Towards Improving Welding Skills: Creating Innovative Modules for Teaching SMAW Integrated 3D Animation

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ABSTRACT

This research aims to develop teaching modules on welding techniques in vocational schools using the problem-based learning (PBL) model, a scientific learning approach, and an authentic assessment of welding competency using the manual arc welding or SMAW welding process. The development of teaching modules at vocational schools will improve the quality of the process and the quality of learning outcomes for SMAW welding engineering subjects at vocational schools. This research uses a development research method with a research design using design-based research (DBR), which refers to the instructional design model (IDM) development model design. The participants involved in this research were class XI vocational school students in East Java. The module validity test assessment results have an average score of 3.8 in the very valid category. The SMAW welding technique module that has been prepared can be used to implement SMAW welding technique learning at vocational schools. The teaching module evaluation stage results show an outstanding category, meaning the teaching module developed meets practical requirements. All students' average normalized gain score (<g>) was 0.72, included in the high improvement category. The results of observations of the implementation of the PBL model facilitated by teaching modules from two observers were analyzed using percentages of agreement (PA). The research conclusion shows that the teaching module developed is valid, practical, and effective.

I. Introduction

The Industrial Revolution 4.0 (I4.0) introduces new opportunities that can disrupt the traditional approach of manufacturing companies by providing increased visibility and better customization. (Bag et al., 2021; Sharma et al., 2020, 2021, 2023). I4.0 is very beneficial for countries that have competent and competitive human resources (HR). However, on the contrary, it will be detrimental to countries whose human resources could be more skilled and have better competitiveness. This will happen because they will be marginalized in the struggle for the workplace. Vocational education has a strategic role in projecting the ASEAN Economic Community (AEC) conditions. By implementing quality education, competent and professional graduates can be produced so that vocational education graduates can compete for domestic and abroad job opportunities. (Jamali et al., 2023). Peraturan Menteri Pendidikan dan Kebudayaan Number 34 Year 2018 concerning National School Education Standards Secondary Vocational Education (SVE) explains that vocational education has a Mission to help students develop their professional attitudes, be able to compete and be able to go through the stages of development so that they can prepare themselves for work and have a career in the world of employment.

Sakti & Nuryanto, (2020) said that most vocational school graduates in Indonesia are less able to adapt to developments in science and technology and develop themselves and their careers in the workplace. The high unemployment rate for vocational school graduates also shows that the relevance of vocational school education to real life is still low (Pranowo et al., 2022). This fact shows that vocational education in Indonesia still needs to be effective, where graduates do not have good work readiness or competence, so many are unemployed. Badan Pusat Statistik (2023) released the open unemployment rate (TPT) in Indonesia in August 2023 of 4.88, with vocational school graduates having the highest TPT in East Java, 8.70%. Soetrisno (2015) stated that the high unemployment rate, especially in the field of welding skills, is not caused by limited job opportunities but rather by the skill competencies not meeting the required

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standards. The welding technique is one of the skills and competencies still very much needed in the industrial world (Kumar et al., 2023).

In general, challenges in education today are related to its complex nature, giving rise to difficulties in conceptual understanding. (Care, 2018; Nieveen & Plomp, 2018) And a lack of tools and processes to engage students in skill development. Students often need help understanding real-world situations to organize and simplify the information provided (Krawitz et al., 2022). Skills are primarily determined by students' understanding when studying theory. Welding material can be explained theoretically and requires simulation or practice. Students still often face problems in understanding content and instructions in conventional laboratory settings. (Yalcin-Celik et al., 2017) due to poor laboratory facilities and interference from fellow students and laboratory instructors (Afacan & Demirbaş, 2013). Students' critical power in conducting experiments and in-depth learning in conventional laboratories is also low. Innovative approaches are needed to integrate knowledge and learning processes that help solve problems, improve teamwork, and design new experiments. (Dunne & Ryan, 2010).

