

Development of a Training Model on the Use of Laser Engraving Technology for Vocational High School Female Students in Semi-Urban Areas: Gender Equality in Education

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Abstract – One of the tasks in the Sustainable Development Goals (SDGs) is gender equality. Gender equality in education includes fields that are predominantly carried out by men. This study aims to test whether the training method designed using materials typically dominated by men can improve the Zone of Proximal Development (ZPD) of female students in vocational high schools in semi-urban areas in Central Java province. The method used is a quantitative quasi-experimental design. The research participants consisted of 518 female vocational high school students. All participants completed a questionnaire measuring their ZPD in relation to the training materials. Subsequently, 32 female students were randomly selected from the 518 participants to join the experimental group. Thus, the training involved two groups of female students: There are 32 students in the experimental group and 486 students in the control group. The experimental group gained high-engagement training through hands-on experience with the laser engraver process. Meanwhile, the control group underwent training by watching videos on the laser engraver process.

Based on this study, it was found that ZPD scores of the experimental group increased by $M = -31.66$ points, while the control group only experienced a ZPD increase of $M = -20.93$ points. Thus, it can be concluded that direct practice using a laser engraver is more effective in improving the zone of proximal development for female vocational students compared to watching videos about laser engraver usage. Hands-on experience resulted in a high level of student engagement. This study also found that female students can have high engagement when using equipment. Research with other tools that are more male-oriented could be conducted to further strengthen the findings of this study.

Keywords – SDGs, ZPD, laser engraver, gender, vocational schools.

1. Introduction

The development of digital technology is growing significantly, particularly in education, when it comes to facilitating and enhancing the learning experience. Several empirical studies [1] have shown that digital technology is highly effective as a learning tool, offering many benefits and conveniences for students. Integrating technology into education has become a fundamental need to improve the effectiveness of learning. The advancement of technology has brought significant changes to the education system, introducing digital learning methods that not only modernize the teaching process but also expand access to education for students, in line with the rapid pace of digitalization [2], [3].

Technological innovations not only revolutionize teaching methods but also enrich evaluation techniques and provide more effective feedback to students. Technology in education supports educators in designing learning processes, evaluating outcomes, comparing various approaches, and offering a strong foundation for formulating more appropriate policies [4].

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In Indonesia, vocational education is part of formal education at the secondary level, implemented through vocational high schools [5]. Vocational school offers various skill-based programs such as accounting, office administration, culinary arts, fashion design, tourism, mechanical engineering, automotive, information technology, and other programs related to specific skills. Vocational education, such as that provided by vocational high schools, focuses on skill development to prepare students for the workforce [6].

Vocational high school students experience and engage in various learning activities, which allows gaining a deeper understanding of the material presented [7]. Vocational education continuously adapts to changes in the industry. The curriculum implemented must include skills that align with market demands and utilize the latest technologies to support learning. Vocational curriculum is designed to prepare students with competencies that meet the needs of technological development related to industry, improve their technical and non-technical abilities, as well as motivating students to be more prepared for technological changes and industry challenges [8].

Various learning models for vocational education have been developed. In vocational education, although more attention is given to general lessons learned through practice, it is assumed that students will be able to access and apply facts and ideas, most of which come from standardized disciplinary knowledge, to solve faced practical problems [9]. Vocational students gain experience from school materials, along with creativity and the use of technology, this can develop into innovation. This creativity encourages them not only to utilize existing knowledge but also to develop new ideas and create innovative solutions in the field of technology [10]. Vocational students must be academically and technically capable, with the capacity to innovatively solve problems [11].

Students' expertise in facing challenges in the workforce can support efforts to achieve the Sustainable Development Goals (SDGs) of quality education and decent employment for all. The SDGs centered on sustainable development [12]. The SDGs have a main objective of reducing poverty, preserving the planet, and ensuring peace and security [13]. This study focuses more on SDG 4 and 5. SDG 4 aims to provide inclusive, equitable, and educational standards, aiming to ensure that every individual, regardless of their background, has lifelong learning opportunities that support both personal and professional development [14]. SDG 5 is about gender equality and empowering girls and women worldwide by providing equal access to various sectors of life, such as education, employment, and social rights, making it possible to reach their full potential in all aspects of life [15].

