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Critical Thinking Skills in Performance-Based Assessment: Instrument Development and Validation

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Abstract: The purpose of this study is to produce a performance-based assessment instrument to stimulate students' critical thinking in welding quality testing courses. The ability to think critically occurs when you understand the material given. Performance-based assessment can be done on the process and learning outcomes. The method used in this study is the Borg and Gall method with ten steps of development. The practice of welding quality testing has an analysis orientation that results in an acceptance decision on the welding quality. The results are validated in terms of content, language, and constructs by specified experts. The results of the performance-based assessment design use five stages, namely: determining the underlying problem, creating an assessment context, determining the assessment rubric, carrying out a performance assessment, and formulating the assessment results, and responding to the evaluation results. The rubric used is a rubric with a scoring form. The instrument design is following the task of the inspection of welding results. The output of welding quality testing learning is a report containing observations results and making decisions on welding quality based on critical thinking skills. The performance-based assessment provides independence in making decisions. Performance-based assessment is suitable for practical learning that collaborates with motoric movements and knowledge.

Keywords: Critical thinking, performance-based assessment, practical learning, instrument validation

1. Introduction

Critical thinking is part of analyzing and evaluating thoughts based on the work in progress (Dykhne, Hsu, McBane, Rosenberg, & Taheri, 2021). Critical thinking skills will raise questions related to the received information rationally (Lee, Sohod, & Ab Rahman, 2019). In testing the welding results, critical thinking skills will determine the acceptance of the welding results following the specified standards. Critical thinking does not mean finding fault with information. However, the method in critical thinking causes caution and anticipates any future possibility that may occur (Hayes, Chatterjee, & Schwartzstein, 2017). Critical thinking becomes an activity of analyzing information which then becomes a recommendation for making better decisions (Marshall et al., 2017). The skills in critical thinking require systematic, logical, and objective characteristics (Cooke, Stroup, & Harrington, 2019). Inspector of welding results must show results with standard standards. The objectivity of the assessment carried out is related to time and cost in welding productivity (Sharma, 2018).

Critical thinking skills can be formed through performance-based assessments (Ghazivakili et al., 2014). Performance-based assessment in learning is a way of collecting, processing, and interpreting information from student

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learning outcomes (Vargas et al., 2007). This performance-based learning assessment can determine the implementation scenario of learning. Besides, the performance-based assessment will provide feedback to students to improve their learning quality (M. Lee & Wimmers, 2016). This assessment system can provide information on the achievement of learning objectives under the specified competencies. Performance-based assessment is an authentic assessment (Prediger et al., 2020). This assessment can be a multi-dimensional assessment technique done in various ways, such as writing, creating, and doing assignments (Sim, Azila, Lian, Tan, & Tan, 2006). The implementation of performance-based assessment requires students to produce products and demonstrate the process. Therefore, the test allows students to carry out activities based on their knowledge.

The orientation of the type of welding that becomes the assessment in the learning of welding quality testing is SMAW welding. The welding results assessed are the results of practical learning carried out in the Metal Welding Technology course. The implementation of the assessment carried out in the learning of welding quality testing still uses objective and essay tests in determining student competency achievements. The use of essay and objective tests is not optimal in assessing the achievement of student competencies in practical learning (Piskurich, 1993). These results were obtained by observing the students who had attended the welding quality testing course. The observation sheet uses closed statements with the specified scoring standardization. The indicators used are 1) the suitability of the assessment technique with the learning objectives, 2) the clarity of the assessment procedure, and 3) the timing of the assessment. The following are the results of the observations made.