Many examples in the literature show how interactive simulations can be successfully used for educational purposes. Among these interactive simulations, three-dimensional (3D) virtual environments represent a group of applications attracting more and more interest in the educational community daily. (Paladines et al., 2023). This is because these systems are engaging and allow students to learn new concepts and procedures by recreating situations that, in the real world, would be too expensive, dangerous, or out of reach for students. When multiple users can visit a 3D virtual environment together over the internet and interact via desktop devices, this 3D virtual environment is usually referred to as a virtual world. Additionally, when students connect to the virtual world via the internet, they can do virtual practice at home without the physical presence of a teacher. This opens the door to virtual practice from remote places where laboratories with adequate equipment are unavailable.

Teaching modules that integrate 3D animation can complement conventional laboratories to increase student knowledge. (Chan & Fok, 2009). This can help students become independent learners because it can be used flexibly and more economically than conventional laboratories. Animated 3D integrated teaching modules can be used as a new pedagogical tool for students, according to research conducted in China, and it is suggested that using mixed laboratories is the best laboratory. (Wang et al., 2018). Studies conducted in Slovenia show that using media integrated with 3D animation technology can help better understand knowledge acquisition (Price et al., 2016).

Connor et al. (2019) Show that interactive 3D animated integrated teaching modules based on specific learning strategies improve skills and learning outcomes more effectively. Integrated 3D animation teaching modules that include text, animated videos, and sound effects can improve skill abilities. Wu & Chen, (2018) Stated that various media types in integrated 3D animation teaching modules can increase student interest. Including more visual and auditory elements in animated 3D integrated teaching modules allows students to understand what they read and learn while having fun. (Liang, 2015). In addition to providing an engaging, challenging, and stimulating experience for students, the animated 3D integrated teaching module enhances their interaction with the learning content and enhances their participation in learning by allowing them to take notes in the animated 3D integrated teaching module. (Çırakoğlu et al., 2022; Gong et al., 2013). Well-designed interactive 3D animated integrated teaching modules can support students' higher-order thinking skills. (Bozkurt & Bozkaya, 2015).

This research aims to develop an integrated 3D animated teaching module for welding that is valid, practical, and effective. The teaching module developed techniques using model problem-based learning (PBL), a scientific learning approach, and authentic assessment of welding competency using the manual arc welding or shielded metal arc welding (SMAW) welding process, taking into account that SMAW welding is the most common type of welding used in Indonesia. The development of this teaching module is expected to improve the quality of the process and the quality of learning outcomes in SMAW welding engineering subjects.

II. Method

A. Research Design

This research uses development research methods, and design is Design-based Research (DBR). DBR design aims to create and expand knowledge about developing, implementing, and sustaining innovative learning environments. The development of teaching modules refers to the development of the Instructional Design Model (IDM), which is illustrated in Figure 1.

IDM starts from (1) Analysis of the learning needs of welding engineering vocational school students using the PBL model; (2) Learning design and development of teaching materials, namely, teaching modules with the PBL model; (3) Validity and limited testing of teaching modules; (4) Evaluation of teaching modules; (5) Improving learning designs and tools, especially teaching modules; (6) Extensive testing; to (7) Evaluation of the practicality and effectiveness of the teaching module.

