SMAW Welding Animation 3D Simulator: Moderating the Relationship between Concept Understanding and Student Psychomotor Learning Outcomes

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Abstract **– The study aims to explain the moderation of 3D simulator Shielded Metal Arc Welding (SMAW) welding animation in the relationship between concept understanding and student psychomotor learning outcomes. The correlation research method and research design used is the Spearman Correlation to measure the strength and direction of the relationship between two variables. This research data was collected by conducting a survey through filling out questionnaire instruments independently to 130 students and the data analysis technique used in this study was Moderated Regression Analysis (MRA). The results showed the sig value of the moderation variable 0.163 and the interaction variable 0.004, so it can be decided if the moderation variable has an insignificant effect, while the interaction variable has a significant effect, based on these results the type of moderation provided by the 3D SMAW welding simulator is absolute moderation.**

The conclusion of the research shows that the 3D simulator of SMAW welding animation moderates the relationship between concept understanding and student psychomotor learning outcomes with the type of absolute moderation.

Keywords **– Learning media, SMAW, relationship, concept understanding, psychomotor.**

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1. Introduction

The industrial revolution 4.0 (I4.0) introduces a new opportunity for the digital revolution in the current generation to digitise all manufacturing processes without manual intervention or minimal human labour processes [1]. Education is a very important capital in life, especially in the I4.0 era, people are required to be able to survive in fierce competition [2]. I4.0 can boost economic growth by improving skills and better opportunities for a better quality of life [3]. However, disparities in education can negatively affect communities by pushing them into a state of marginalisation or poor quality of life. Technological changes are flowing so fast, today's society has more knowledge compared to the past, but still not everyone benefits in terms of the manufacturing industry in the future [4]. Quality education and training can be achieved by measuring broad areas with clear challenges (Sutainable Development Challenges). The challenges of sustainable development are many, such as poverty and its relationship with the quality of education and training [5]. Access to education is crucial including technical and vocational education recently [6]. Countries with well-established education systems can provide opportunities for sustainable development in Industry 4.0.

Presidential Regulation No. 68 of 2022 on the Revitalisation of Vocational Education and Training hopes that vocational education can provide work competence, productivity, discipline, attitude, work ethic at a high level of expertise qualification.

Vocational education in Indonesia is not a new thing to focus on. In 2004, the Indonesian government implemented competency-based education, as stipulated in Regulation No. 20/2003 on the National Education System. This education system is called the Competency-Based Curriculum. [7] said that the implementation of vocational education using the lens of the Competence-Based Education (CBE) framework in Indonesia has different practical realisations. Of the 41 schools tested, less than 20 % scored four in terms of competence. This skewed implementation has led to low maturity outcomes in vocational education at every level in terms of teachers and students mastering digital technology [8]. Lack of access to simulation labs and up-to-date technology limits learners' learning experiences, making it difficult for many learners to connect theory with real-world applications. This suggests that many students do not understand the concepts of the material presented. A good understanding of concepts can help learners to understand the basic principles, procedures and mechanisms behind the skills they need to practice [9]. Students who have a strong conceptual foundation tend to be more confident and effective in applying psychomotor skills [10].

Psychomotor learning outcomes in education also require practice-based learning, such as operating technological tools [11], but in reality, students often lack relevant facilities. Psychomotor experiences can strengthen concept understanding as students can relate theory to real situations, improve memory and skills [12]. This relationship is particularly important in vocational education, which demands simultaneous mastery of theory and practice. The reality in education shows that not all educators are trained to use methods that integrate technology-based learning and the assessment of psychomotor outcomes also requires direct feedback, which is sometimes missed [13]. Welding skills in terms of psychomotor learning outcomes can help learners to promote understanding of welding concepts and psychomotor skills that will benefit their future [14].

Many experimental cases show how effective simulation can positively influence learners for educational purposes. One of the effective simulations is a simulation with a three-dimensional (3D) presentation that can make students interactively enter the real world of learning objects [15]. The emphasised 3D simulation is very engaging and makes students learn new concepts or procedures by creating appropriate situations.