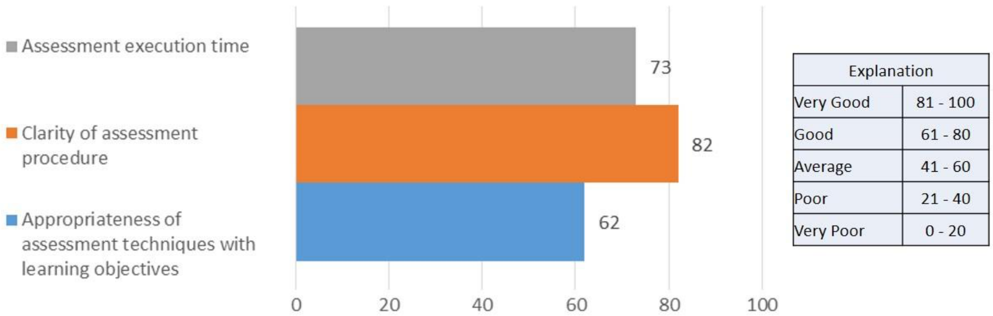

Fig. 1 - Student responses to the implementation of the assessment in welding quality testing courses

The observation instrument for the implementation of the assessment used a range of 0 to 100. The number of students who filled out the observation sheet was 64 and took welding quality testing courses. The summary of student responses analysed for the mean value shows that the implementation of the assessment is not yet at the optimal value. This result is reinforced by interviews conducted with several students as representatives saying that the assessment of performance is mostly seen from the results of written tests and reports on the implementation of activities. A review of the work process is not carried out. The form of written tests and made portfolios do not represent the process of carrying out tests that tend to be motoric activities.

The novelty of the research lies in the urgency of performance-based assessment in improving critical thinking skills formed in students practising and applying their knowledge in the context of the specified criteria. The aspects of performance-based assessments are: 1) knowledge, 2) application of knowledge in practice, 3) skills in the form of communication skills, accuracy, and visual performance, 4) the product created, 5) learning attitudes in the form of values, interests, and motivations (Shanteau, Weiss, Thomas, & Pounds, 2002). The orientation of the main characteristics of performance-based assessment is on the process during practices that can show the ability to produce the planned product. The performance assessment can measure processing and producing skills (de Klerk, Veldkamp, & Eggen, 2018).

Learning welding quality testing in line with welding inspector competence requires critical thinking skills as a basis for decision making (Hughes, 2009). Reports of acceptance criteria and tolerances for the analysed welding results can be recommended for feasibility and corrective actions for unfit welded parts. The use of performance-based assessment is needed in learning welding quality testing. The design can stimulate students to think critically from the practices they did to get a measurable report following the standards of acceptance of welding results.

2. Methodology

The type of this research is development research using the Borg and Gall method (Gall, Borg, & Gall, 1996). This method was chosen due to the product development in the form of an assessment instrument (Merta Dhewa, Rosidin, Abdurrahman, & Suyatna, 2017). There are ten steps in the Borg and Gall development method seen in the following figure 2.

