Instruments (Grids, Performance Appraisal Sheets, Appraisal Rubrics, and Appraisal Guidelines). The average result of the V Coefficient value of the validator assessment is interpreted with Aiken's V Table ($p<0.05$). Demonstrate that all aspects of the product, a set of STEM-based performance assessment instruments for analyzing students' Creativity, fall into the valid category.

2. Product Reliability

Retnawati (2017) revealed that in reliability of assessment, a student's ability is said to be reliable if measurements are made, the measurement results will be the same information, even though the examiners are different, the correctors are different or the question points are different but have the same characteristics.

The reliability test used in this study is by inter-rater method or ICC (Intraclass Coefficient Correlation). Seven raters assess several aspects of student performance during learning. The results of ICC (Intraclass Coefficient Correlation) analysis of student performance assessed in small-scale and large-scale trials are presented in Table 5.

Table 5. Product Reliability

No	Aspects	Small Scale Trials		Large Scale Trials	
		ICC Value	Category	*ICC Value*	Category
1	Work Preparation	0.914	Very Good	0.790	Good
2	Work Process	0.788	Good	0.789	Good
3	Work Result	0.875	Good	0.757	Good
4	Work Attitude	0.816	Good	0.865	Good
5	Time	0.875	Good	0.835	Good

Based on Table 5 above, it shows that all aspects of STEM-based performance assessment instruments to analyze students' Creativity in both small-scale and large-scale trials are included in the reliable category, although the values shown are different. This is because the level of reliability of an assessment instrument is influenced by several factors. Ary in (Setiyorini, Jaelani, & Ngafif, 2022) mentioned several factors that affect the reliability of an assessment instrument, including 1) Test length, 2) Heterogeneity, 3) Individual ability, 4) Special techniques used for reliability estimation, 5) The nature of the variables measured, 6) Objectivity of assessment. According to the observations of researchers, the factor that influences the difference in reliability values that occur in small-scale trials and large-scale trials is individual ability, where the research subjects of small-scale and large-scale trials are carried out in two different schools in Brebes Regency where the individual abilities of the students of the two schools are different. In addition, the objectivity of assessment is also one of the influencing factors where observers involved when carrying out small-scale and large-scale trials are different. However, the results of statistical tests carried out still show reliable results for STEM-based performance assessment instruments that have been developed in both small-scale and large-scale trials. Based on this, it can be said that STEM-based performance assessment instruments are valid and reliable so that they can be used to analyze students' Creativity. This is in line with(Furwana, 2019; Sugiono, Noerdjanah, & Wahyu, 2020; Surucu & Maslakci, 2020) which states that a good measuring instrument is a valid and reliable measuring instrument.

Student Creativity Skill Profile

Once declared valid and reliable, the developed STEM-based performance assessment instrument can be used to analyze students' Creativity based on assessments that have been given by raters. The Creativity profile of High School A students in Brebes Regency that has been analyzed using STEM-based performance assessment instruments is presented in Figure 2.

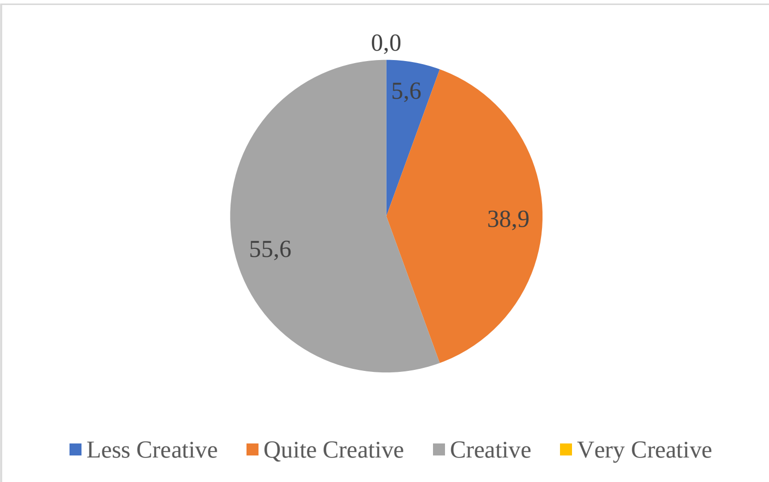

Figure 2. Profile of Creativity of High School A Students in Brebes Regency

Based on the data, it can be seen that most of the students of High School A in Brebes Regency (55.6%) are creative students who can display their performance creatively and show improved performance during learning so that most competencies can be mastered properly. Different results were shown by students of High School B in Brebes Regency. Most (55.6%) are moderately creative students who show less creative performance from most stages of performance performed and student performance is inconsistent so that only a small part of the competencies can be achieved by students. The Creativity profile of High School B students in Brebes Regency that has been analyzed using STEM-based performance assessment instruments is presented in Figure 3.