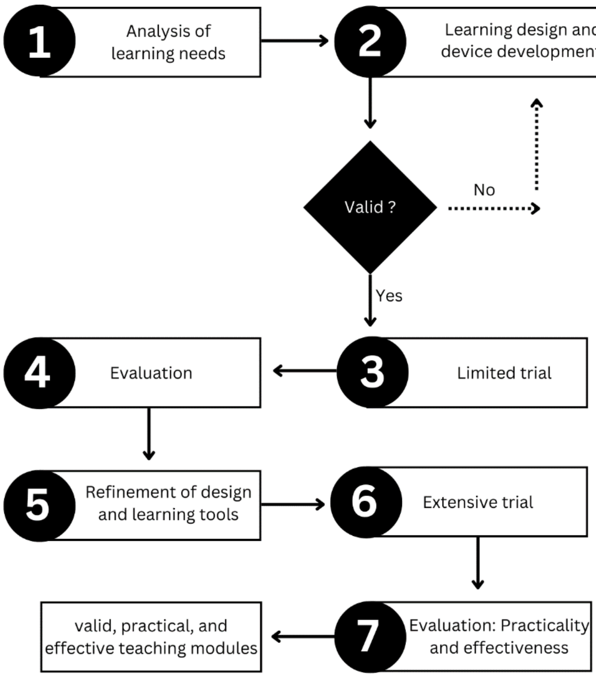

Fig. 1. Development model design instructional design model (IDM). Source: Ley & Gannon-Cook, 2023.

B. Participant

The participants involved in this research were class XI vocational school students in East Java. The technique for taking participants in this research was carried out by considering specific criteria based on the research objectives. The subjects for the individual trial were three students selected with the requirements of one high achieving student, one medium achieving student, and one low achieving student; for the small group test with a total of 15 test subjects selected with the criteria of five high achieving students, five medium achieving students, and five low achieving students. A pretest is done in the class where the subject is trying to be taken to determine students based on these criteria. Mark pretest This is also used as value data to pretest students before the developed teaching module facilitates learning. Subjects in extensive testing of teaching module products are assigned to classes that still need to be tested.

C. Instrument

The research instrument used is the validity, practicality, and effectiveness of the teaching module by the research objectives. The validity of the teaching module in this research was analyzed based on the results of expert validation. In contrast, the practicality and effectiveness of the model were analyzed based on the results of extensive testing of the teaching module. The validation instrument for the SMAW Welding Technique Module uses an instrument consisting of seven assessed components. The validation instrument grid for this module can be seen in Table 1.

Practicality analysis was also obtained from observations of learning implementation carried out in limited trial classes. Analysis of the effectiveness obtained from implementing teaching modules in learning using the PBL model was carried out using the One-Group Pretest-Posttest Design. The practical instruments filled out by students can be seen in Table 2, Table 3, and Table 4.

Table 1. SMAW Welding Technique Module Validation Instrument Indicators

No	Assessed Components	Item Number
1	Aspects of Module Characteristics	1, 2, 3, 4, 5
2	Indications and Prerequisites for Using the Module	6, 7, 8
3	Aspects of Content and Material in the Module	9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24
4	Format	25, 26, 27, 28, 29
5	Cover	30, 31
6	Language usage	32, 33, 34
7	Module Utilization	35, 36, 37, 38, 39

Table 2. Indicators of Learning Aspects

No	Attribute	Item Number
1	Clarity of Competency Formulation	1
2	Clarity of Learning Objectives	2
3	Learning strategies	3
4	Method Selection	4
5	Presentation of Practice Questions and Evaluation	5
6	SMAW Welding Technique Job Sheet Presentation	6
7	Language Accuracy	7
8	Motivation	8

Table 3. Content Aspect Indicators

No	Attribute	Item Number
1	Material Quality	1
2	Language Quality	2
3	Visual Quality	3
4	Weld Simulator Quality	4
5	Video Quality	5
6	Accuracy of Question Formulation	6

Table 4. Layout Aspect Indicators

No	Attribute	Item Number
1	Text Readability	1
2	Image Quality	2
3	Color Harmony	3
4	Audio Quality	4
5	Layout	5
6	Animation	6
7	Weld Simulator	7
8	Video	8
9	Transition	9
10	Bottom	10
11	Resolution	11

The effectiveness of implementing teaching modules in learning using the PBL model is measured using the One-Group Pretest-Posttest Design. The effectiveness indicator instruments can be seen in Table 5.