The availability of 3D simulations can connect the virtual world into students' workplaces via the internet, which means that students can also access the virtual world at home without the presence of the teacher. This will make it easier for teachers in the future to compress the teaching process and develop it into something that students can understand.

The virtual practice of 3D animation can make students recreate the situation that the teacher wants to show. Teaching materials with 3D animation in the subject can make the media very feasible to use and have a positive impact on learning motivation [16]. This can help students to cope with multiple tasks and prefer to work independently due to the high flexibility and thus lower cost compared to conventional learning. 3D animation simulation in vocational learning and training can be used as a new method tool in pedagogical teaching, according to research conducted in China, it is suggested that CAD virtual reality technology has been widely applied in the Chinese Academy of Sciences because virtual reality is the same terminology as 3D simulation, due to the use of computer modelling so that one can interact with an artificial 3D environment [17]. Studies conducted in Finland show that 3D modelling activities in schools evoke feelings of empowerment, engagement and excitement in creating art artefacts [18].

This study aims to explain the moderation of 3D simulator animation of SMAW welding in the relationship between concept understanding and student psychomotor learning outcomes. The teaching method carried out in this study uses a scientific method approach, with welding competency assessment using the manual arc welding process or shielded metal arc welding (SMAW). The SMAW welding process was chosen because it is the most widely used welding process in the manufacturing industry in Indonesia. This computer-assisted welding teaching method is expected to improve the quality of the SMAW welding course while focusing on 21st century skills to increase competition in Industry 4.0.

2. Methodology

The type of research used in accordance with the objectives of this study is quantitative with a correlation research method and the research design used is the Spearman Correlation. Spearman correlation is used in research to measure the strength and direction of the relationship between two ordinal variables or data that does not fulfil the assumption of normality. This method is done by converting data into ranking form and then measuring the relationship between these rankings [19].

The data for this study were collected by conducting a survey through filling out questionnaire instruments independently to 130 students of the Mechanical Engineering Department from Surabaya State University.

According to [20], the minimum sample size of 130 allows the research model with 2 exogenous variables to determine an R2 coefficient of 0.10 and a significance level of 1% within 80% statistical power, which is commonly applied. Therefore, the sample size in this study justifies the use of the PLS analysis approach [21]. The data analysis technique used in this study is Moderated Regression Analysis (MRA) with the interaction method. The MRA statistical technique is suitable for examining the interaction between the independent variable (X1) and the moderating variable (Z) on the dependent variable (Y). This technique helps determine whether the strength or direction of the relationship between the independent and dependent variables changes depending on the moderation value.

MRA essentially assesses whether moderating variables influence the effects of independent variables on dependent variables, which offers insight into complex relationships in research [22]. Analysis with the MRA technique was carried out using the SPSS application to help facilitate the data analysis process. The basis for decision making in Moderated Regression Analysis (MRA) depends on the significance of the interaction between the interaction variable (X. Z) and the moderator variable (Z) as shown in Table 1.

Table 1. Significance of interaction between variables

No	Test Result	Moderation Type
1	Moderating Variables: Not Significant Variable Interaction: Significant	Pure Moderation
2	Moderating Variables: Significant Interaction Variable: Significant	Pure Moderation
3	Moderating Variables: Significant Interaction Variable: Not Significant	Moderation Predictor
4	Moderating Variables: Not Significant	Potential Moderation

Table 1 shows the type of moderation formed, to see whether the value is significant or not, the result seen is the sig value, if the value is <0.05 the data can be categorised as significant, and if the value is >0.05 the data can be categorised as insignificant. The results of the analysis with the MRA interaction method can be made a regression equation as shown in Equation 1.

$$Y = \alpha + \beta_1 X + \beta_2 Z + \beta_3 XZ \quad (1)$$

Description:

Y = Dependent variable
α = Constant
β_1 = Regression coefficient of independent variables
X = Independent variable
β_2 = Moderate variable regression coefficient
Z = Moderating variables
β_3 = Regression coefficient of interaction variable
$X.Z$ = Interaction variable

3. Results

This research was conducted on 130 students majoring in Mechanical Engineering from Universitas Negeri Surabaya. All participants who are members of this study have tried the SMAW Welding Animation 3D Simulator and filled out the questionnaire instrument. The results obtained responses on each variable are shown in Figure 1, Figure 2, and Figure 3.