One approach in education is the social constructivist approach by Lev Vygotsky [16]. In this approach, skill development is achieved through social interaction and guidance from more experienced individuals. The ability to perform tasks independently without assistance represents the lower limit of an individual's capability, while the upper limit is determined by the amount of direction or help provided. This is known as the Zone of Proximal Development (ZPD). In the ZPD, a person is able to master new skills or complete difficult tasks more effectively with the help of others than if done alone [17], [18]. The improvement in a student's abilities, from their initial condition to what has been achieved through training, can be measured by ZPD. This shows how social interaction impacts learning. ZPD shows how the interconnection between subjects can deepen knowledge and enhance understanding more effectively [19].

One digital technology that can serve as a benchmark in efforts to improve ZPD is the laser engraver [20], a device that operates by utilizing a CNC (Computer Numerical Control) system to control its various functions with precision. This tool plays a significant role in education, especially in technology and vocational training, as the laser engraver can be considered an advanced printer capable of engraving or cutting on various surfaces [21], ranging from wood, metal, to synthetic materials. This flexibility and innovation in the learning process allows students to put their skills to use [22]. CNC is a technology that automates the control of machine tools through the use of computers [23]. Moreover, CNC is a production method that automatically controls machine tools to produce components with a high level of accuracy [24]. In the context of laser engravers, CNC controls the position and speed of the laser, ensuring that engraving and cutting are carried out with very high precision.

The laser engraver can produce fine marks or engravings on the surface of objects with a high level of precision, allowing for the creation of very detailed designs, including characters, symbols, and patterns that are resistant to fading or damage [25]. The use of laser technology spans various fields, from cutting to decorating textile materials [26]. The use of laser engravers has become increasingly popular and is utilized across different industries [27]. This laser uses beams to cut or engrave materials with a high degree of precision, making it very useful in manufacturing and production processes [28]. Furthermore, this tool is capable of operating on various materials such as metal, wood, glass, plastic, and fabric. Laser engravers can produce beautiful and durable engravings, making them highly suitable for various purposes, such as product personalization, prototype creation, and the creative industry [29].

This capability allows for the production of products with intricate details and consistent accuracy. This tool can also be integrated with automation technology to speed up the production process without compromising the quality of the final output [30]. Based on the above description, the researcher aims to explore the development of a training program for laser engraver technology for female students in vocational high schools in semi-urban areas. The training module designed based on experiential learning [31] also the concept of student-centered learning. Experiential learning emphasizes the importance of hands-on experience or direct engagement with the subject being studied [31]. This theory is based on the premise that knowledge is acquired by the process of transforming experience. Optimal learning occurs when students can fully participate in all four cycles of learning. These cycles are concrete experience, reflective observation, abstract conceptualization, and active experimentation. This experiential learning approach is integrated with the approach that employs several concepts from the learner-centered psychological principles developed by the work group of the American Psychological Association Board of Educational Affairs in 1997 [32].

2. Research Method

This study was conducted in July 2024, using a quantitative research method. The research employs a quasi-experimental procedure to measure the effectivity of technology-based training using a laser engraver machine on the improvement of the Zone of Proximal Development (ZPD) among female students in vocational high schools.

2.1. Research Participants

This study involved 2 state vocational high schools in semi-urban areas of Central Java Province, with a total of 518 female students as participants. Participants purposively selected through non-probability sampling technique with a purposive sampling method. This means that researcher selected the participants based on the following criteria based on specific considerations. In this case, the researcher determined participants based on their class majors, selecting those from fields that are rarely exposed to digital technologies typically used by males. All participants in this study were female students from areas that rarely utilize technology.

2.2. Data Collection

The study was conducted by dividing participants in two groups: experimental and control. Those assigned to the experimental group were given the following treatment in the form of hands-on experience and actively participated in training activities for operating the laser engraver to create a work. The experimental group's activities are shown in Figure 1.



Figure 1. Experimental group's activities

2.3. Research Instruments

Data collection was conducted by providing a questionnaire on the use of laser engravers, developed by the Science, Technology, and Society Research Group (STS RG). The indicators in the questionnaire have undergone an expert judgment process, ensuring that the questionnaire accurately measures the desired aspects. The expert judgment process was carried out to ensure the validity of the questionnaire to be used.

The researcher then conducted readability and face validity tests with the students. The readability and face validity tests were carried out to ensure that the questionnaire is relevant and easy to understand. In this process, the researcher received feedback from participants about the appearance, accuracy and appropriateness of the questionnaire items. The questionnaire provided to the female students consisted of 2 parts: a pre-test and a post-test.