Table 5. Effectiveness Indicators

No	Indicator	Attribute
1	Work preparation	Equipment Completeness
		Completeness of Practice Materials
2	Process	Connecting and Setting Up Welding Equipment
		Welding Materials Using the Correct Process According to Standards
3	Work result	Appearance
		Inside Las
		Weld Defects
	Work Attitude	Use of Hand Tools and Measuring Instruments
		Job Security
	Time	Practice Completion Time

D. Analysis Technique

Data collection in this research was carried out using surveys and written tests. The data analysis technique used in this research analyzes the validity, practicality, and effectiveness of teaching modules according to the research objectives. Analyze data on the effectiveness of learning modules so that they can be said to be effective if they meet effectiveness indicators, including:

1) Validity and Reliability

The teaching module validity analysis technique is used by Aiken (1985). To see reliability, Cronbach's Alpha (α) and McDonald's Omega (ω) were used (Malkewitz et al., 2023). α is used to calculate how closely the relationship between each item in the measurement instrument is and how well the items measure the same concept. ω uses factor analysis to calculate the internal consistency of a measurement instrument by considering variations in factors that might influence internal consistency (Creswell, 2011). α and ω exceed the minimum requirement of ≥0.70, so they are declared reliable (Black & Babin, 2019; Hayes & Coutts, 2020; Mohammed et al., 2022).

2) Assessment in the Practical Category.

Data analysis of the practicality of the teaching module was analyzed based on the results of assessing the responses of teachers and students as users of the product developed using a Likert scale. Categorization is used to state the practical status of the teaching module product, as shown in Table 6.

Table 6. Practicality Test Score Categories

The average score for each aspect assessed (M)	Category
3,51 ≤ M ≤ 4,0	Very Practical
2,51 ≤ M ≤ 3,50	Practical
1,51 ≤ M ≤ 2,50	Less Practical
0,0 ≤ M ≤ 1,50	Very impractical

E. Increasing Student Competency

Calculate the magnitude of the increase in student competency in SMAW welding engineering subjects, calculated from the rise in grades gain score (<g>) on SMAW welding technique subjects between before and after being treated with learning modules. The magnitude of the increase (<g>) can be calculated using the formula Equation 1.

$$< g > = \frac{score\ posttest - score\ pretest}{score\ max - score\ pretest}$$

To express high and low ($<g>$) table is used in the interpretation from Hake (1998) which can be seen in Table 7.

Table 7. Interpretation Gain Score Normalized

<g>	Category
(<g>) > 0,7	High
0,3 ≤ (<g>) < 0,7	Medium
(<g>) < 0,3	Low

F. Implement the ability

Status of implementation of the PBL learning model with teaching modules by two observers using the criteria for implementing the learning model. The assessment results from the two validators are then continued with calculations and analyzed to determine agreement based on the results of each observation implementation of learning, which is then described using Cohen's Kappa coefficient (κ). κ is a coefficient that evaluates and measures probability correction agreement between two observers (Cohen, 1988). Formulas κ used can be seen in Equation 2.

$$k = \frac{Po - Pe}{1 - Pe}$$

Information:

Po: relative observed agreement among raters
Pe: hypothetical probability of chance agreement
Criteria κ can be seen in Table 8.

Table 8. Interpretation Kappa Statistic

Kappa Statistic	Interpretation
$\kappa < 0.00$	No Agreement
$0.00 \leq \kappa < 0.21$	Slight Agreement
$0.21 \leq \kappa < 0.41$	Fair Agreement
$0.41 \leq \kappa < 0.61$	Moderate Agreement
$0.41 \leq \kappa < 0.61$	Near Agreement
$0.81 \leq \kappa \leq 1.00$	Perfect Agreement

Results of recapitulation of implementation for each indicator were later categorized as presented in Table 9.

Table 9. Criteria for Implementing the Learning Model

Average percentage (%)	Category
0,00 - 24,99	Very less
25,00 - 37,59	Less
37,60 - 62,59	Currently
62,60 - 87,59	Good
87,60 - 100,00	Very good

III. Results and Discussion

A. Result

The module created and produced is then subjected to expert validation (expert judgment) to obtain an expert assessment of whether the product being developed meets the feasibility of being implemented. Validation of the learning module created in this research was carried out so that the module could be implemented, so it needed to be consulted and discussed with several experts, namely learning module development experts, multimedia experts, and material experts. Validation results and reliability of the SMAW welding technique module assessment can be seen in Table 10 and Table 11.