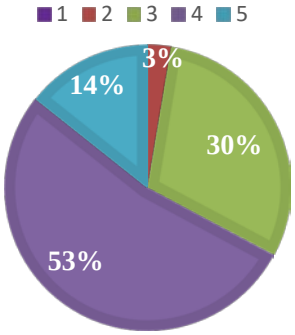

Figure 1. Percentage of variable X

Figure 1 is a pie chart showing the percentage distribution of 130 students' answers to statements related to variable X (concept understanding). Most of the students answered 4 with a percentage of 53% and the least was answering 1 with a percentage of 0%.

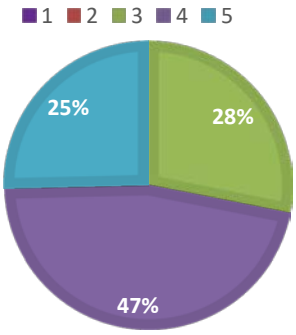

Figure 2. Percentage of variable Z

Figure 2 is a pie chart showing the percentage distribution of 130 students' answers to statements related to variable Z (3D Simulator SMAW Welding Animation). Most of the students answered 4 with a percentage of 47% and the least was answering 1 with a percentage of 0%.

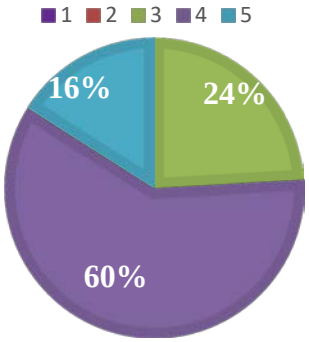

Figure 3. Percentage of variable Y

Figure 3 is a pie chart showing the percentage distribution of 130 students' answers to statements related to variable Y (psychomotor skills). Most of the students answered 4 with a percentage of 60% and the least was answering 1 with a percentage of 0%. The data obtained from the questionnaire was then processed using the MRA technique with the help of SPSS and the results can be seen in Table 2.

Table 2. MRA analysis results

Variable	Coefficients	t	Sig.
(Constant)	78.341	.752	.454
Concept Understanding Ability	2.960	2.912	.004
SMAW Welding Animation 3D Simulator	1.867	1.404	.163
X1.X2	.183	2.895	.004

Table 2 shows the coefficients values used to create the regression equation by substituting into Equation 1 so that the results can be seen in Equation 2.

$$Y = 78.341 + 2.960X + 1867Z + 0.183XZ \quad (2)$$

Equation 2 shows that the coefficients are mostly positive, meaning that the relationship between the variables is comparable. If variables X and Z are increased, variable Y will also increase, and conversely [23].

Table 2 also shows the sig value to determine the type of moderation in this study by looking at the criteria of the interaction variable with moderation.

The sig value of the moderation variable is 0.163, if this value is compared to 0.05 [24], then the value is greater (0.163>0.05) so it can be decided if the moderation variable in this study has an insignificant effect. The sig value of the interaction variable is 0.004, if this value is compared to 0.05, then the value is smaller (0.004> 0.05) so it can be decided if the interaction variable in this study has a significant effect. The results of this analysis can be concluded, that the interaction variable has a significant effect and the moderation variable has an insignificant effect, so the type of moderation based on Table 1 is absolute moderation.