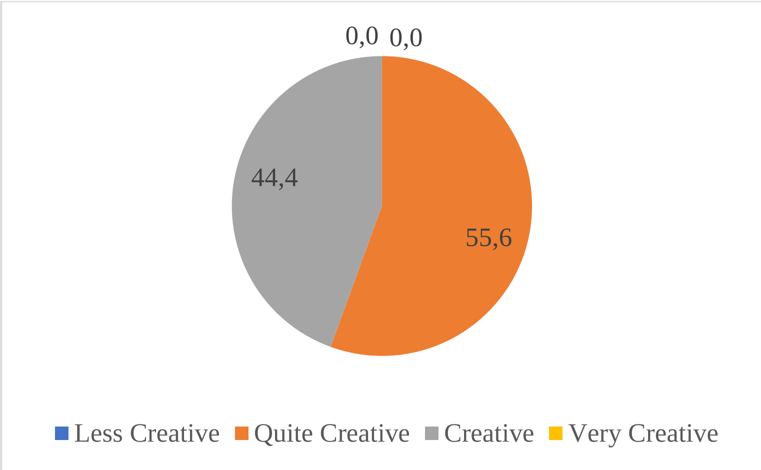

Figure 3. Profile of Creativity of High School B Students in Brebes Regency

This is following the observations of researchers during the implementation of trials in the two schools. Based on the products produced, none of the students of High School B in Brebes County managed to fly their lanterns at all, in contrast to the students of High School A in Brebes Regency. The discipline of attitude and time in making products shown Ne students of High School A in Brebes Regency with High School B in Brebes Regency also showed different results, students of High School A in Brebes Regency tended to show more discipline in attitude and time during product manufacturing. The selection of tools and materials used by students of High School B in Brebes Regency tends to be the same, different from High School A in Brebes Regency which is more varied so that the products produced are more varied in color and shape.

Looking at the profile of students' Creativity in two high schools in Brebes Regency, it can be seen that students' Creativity tends to show low results, this can be seen from the data that there are still students who are less creative in High School A in Brebes Regency. While at High School B in Brebes Regency, most of the students only have creative abilities. Even in these two schools, there have not been students who have very creative abilities. Seeing this, there is an urgency for learning and learning assessments that can improve and measure students' Creativity. The STEM-based performance assessment that has been developed is expected to be one alternative to answer these needs. Given that performance assessment is not only used as a tool for assessment, but can also be used as part of the learning process (Nisrokha, 2018) and in line with this, several studies reveal that STEM-based learning can increase students' creativity abilities (Arsy & Syamsulrizal, 2021; Sarwi, Nisa, & Subali, 2021; Shahbazloo & Abdullah Mirzaie, 2023; Siswanto, 2018) And performance assessment also has the potential to be able to measure students' Creativity (Irawati, 2021; Rahayu et al., 2019).

CONCLUSION

The results of product development of a set of STEM-Based Performance Assessment instruments to Analyze Student Creativity, Physically produced products in the form of books printed with A4 paper size 80 grams. Meanwhile, in terms of content, the products developed contain 1) Lesson Plan, 2) Student Worksheets, 3) Grid, 4) Performance Assessment Sheet, 5) Assessment Rubric, and 6) Assessment Guidelines.

The experts' assessment of product validity show valid criteria on all aspects assessed. Similarly, the results of inter-rater analysis of product reliability developed using ICC (Intraclass Coefficient Correlation) analysis, show reliable criteria in all aspects analyzed. Based on this, it can be said that the STEM-based performance assessment instrument that has been developed has qualified as a good measuring tool, namely a valid and reliable measuring tool, so that it can be used to analyze students' Creativity.

The profile of students' Creativity in two high schools in Brebes Regency shows results that tend to be low, this can be seen from the data that there are still students who are less creative in High School A in Brebes Regency. While at High School B in Brebes Regency, most of the students only have creative abilities. Even in these two schools, there have not been students who have very creative abilities. Seeing this, there is an urgency for learning and learning assessments that can improve and measure students' Creativity. The STEM-based performance assessment that has been developed is expected to be one alternative to answer these needs.

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