Table 10. Recapitulation of SMAW Welding Technique Module Validation Results

No	Components to be assessed	Rates Score	Category
1.	Aspects of Module Characteristics	3,8	Very Valid
2.	Indications and Prerequisites for Using the Module	4,0	Very Valid
3.	Content/Material Aspects	3,9	Very Valid
4.	Format	3,7	Very Valid
5.	Face or cover	3,5	Valid
6.	Language usage	4,0	Very Valid
7.	Module Utilization	3,6	Very Valid
	Rates	3.8	Very Valid

Table 11. Reliability of SMAW Welding Engineering Module

Estimate	Cronbach's alpha	McDonald's omega
Point estimate	0.927	0.921
95% CI lower bound	0.886	0.835
95% CI upper bound	0.942	0.910

Based on Table 10. The SMAW welding technique module is valid. Table 11 shows α and ω > 0.70; this indicates that the SMAW welding technique module is reliable. A limited trial was carried out by taking three class students XI TL2 odd semester (XI/3) from welding engineering skills competency and three SMAW welding engineering subject teachers to accompany the subject and to obtain teacher responses to the product being developed to obtain information regarding the advantages and disadvantages of the product being developed as a material for improvement. The instruments are adjusted to students' abilities and validated by material, media, and learning experts. The discussion of the results of individual trials by students regarding these four aspects is explained as follows:

1) Analysis Results of Student Evaluation of Learning Aspects

Analysis of evaluation results by individual trial subjects for each component of the learning aspect is presented in Table 12. Indicators for components that score three or good criteria are still being revised for the subsequent trial. Likewise, other elements can still be revised if the evaluation score is below 4. For this purpose, minor revisions will still be carried out on components whose assessment score is ≤ 3. They will be reviewed again according to the student's assessment results: material experts and media experts.

Table 12. Results of Student Evaluation of Learning Aspects

No.	Component	Evaluator			Rates	Conclusion
		1	2	3		
1.	Clarity of Competency Formulation	4,00	3,50	4,00	3,83	Very good
2.	Clarity of Learning Objectives	4,00	3,00	4,00	3,67	Very good
3.	Learning strategies	3,67	4,00	3,67	3,56	Very good
4.	Method Selection	3,67	3,67	3,67	3,67	Very good
5.	Presentation of practice and evaluation questions	3,75	3,5	3,5	3,58	Very good
6.	Serving Job Sheet Teknik Las SMAW	3,80	3,40	3,60	3,67	Very good
7.	Accuracy of language selection	3,50	4,00	3,50	3,67	Very good
8.	Motivation	4,00	3,67	3,33	3,67	Very good
	Rates	3,71	3,61	3,74	3,66	Very good

2) Analysis of Student Evaluation Results on Content Aspects

From the individual evaluation results presented in Table 13, the content or material aspects of the teaching modules developed are in the outstanding category. However, revisions are made according to expert validators' input before carrying out extensive trials to improve the quality of the teaching modules' content.

Table 13. Results of Student Evaluation of Teaching Module Content Aspects

No	Component	Evaluator 1	Evaluator 2	Evaluator 3	Rates	Conclusion
1.	Material quality	3,75	3,50	3,63	3,63	Very good
2.	Language quality	3,50	3,50	4,0	3,67	Very good
3.	Visual quality	3,67	4,00	3,33	3,78	Very good
4.	Quality Weld Simulator	3,50	3,50	3,50	3,50	Very good
5.	Video Quality	4,00	3,50	3,50	3,67	Very good
6.	The accuracy of the formulation of the question	3,50	3,50	4,0	3,67	Very good
	Rates	3,65	3,58	3,71	3,65	Very good

3) Analysis of Student Evaluation Results on Display Aspects.