The questionnaire was designed to determine the comparison of the Zone of Proximal Development (ZPD) of female students after receiving treatment based on groups: experimental and control. This questionnaire consists of 2 parts: a pre-test and a post-test. To provide a comparison on the effects of given treatments, pre and post-test methods are used.

This research questionnaire consists of 10 statement items related to knowledge about laser engraver machines to measure the understanding of female students regarding this technology. A 7-point Likert scale is used in the questionnaire. The scale ranges from "strongly does not represent me" to "strongly represents me." The scale used provides insight into how the students perceive their understanding of laser engraver technology.

The research data that has been collected will be processed and analyzed using Statistical Package for Social Sciences International Business Machine (SPSS IBM) 20. The data will undergo reliability testing and paired samples t-tests. The reliability test of the measurement tool involves 518 female students from 2 state vocational high schools in semi-urban areas of Central Java Province. The reliability test results show the consistency, relevance, and correlation of the items in the questionnaire with what is expected.

It can be explained that the questionnaire used in the research on the use of laser engraver has a good level of reliability based on the results of reliability analysis using SPSS. The number of samples analyzed was 518 respondents. The Cronbach's alpha value obtained in the reliability statistics table is 0.844 for the 20 questionnaire items used. This shows that the questionnaire is consistent in measuring the use of laser engraver on the subject of the study, namely vocational students.

The paired samples t-test compares and measures two sets of the same data to observe the differences between them. The paired sample t-test was used in this study to measure and compare the effects of the intervention on both the experimental and control groups. The results from the paired samples t-test will indicate the differences in significant understanding improvement between the experimental and control groups. The process of comparing the pre and post-test scores from both groups can help identify whether the treatments given to both groups significantly influenced the score improvement. Additionally, the researcher can also identify which treatment significantly improved the scores based on the comparison results.

2.4. Research Procedure

This quasi-experimental procedure consists of 5 steps. First, a pre-test was administered to measure the Zone of Proximal Development (ZPD) in terms of students initial knowledge of laser engraver machines. Second, students in the experimental group watch a video about how the laser engraver works.

Third, the experimental group participates directly in a demo training session on operating the laser engraver, while the control group watches a video about the operation of the laser engraver. Fourth, the students work on a student activity sheet in groups to discuss the results of the laser engraver demo. Fifth, the students complete a post-test, which was administered to measure students' knowledge after receiving treatment based on the experimental and control groups.

Figure 2 shows the flowchart outlining the stages of the research process conducted in the experimental group.

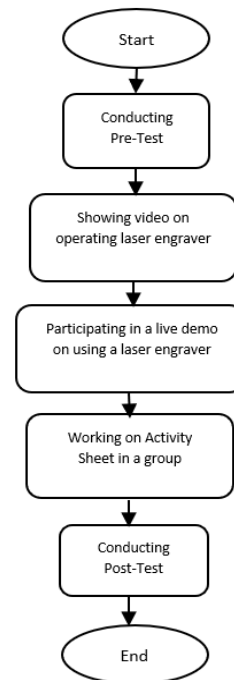


Figure 2. Experimental group flowchart

See Figure 3 for the flow chart that explains the research process conducted in the control group.

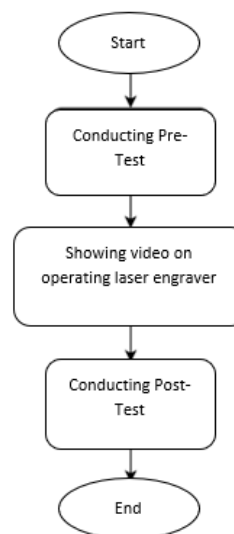


Figure 3. Control group flowchart

The laser engraver machine used in the training can be viewed in Figure 4 and Figure 5.



Figure 4. Laser engraver machine

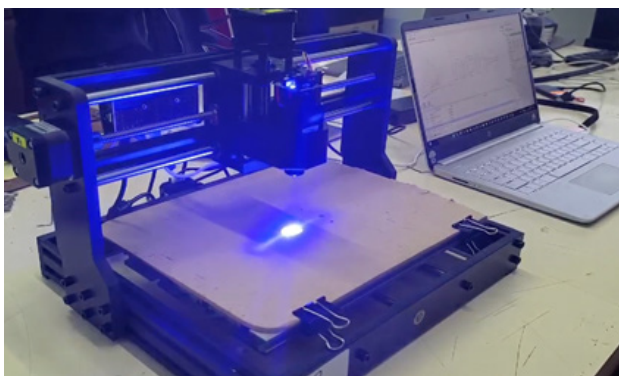


Figure 5. Operation of laser engraver machine

3. Results

The analysis results from the study on the development of a training model for laser engraver technology for vocational high school female students indicate a significant increase in the pre and post-test result for both groups. The experimental group that was trained to use the laser engraver experienced a significant increase in scores following the intervention. The average pre-test score for the female students was mean (M) = 10.88 with standard deviation (SD) = 2.31, while the score on post-test increased to M = 42.53 with SD = 15.31. The score increase was M = -31.66 with SD = 15.23.