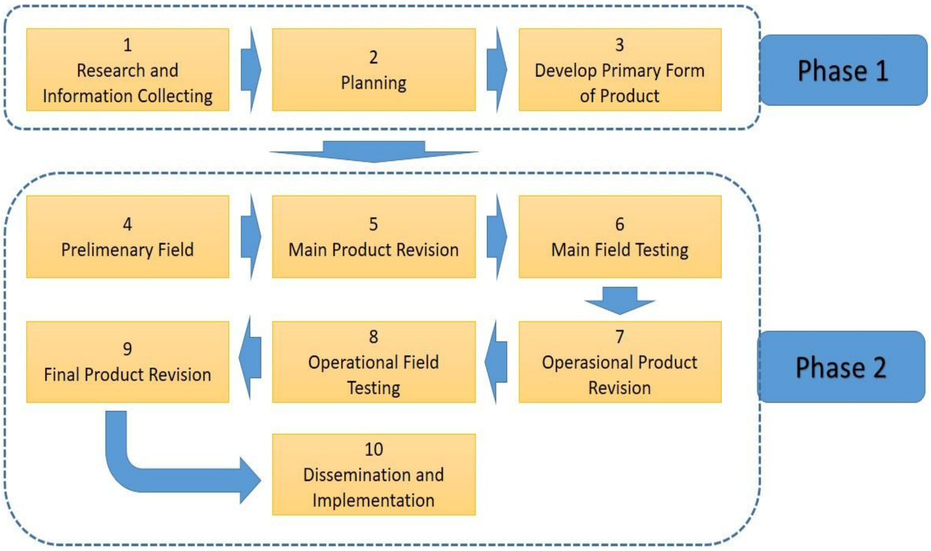

Fig. 2 - Research procedure diagram

This research is the first of a series of ongoing studies. For this article, we will discuss the development of performance assessment instruments used in learning welding quality testing, as shown in Figure 2, phase 1. The design of the performance-based assessment instrument is adjusted to the characteristics of students who have participated in metal welding technology learning. Learning metal welding technology aims to deepen the hard skills of SMAW-type welding abilities. The products produced in the metal welding technology course will be used as test materials in welding quality testing lessons. The metal welding technology course is a prerequisite for participating in welding quality testing lessons. The assessment instrument is prepared by considering the competence in learning welding quality testing and critical thinking skills in learning. The results of the assessment instrument design will be implemented in welding quality learning in the Department of Mechanical Engineering, Faculty of Engineering, State University of Padang. Experts also validated these results.

The content, construct, and language was validated by expert in the context of technical and vocational education (Jalinus, Nabawi, & Mardin, 2017; Wardina, Jalinus, & Asnur, 2019). There are some indicators used in content validation. 1) the suitability of the task design with the instrument material. In the evaluation activities, the tasks given correspond to the measurement indicators (Sumarni, Supardi, & Widiarti, 2018). 2) The clarity of indicators from each aspect. The indicators act as the standard to elaborate the outline into several measurement items. 3) clarity of item formulation. The measurement item in the instrument has a clear purpose (Wolfe & Smith Jr, 2007). 4) the suitability of the indicator with the item. The suitability of the indicator with the assessment item is needed to avoid bias in the assessment results (McCoach, Gable, & Madura, 2013). In the language context (*Bahasa Indonesia*) (Syahrul, 2008), the indicators used in language validation were 1) ease of interpreting or understanding items, 2) legibility and ease of reading, 3) standard notation, letters, formats, and layouts, and 4) use of standard language (Mullis, Drucker, Preuschoff, Arora, & Stanco, 2011). For construct validation, (A Ambiyar & Dewi, 2019; Ambiyar Ambiyar et al., 2019), the indicators used in construct validation were 1) the ease of filling out the instrument (Hsu, Kannan, Leong, & Tan, 2006), 2) the efficiency of time and energy in filling out the instrument (Grant & Davis, 1997), 3) the proportion of the number of items in each competency (McCoach et al., 2013). The validation results from those experts were used to revise the instruments for this study.

3. Result

The design of the assessment implementation activities using the performance-based assessment method formulates several implementation steps. Based on the design, there are five steps in doing a performance-based assessment that stimulates students' critical thinking skills implemented in the welding quality testing course. Learning the welding quality testing requires critical thinking skills to be the standard to determine the acceptance of welding results. The orientation of critical thinking is on the accuracy of decision-making (Chinedu, Olabiyi, & Kamin, 2015). The steps outlined in this design are:

3.1 The First Step is to Determine the Underlying Problem

Problems in learning are very complex (Tan, 2021). In this case, the focus of the problem is on competencies measured using performance-based assessment instruments. In performance-based assessment, the first step is to formulate goals related to the knowledge, skills, thinking habits, and outcome indicators that become the focus of learning (Amiel et al., 2006). In general, three statements are commonly used in determining the concepts to be taught. They are 1) determining the content of knowledge that students must obtain in learning, 2) skills needed by students in implementing their knowledge, and 3) thinking habits needed to implement knowledge effectively by practising to achieve learning success (Roberts, 2005).

In making performance-based assessments, the evaluation must fit the learning objectives. These goals are 1) competencies that cannot be obtained by written tests, and 2) the results obtained by students with practicing their knowledge (Stiffler, 2006). These results cannot be assessed by written tests. Information obtained by performance-based assessment is integrated with the ability to obtain information, organize information, and use the knowledge they learned. This information becomes the basis for determining the underlying problems of the preparation of performance-based assessment instruments.