Table 14. Results of Student Evaluation of Teaching Module Display Aspects

No.	Component	Evaluator 1	Evaluator 2	Evaluator 3	Rates	Conclusion
1.	Text Readability	3,75	3,50	3,75	3,67	Very good
2.	Image Quality	3,50	4,00	3,50	3,67	Very good
3.	Color Harmony	3,33	3,67	3,67	3,56	Very good
4.	Audio Quality	3,67	3,67	3,67	3,67	Very good
5.	Layout	3,67	3,67	3,67	3,78	Very good
6.	SMAW Welding Simulation Animation 3D Video	4,00	3,67	3,67	3,67	Very good
7.	Weld Simulator	4,00	3,5	3,50	3,50	Good
8.	Video	3,67	3,33	3,67	3,44	Good
9.	Transition	3,50	3,50	4,00	3,67	Very good
10.	Button	4,00	3,67	3,67	3,78	Very good
11.	Resolution	3,33	3,67	4,00	3,56	Very good
	Rates	3,67	3,65	3,71	3,63	Very good

Based on the evaluation results, the display aspect of the teaching module received an average score of 3.63, which is in the outstanding category. However, before this instrument is used in small group tests, the component indicators of the evaluation results are revised according to input from expert validators, and revisions are carried out first.

4) Analysis of Teacher Evaluation Results on Learning Aspects, Content Aspects, and Display Aspects in Learning Modules.

Based on the results of teacher assessments on all aspects evaluated, namely learning, content, and display aspects, which are presented in Table 15. The average score of the overall teacher assessment results is 3.72, which is an excellent grade. This criterion shows that the teaching module developed meets practical requirements. Teachers gave excellent responses to the results of the development of the teaching module.

Table 15. Teacher Evaluation Results on Learning Aspects, Content Aspects, and Display Aspects in the Learning Module.

No.	Aspect Modules which are Evaluated	Evaluator: Teacher 1	Evaluator: Teacher 2	Evaluator: Teacher 3	Rates	Conclusion
1.	Learning Aspects	3,79	3,79	3,76	3,78	Very good
2.	Content/Material Aspects	3,71	3,65	3,72	3,69	Very good
3.	Display Aspects	3,67	3,70	3,72	3,69	Very good
	Rates	3,72	3,71	3,73	3,72	Very good

Based on the student and teacher evaluations on all aspects assessed, namely learning, content, and appearance, the overall average score of the assessment results was obtained, which was in the outstanding category. These results indicate improvements after revisions based on suggestions for improvements in the small group test. The results of this assessment also mean that the teaching module developed has met practical requirements. Based on the teacher's evaluation of the teaching module after it was implemented in the implementation of learning using the PBL model, the teacher assessed it as very good. This means that as one of the components of the learning tools developed, the teaching module is suitable for use in learning SMAW welding techniques in welding engineering skills competencies at vocational schools. Once valid and practical, a field trial of the teaching module operational product is carried out in a significant group test. The learning environment settings are the same as authentic learning. In the extensive group test, the trial process was carried out following the learning implementation procedures designed in the welding technique learning implementation plan assisted by the teaching module using the PBL model.

The effectiveness test in this research was carried out by implementing the teaching modules within class XI-TL3 odd semester (XI/3) Mechanical Engineering Skills Program, Welding Engineering Skills Competency with 32 students trying subjects. The material tested in this extensive group test consisted of two test materials, namely (1) Theory and practice of welding butt/end joints (butt joint) underhand position (1G), and (2) Theory and practice of welding joints butt joint position vertical up (3G). Before students are given treatment, they apply the PBL model, facilitated by the teaching modules that provide pretests to measure students' initial abilities. After being given treatment, students are given treatment at the end of the lesson posttest to measure their abilities. Results of the pretest and posttest can be seen in Table 16.