The t-test produced a value of $t(31) = -11.761$, with probability $(p) < 0.01$, indicating the difference of the pre and post-test scores is statistically significant (95% confidence level). This result confirms that the training provided significantly improved the students' ability to use laser engraver technology. The calculations are shown above in Table 1.

Table 1. Descriptive analysis results of the experimental group

Paired Sample Statistics					
	Mean	N	Standard Deviation		
Total Pretest	10.88	32	2.31		
Total Posttest	42.53		15.31		
Paired Sample Correlations					
	N	Correlation	Sig		
Total Pretest-Posttest	32	.112	.541		
Paired Sample Test					
	Mean	Standard Deviation	t	df	Sig (2-tailed)
Total pre-post test	-31.66	15.23	-11.76	31	.000

Meanwhile, the control group that received a different treatment by watching a short video showed a significant difference between the pre- and post-test scores. The control group's average pre-test score was mean (M) = 11.67 with standard deviation (SD) = 5.77, while post-test score increased to M = 32.60 with SD = 13.00. The t-test score on this group showed a value of $t(381) = -20.93$, with probability $(p) < 0.01$, indicating that the score difference before and after the intervention is also statistically significant. The results of this calculation can be seen in Table 2. Although this group did not receive training in laser engraver technology like the experiment group's post-test scores showed a significant improvement.

Table 2. Descriptive analysis results of the control group

Paired Sample Statistics					
	Mean	N	Standard Deviation		
Total Pretest	11.67	382	5.77		
Total Posttest	32.60		13.00		
Paired Sample Correlations					
	N	Correlation	Sig		
Total Pretest-Posttest	382	.106	.039		
Paired Sample Test					
	Mean	Standard Deviation	t	df	Sig (2-tailed)
Total pre-post test	-20.93	13.66	-20.95	381	.000

Based on the results that have been presented, the experimental group has a significant increase of abilities compared to the control group on laser engrave technology training. The higher improvement in the experimental group reinforces the effectiveness of the developed training model.

4. Discussion

The outcome of this study affirms the effectiveness of the laser engraver technology training model in enhancing the skills of vocational high school students. The significant increase in post-test scores in the experimental group proved the success of the training intervention. Students who received the laser engraver training demonstrated a much greater improvement in their knowledge and skills, while the control group, although showing improvement, did not reach the same level of progress.

These results indicate that structured training in the latest technologies, such as laser engravers, can significantly enhance students' technical competencies. Further studies could explore how similar training models can be adapted for other technological tools, thereby expanding the scope of educational and vocational training programs.

5. Conclusion

This study demonstrates the effectiveness of laser engraver training in significantly improving the skills of female vocational school students. In order to measure the results of the training model, Zone of Proximal Development (ZPD) was measured by comparing pre- and post-tests in terms of ZPD related to the use of a laser engraver. The high reliability of the questionnaire supports the validity of these findings, where the experimental group showed a greater increase in skills compared to the control group. Compared to the control group training, the experimental group training is characterized by: (a) an interactive situation between the trainer and the trainees; (b) the trainees have the opportunity to see a hands-on demonstration of the use of the laser engraver. However, the improvement seen in the control group suggests an external influence on the learning process.

Based on the result above, this training model proved to be useful. Although the experimental group's score increased more significantly, the control group's score did also increase. This indicates that both groups had factors in common, which made them relatively engaged with the training activity. Characteristics of activities that create engagement are: (a) using technology that is capable to produces a product that can be seen by the students; (b) involving technological knowledge that is relatively new to the students; (c) involving the use of technology that is rarely used by female students.

Therefore, to create effective training to increase the ZPD of new tool using skills for female students, necessary to consider the characteristics of the activities that engage these students.

The main benefit of this research is its contribution to the development of an effective technical training model for students. Further studies could adapt this approach to other technologies, aiming to expand vocational education across various fields and level of education.

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