Table 1 - The formulation for obtaining, organizing, and using knowledge and information in learning welding quality testing

Collecting Information	Organizing and Using Information
Communicating	**Organizing**
Explaining the concept of inspection	Classifying the result of the inspection
Demonstrating the implementation of inspections	Categorizing the findings of the inspection
Drawing the inspection results	Compiling the findings
Writing the inspection results	Arranging the inspection result recommendations
Assessment	**Problem Solving**
Calculating the acceptance criteria for welding defects	Identifying problems found with welding results
Adjusting the inspection results with the acceptance criteria for the welding results	Interpreting the risk of welding defects
Examining the inspection results	Determine the reaper step on welding defects
Investigation	**Making decision**
Collecting references for knowledge	Determining alternatives to welding defects
Implementation of knowledge in doing the inspections	Determining the action taken based on the welding results
Observing welding defects	Making recommendations from observations

When the underlying problem has been formulated, the objectives and focus of the assessment have been determined. Henceforth, it can be described in the context of performance-based assessment on welding quality testing learning. The results will be implemented in the Department of Mechanical Engineering, Faculty of Engineering, *Universitas Negeri Padang*.

3.2 Creating an Assessment Context

The assessment context aims to design a task that integrates the possessed knowledge and skills (Stiffler, 2006). The assessment design must follow the work stages in inspecting the welding results. The focus of the tasks is suitable to achieving competence objectives. Furthermore, the assessment design must be able to explain the expected solution. Therefore, this assessment triggers the critical thinking attitude of students. Student activities must be following standardized procedures (McMillan, 2000).

The task design is made clear with the inspection work steps that lead the students in making decisions. The format of this task becomes a guide for students' physical activity in practising their knowledge and skills (Alpine, O'Connor, McGuinness, & Barrett, 2021). The implementation of knowledge and motor movements carried out by students becomes an indicator of the assessment carried out in the learning process (Ried et al., 2007). This assessment design's difficulty level follows the highest competence expected in welding quality testing learning. Schuwirth et al. Schuwirth et. al., (2005) said that a good assignment design provides an opportunity for educators to conclude the level of competence and problem-solving abilities possessed by students compared to essay or multiple-choice tests (Schuwirth et al., 2005).

The task design contains several decided solutions together with the processing steps. The mental attitude of students in making decisions will be related to Self-Regulated learning (Uzelli Yilmaz & Sari, 2021). Cognitive strategies needed by students in conducting inspections direct the resulting decisions. The points contained in the assessment instrument will measure students' gross and fine motor skills in carrying out tasks.

3.3 Determining the Scoring Rubric

If educators evaluate, it means giving justice to the efforts made by students in learning (Carr, Wilder, Majdalany, Mathisen, & Strain, 2013). To examine the achievement of performance, educators can use the assessment (Jasch, 2000). The assessment rubrics are made with a scoring system. The scoring system can minimize the assessor bias in determining performance results. In general, performance tests require four learning achievements (Paechter, Maier, & Macher, 2010).

Table 2 - Competence in performance assessment

1.	Product	Inspection reports and action recommendations
2.	Complex cognitive processes	Ability to perform visual inspections and use inspection tools such as penetrant tests, magnetic tests and ultrasonic tests.
3.	Observed performance	Physical movements such as measuring welding defects, determining the acceptability of welding results, using tools during inspection
4.	Habits of mind and social skills	Mental and behavioural habits such as persistence, accuracy, thoroughness, and work attitude

In general, there are three categories of rubrics that usually use in performance-based assessments, namely checklist, rating scale, and overall assessment (Symonds, Campbell, & Randall, 2017). The design of performance-based assessment on learning quality testing of welding is selected using a rubric with a scoring form. The selection of this scoring form is based on the expected inspection skills related to the gross and fine motor skills of students. Scoring is considered suitable to measure skills that involve thoroughness and accuracy during the inspection. The complex scoring can see the overall skills in performing the task. The rating scale focuses on accuracy, thoroughness, and students' logic. The analytical scale number uses five levels of scoring, commonly referred to as primary trait scoring (Saddler & Andrade, 2004).