Table 16. Summary of Pretest and post-test results, Average Gain Score, and Gain Score Normalized on Large Group Test

Test Material	Average Value		Rates *Gain Score*	*N-gain*	Interpretation		The number of students	
	Pretest	*Posttest*			N-*Gain* (< g >)	Category	Unit	(%)
Theory and practice of welding butt/end joints *(*butt joint) underhand position (1G)	57,46	87,29	29,60	0,70	(< g >) > 0,7	Height	24	75
					0,3 ≤ (< g >) < 0,7	Currently	8	25
					(< g >) < 0,3	low	0	0
Theory and practice of welding butt/end joints (butt joint) position vertically up (3G)	57,46	87,83	30,4	0,72	(< g >) > 0,7	Height	28	87,5
					0,3 ≤ (< g >) < 0,7	Currently	4	12,5
					(< g >) < 0,3	low	0	0

Based on Table 16, the average (<g>) for all students is 0.70, which is in the high improvement category. Meanwhile, from the results of the second material trial with the same number of test subjects, there were no students who entered (<g>) < 0.3, which was in the low improvement category. All students' average (<g>) is 0.72, which is in the high improvement category. These results show that the teaching module, as one of the learning model tools developed, is effectively used to increase student competence in SMAW welding engineering subjects at vocational schools.

To determine the implementation of the model facilitated by the teaching module, observations were made by two teachers as independent observers during the implementation of learning using the PBL model. The results of observations of the implementation of the PBL model facilitated by teaching modules from two observers were analyzed using a percentage of Agreement (PA). Observations were carried out in four encounters for the two materials tested. The results of observations on each test material can be seen in Table 17.

Table 17. Observation Results of the Implementation of the PBL Model Using Teaching Modules

No.	Test Material Large Group	Meeting	Average Applicability Model (%)		Kappa	Conclusion Implement ability
			P_1	P_2		
1.	Theory and practice welding mild steel plate joints at end joints (butt joint) welding position underhand (1G)	1	89,21	90,07	0.90	Good
		2	98,21	96,43	0.82	Very good
	Rates		93.71	93.25	0.86	Very good
2.	Theory and practice welding mild steel plate joints at end joints (butt joint) vertical up welding position (3G)	1	92.86	96.43	0.81	Very good
		2	98.21	98.21	1.00	Very good
	Rates		95,54	97,32	0.90	Very good

The results of the implementation of learning using teaching modules are presented in Table 17. The average percentage of implementation of the model in two meetings in the first and second learning material obtained excellent results with the agreement of each observer having a good relationship perfect agreement. Thus, the teaching module can be implemented well, which is very effective.

B. Discussion

The SMAW Welding Techniques Module is a teaching material for SMAW welding techniques that contains objectives, definitions, principles, methods, and procedures that must be considered when welding using the SMAW welding process by the Welding Procedure Standard (WPS). The material in this module is a practical theory of SMAW welding, which is closely related to the practical tasks carried out by vocational school students in the mechanical engineering skills competency program for welding techniques. Explanations of material and work procedures are equipped with pictures to make it easier for students to understand the studied material. This SMAW welding technique module can be used side by side in learning SMAW welding technique subjects using PBL. This is because not all the material in the module, especially the material, is suitable for the PBL model. The module is also equipped with practice questions in the fill-in form and the answer key that students can use when working on SMAW welding technique practice questions. However, for the needs of students and teachers, it is sufficient to implement learning using the PBL model at school and for independent learning purposes outside of school.