4. Discussion

The type of moderation of the SMAW Welding Animation 3D Simulator variable on the relationship between concept understanding ability and psychomotor skills is absolute moderation. Absolute moderation is one form of moderation in the analysis of the relationship between variables, this concept is used when there is a moderator variable (Z) that affects the relationship between the independent variable (X) and the dependent variable (Y). In absolute moderation, the moderator variable interacts directly with the independent variable without taking into account the absolute value of the moderator variable itself [22]. Variable interaction theory explains that the relationship between two variables (independent and dependent) can be modified by a third variable, known as a moderator. In the context of absolute moderation, the moderator variable (SMAW Welding Animation 3D Simulator) only influences the relationship between concept understanding ability and psychomotor skills through its interaction effect, without any direct influence on psychomotor skills.

Animated 3D simulators can help students visualize complex concepts in a more tangible and understandable way [25]. The advantages of simulation can help students for increased opportunities to practice certain procedures in a safe and controlled environment, and connect theory with practice [26], [27]. Skills can be enhanced through active education methods, such as simulations that mimic actual environments [27]. Students can practice psychomotor skills in a simulated environment without the risk of damage or injury, which can improve confidence and skills. With the animated 3D simulator, students can integrate the understanding of concepts with the application of psychomotor skills in a relevant and real context. The combination of deep concept understanding and psychomotor skill practice in the simulator can improve information retention and skills [28], [29].

Constructivist Learning Theory states that learning is the result of an active process in which individuals construct knowledge based on their experiences [30]. In this case, the ability to understand concepts is the basis for the formation of psychomotor skills. The SMAW Welding Animation 3D Simulator acts as a learning tool that enhances the effectiveness of that relationship by providing a simulated environment that supports the transfer from theoretical knowledge (concept understanding) to psychomotor skills. Absolute moderation occurs because the simulator is only effective in the context of the relationship between conceptual understanding and psychomotor skills, but does not directly influence psychomotor skills in the absence of conceptual ability [31]. Cognitive and psychomotor psychology theories explain the difference between cognitive and psychomotor domains in learning [32]. To master complex psychomotor skills, a deep understanding of concepts is required as a first step.

The role of the 3D simulator as an absolute moderator allows students to connect the concepts they understand with practical experience, thus modifying (strengthening) the relationship between concept understanding and psychomotor skill development. Without concept understanding, the use of the simulator may not provide significant benefits to psychomotor skills, so the simulator functions more as a support (rather than an independent factor) [31]. According to technology-based learning theory, tools or technology such as simulators can act as an amplifier of the learning process by providing a realistic and interactive environment [33]. The SMAW Welding Animation 3D Simulator strengthens the link between concept understanding and psychomotor skills by simulating real situations. However, the tool is not effective if it is not based on prior theoretical understanding (conceptual ability). This is consistent with absolute moderation, as the role of the simulator emerges only through its interaction effect with conceptual understanding [34].

5. Conclusion

The results of this study indicate that the SMAW Welding Animation 3D Simulator acts as an absolute moderator in the relationship between concept understanding and students' psychomotor learning outcomes. The Moderated Regression Analysis (MRA) revealed a significance value of 0.163 for the moderating variable, indicating an insignificant effect, while the interaction variable obtained a value of 0.004 (<0.05), which is statistically significant. This confirms that the 3D simulator does not directly enhance psychomotor skills but strengthens the link between concept understanding ($\beta = 2.960$; sig. = 0.004) and psychomotor performance ($Y = 78.341 + 2.960X + 1.867Z + 0.183XZ$).

The findings highlight the critical role of conceptual mastery as the foundation for vocational skills development, with simulation technology functioning as a catalyst in transferring knowledge from theory to practice. However, this study is limited by its reliance on self-reported questionnaire data and a single-institution sample, which constrains generalizability. Future research is recommended to adopt experimental designs, extend the application to other vocational domains, and explore advanced technologies such as Virtual Reality (VR) or Augmented Reality (AR) to enhance realism in learning and better prepare students for Industry 4.0 workforce demands.

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