Table 3 - The design of performance assessment rubric

No	Activities	Observation indicator	Score				
			1	2	3	4	5
1	Visual inspection	Ability to hold measuring tools*					
		Skills in measuring crack dimensions on welding results**					
		Ability to calculate percentage porosity**					
		Root height measuring skill**					
		Capping height measuring skill**					
2	Inspection with penetrant	Penetrant spraying skills*					
		Skills in measuring visible cracks in welding results**					
		Skills in determining undercuts that occur in welding results**					
3	Using magnetic particles inspection	Ability to operate magnetic particles*					
		Magnetic powder sprinkling skill*					
		Skills in determining welding defects with magnetic particles**					
4	Using ultrasonic test inspection	Ultrasonic operating skills*					
		Ultrasonic test result chart analysis skills**					
5	Inspection Result Report	Clarity of report content					
		Accuracy of measurement and analysis results					
		Detailed recommendations on inspection results					

Explanation:

1	:	Unskilled and not knowledgeable
2	:	Less skilled, less thorough and lack of knowledge
3	:	Quite skilled and thorough but lack of knowledge
4	:	Skilled but not thorough but have knowledge
5	:	Highly skilled with thoroughness and knowledgeable
*	:	Gross motor movement
**	:	Fine motor movement

Learning outcomes are an interpretation of the competency achievements of students (Darby, 2007). The results of the performance evaluation revealed by using an assessment rubric are analysed using the following formula:

$$Learning\ Outcomes = \frac{Score\ obtained}{Maximum\ score} x\ 100 \tag{1}$$

The design of the assessment activity contains an assessment instrument. Before the assessment instrument is implemented, validation is carried out on the instrument (Arafat, Chowdhury, Qusar, & Hafez, 2016). The validation method used in the assessment instrument uses the expert judgment method (Tojib & Sugianto, 2006). Instruments are validated by experts in their fields. Validation includes content, language, and constructs. Here are the results of the validation carried out by the expert.

Table 4 - Instrument validation results

Field	Indicator	Score	Expert Comment
Content	The suitability of the task design with the instrument material	95	The design of the task is following the material in the assessment rubric
	Clarity of assessment aspects	92	The indicators are clear, it's just that the detailed assessment aspects need to be explained in the task design
	Clarity of assessment item formulation	90	The specification of the item can reveal the aspect of the assessment that will be measured
	The suitability of the indicator with the assessment item	96	The description of indicators can explain the mastery of competence
Language	Ease of understanding assessment items	95	The use of words in items is easy to understand
	Ease of reading the assessment instrument	96	The instrument is easy to read because it uses a standard size and typeface
	Standar notasi, format huruf dan layout	85	The layout needs to be improved to make it easier to score by raters
	Standard language usage	95	Have used standard language
construct	Easy filling of instruments	98	Scoring has been explained in the scoring guide
	Time and energy efficiency in instrument charging	95	The number of assessment items must be able to summarize all competencies and be concise but clear.
	The proportion of the number of items in each competency	98	The composition of items in each competency has been well structured+

3.4 Assessing Performance

Performance-based assessment can be done during the learning process and product (Amiel et al., 2006). In the research design, the evaluation is during the inspection process and product inspection results in learning welding quality testing. The assessment rubric is filled directly by the educator. The assessment will reveal the achievement of competencies possessed by students in conducting inspections of welding results. This research is early-stage research that produces limitations on the development of performance instruments that will be used in learning welding quality testing that has been validated by an expert (figure 2 phase 1). The implementation process for students will be carried out in phase 2.

3.5 Formulation of Assessment Results and Responses to Evaluation Results

Learning outcomes from performance-based assessments will be in the form of numbers (Otaya, 2017). The value formulation is taken from the scoring rubric result during the learning in the inspection results of the welding. The value obtained proves the skill and ability of students in inspecting the welding results. To make the evaluation more meaningful, educators must provide feedback on the assessment results. Responding to the evaluation results makes students aware of weaknesses and shortcomings in achieving welding inspection competence. It can stimulate students to improve their knowledge and skills in aspects that are still considered less mastered.