Application of the SMAW welding technique module implemented with the PBL model up to sequence inside it adapted to the PBL syntax, which begins with face-to-face problem identification. Wijnia et al. (2024) stated that learning that starts with a problem can attract students' interest in the subject matter. Focusing the learning process on real-world issues is thought to make learning more exciting and relevant to students' lives and future professions (Schmidt et al., 2011). Armed with initial knowledge and connecting it with previous knowledge, students can identify problems that arise through problem identification. Core activities in the SMAW welding engineering module are customized with the PBL stage, which aims to help and facilitate students in solving problems found in the first syntax. The core activities in the SMAW welding engineering module being developed are supported by several learning theory perspectives that underlie the development of the module, namely social constructivist learning theory and cognitive theory. According to constructivist learning theory, learning with the help of technology will be effective if prior knowledge and learning experiences with new material go hand in hand, and the use of technology can support student involvement in conducting investigations. Boublil et al. (2024) explain that a suitable learning module must be able to require critical thinking in every activity with guidance to analyze facts, provide reasons, convey arguments, and draw conclusions with implications. Based on social constructivism theory and scaffolding theory, through differences of opinion, the free exchange of ideas, and being given complex assignments, providing sufficient assistance to complete these assignments can improve students' skills (Eggen & Kauchack, 2020).

Data on the validity of the teaching module is presented, which shows that the experts' assessment has very valid criteria, meaning that the experts agree that the SMAW welding engineering module is very valid and reliable because it was designed according to the needs of the model development, elements of up-to-date knowledge (state of the art knowledge), theoretical support, and learning environment. Arends (2015) explains that a valid learning model pattern can direct the achievement of specific competencies. Panebianco et al. (2024) also explained that a valid learning module can help teachers and researchers design learning because it is constructed from correct learning principles and models. The teaching module developed has been proven practical, where at the evaluation stage, the teaching module in Table 12, Table 13, and Table 14 shows an outstanding category, which means teachers and students can implement this teaching module. This is by Wensveen & Matthews (2014) who states that a research prototype is said to be practical if it can be applied to a given condition. This is also true of constructivist learning theory, which states that the readiness of teaching modules can support knowledge construction and facilitate social interactions that encourage knowledge construction and skills development (Papadopoulou, 2020). Nardo (2017) states that the advantage of providing teaching modules in the learning process is that they can direct students' learning activities, act as a guide, and monitor progress in solving a problem. Teaching modules can also help students discuss, solve problems, think critically, and understand lesson material (Marlena et al., 2022).

The effectiveness of the SMAW Welding Technique Module can be seen in improving students' skills by testing the teaching module and implementing the PBL model using the teaching module. Skill improvement data obtained by analyzing (<g>) the pre-test and post-test scores, as in Table 16, shows a varied increase in skills after implementing the teaching module in the PBL learning model. In general, students' skills increase within high criteria. The developed SMAW welding technique module meets the characteristics of a learning module based on a constructivist view. According to Arends (2015), one of the characteristics of the student-centered constructivist learning model is that students play an active role in learning, there is interaction between students and other students, and there is the active participation of students in carrying out investigative activities and solving problems. The developed teaching module still needs to be refined again to be re-integrated with increasingly sophisticated technology such as by integrating augmented reality and virtual reality. With the addition of technology that is increasingly sophisticated and can visualize, it will be easier for students to practice their skills.

IV. Conclusion

This research produced the SMAW welding technique module. The SMAW welding technique module was validated by learning module development experts, multimedia experts, and material experts. The average result of validation from experts obtained a score of 3.8. The SMAW welding technique module has met the valid criteria. The results of the practicality assessment of the teaching module assessed by students and teachers in the learning aspect of 3.72, the content aspect of 3.67, and the appearance aspect of 3.66 which is included in the practical category. This module proved practical in its use, with positive feedback from teachers and students indicating that it is easy to implement in a classroom environment and supports an efficient learning process. The developed module has met the effective criteria, where the implementation of teaching modules for learning SMAW welding techniques in SMK shows that the implementation of this module can be carried out very well and obtained an average percentage of 95.54% and 97.32% with the agreement of each observer having a good relationship, namely perfect agreement. This module can also improve student competence in SMAW welding technique subjects in SMK with an N-gain value of 0.71 in the high improvement category. From this research, it can be concluded that the teaching module developed is valid, practical, and effective so that it can be used as one of the learning modules for SMAW welding techniques in SMK. However, some suggestions and revisions to the module need to be considered. Some other schools also need extensive trials to ensure that the teaching module developed is efficient for future use.

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