4. Discussion

Implementation of evaluation becomes a process of measuring competence possessed (Oliver, 2000). Many evaluation models are often used to determine student competencies (Van der Knaap, 2004). In the study of welding quality testing so far, the assessment process is still carried out with essay and portfolio tests. This test model does not follow the characteristics of practical activity-oriented learning (McCoach et al., 2013). In this study, a performance-based assessment evaluation model was developed. This method is considered suitable for practical learning related to psychomotor (Stiffler, 2006). The research instrument was validated using the expert judgment method (Tojib & Sugianto, 2006). Three indicators are used to validate the evaluation instrument: content, language, and construct. The design of the performance-based assessment model in welding quality testing learning is expected to reveal the level of competency achievement of students.

Critical thinking is crucial in decision-making (Lee et al., 2019). Welding quality testing courses train the learners to be competent in inspecting the welding result. A welding inspector must be able to determine the quality of the welding results following acceptable standards. The knowledge possessed must be integrated with the skills. These skills are then analysed to decide the quality of the welding results. Performance-based assessment stimulates critical thinking skills to make decisions in inspecting the welding results. The performance-based assessment design uses five steps. The first step is to determine the underlying problem. Determining the underlying problem is needed to determine the desired competency limits in welding quality testing learning. The assessment focuses on the competence of visual inspection skills, using penetrant, magnetic tests, and ultrasonic tests. The underlying problem is formulated by identifying the content that students must master, the expected skills, and the habit of thought possessed by students. In the research done by Kling, Seyring, Tzanova (2016), the determination of the underlying problem provides the limits of the competence to be measured. It is crucial to prevent the assessment's wide range of aspects. Determination of assessment limits is also considered significant in coordinating the information contained in the task design on performance assessment (Kling, Seyring, & Tzanova, 2016).

The second step is to create a context for the assessment. In this design, the performance assessment focuses on gross and fine motor movements to portray competencies possessed by students. In Chairilsyah's research (2019), performance is a skill that involves the integration of movement and knowledge (Chairilsyah, 2019). In addition, the context of the performance assessment must specify the work in the task design. The work standards and observed actions must be clear to make it easier for the assessor to observe each step of the work. Thus, it will be easy for assessors to conclude the level of competence possessed by students (Sumarni et al., 2018).

The third step is to determine the assessment rubric. This design uses a suitable scoring rubric for assessing the performance of inspecting abilities. The use of a scoring rubric can minimize the assessor bias in determining performance results. In general, performance tests require four learning achievements. The achievements include complex cognitive processes, observed performance and thinking habits, and social skills (Paechter et al., 2010). The rubric is prepared based on the limitations of the assessment context analysis; the competencies expected in learning welding quality testing. Performance during inspection activities involving motoric movements must be separated to see accuracy and precision in performing the tasks. Practical learning in a performance-based assessment provides the students with actual practice assignments (Otaya, 2017). Independence in performing tasks makes the accuracy of the accountability of the performance assessment.

The fourth step is to assess performance. The task design must provide a direct experience of inspection activities to students. This assessment design is given during the welding quality testing course in the odd semester of 2021/2022. Several significant assessment indicators are student characteristics, task design, and evaluation methods (Peeters & Schmude, 2020). Performance-based assessment is suitable to be used to see competence in welding quality testing. Movements that are integrated with knowledge follow the characteristics expected in welding inspection activities. Critical thinking skills will help to decide the output of inspection activities during the welding quality test learning.

The fifth step is to formulate the assessment results and responses to the evaluation results. The evaluation results are the final form of learning activities (Daugherty & Elder, 2020). The formulation of the evaluation results from the performance-based assessment explains the level of motor skills and knowledge students possess in inspecting welding results. Formulating the assessment results is essential for students to realize their abilities. As educators, providing feedback on the results of the assessment is significant. The response to the evaluation results will explain the student's weaknesses. For sustainability learning, students can strengthen their abilities in aspects that get scores that are still low.

5. Conclusion

Welding quality testing learning activities which are practical learning have linearity with work skills. To assess work skills, it would be appropriate to use a performance appraisal instrument. The performance-based assessment design uses five steps. Those steps are determining the underlying problem, creating an assessment context, determining the assessment rubric, carrying out a performance assessment, and formulating the assessment results and the responses to the evaluation results. Performance-based assessment triggers critical thinking skills following the designed task. The learning of welding quality testing has the characteristics of accuracy and precision. They stimulate students to think critically as the basis for decision-making.

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