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An Immersive Virtual Reality System for Practicum Chair Assembly Training to Increase Effectiveness of PPTI 2

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Abstract. *The implementation of practicum chair assembly training in PPTI 2 still uses conventional method training. The use of conventional methods has some drawbacks including high resource requirements when starting out and requires an experienced coach who should always be there whenever there is training. The use of conventional methods in the training of practicum chair assembly is considered less effective. There needs to be other alternatives in practicum chair assembly training. The alternative chosen is training using Virtual reality (VR). This paper contains a comparison between training using conventional methods and using virtual reality. That proves training uses VR more effectively than training with conventional methods.*

Keywords: *practicum; training; assembly; virtual reality system*

I. INTRODUCTION

The integrated practical works in the Industrial Engineering Study Program of Universitas Sebelas Maret (PSTI UNS) is known as the Industrial Engineering Design Practicum (PPTI). PPTI in its implementation using a learning factory approach. Learning factory is a learning concept that is done with a real production process that is adapted to achieve learning goals (Wagner et al., 2012). PPTI study is still being developed and evaluated every year. One of the stages of practicum that is still being evaluated is the PPTI 2. PPTI 2 plays a role in the product manufacturing process that has been planned in PPTI 1. The implementation of PPTI 2 produces products in the form of practicum chairs. Every start of the workshop activities at PPTI 2 all practices will be given training tailored to the needs of each station. The portion of exercise for each practice is the same regardless of the ability of practice. However, the implementation of training at each workshop station is less implemented optimally, especially in practicum chair assembly sessions. This condition arises because in practicum chair assembly training still uses conventional methods.

Conventional training methods are training methods provided by experienced trainers and are responsible for transmitting knowledge and skills to trainees, using real machines or components (A Peniche et al., 2012). The use of conventional methods has some drawbacks including high resource requirements when starting out and requires an experienced coach who should always be there whenever there is training. In addition, conventional training methodologies have a limited number of scenarios that can be trained, so tasks of a risky or dangerous nature cannot be trained using this methodology.

This condition is similar to the PPTI 2 which also uses conventional method training with an average of 2 coaches for each workshop station, some activities also require large resources and a limited number of scenarios that can be trained due to time constraints. To improve this situation there needs to be other alternatives in training in PPTI 2. Alternative training using Virtual Reality (VR) technology.

VR is a high-end human-computer interface that allows users to interact with virtual worlds in real time and through many senses (Burdea & Coiffet, 2003). The virtual environment is created by a computer and enables for real-time

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immersive interaction. The quality of the 3D reconstruction, the time between actions and input, and the realistic behavior of the elements, among other things, all contribute to the immersive experience (Pérez et al., 2019). VR has recently been expanded to industry because to its numerous applications (Choi et al., 2015). Scientists and engineers have realized the benefits of VR technology, which has applications in architectural modeling, industrial plant planning, training in equipment maintenance, medicine, and more. As a result, many notable contributions to the development of VR-based systems for assembly operations have been made.

One of the benefits of VR is that it may be utilized for assembly training (Al-Ahmari et al., 2016). Lu et al., (2012) in his research conducted assembly training with VR to assemble a constraint-based aircraft engine. The use of VR in training provides many advantages over using conventional training methods, not only when training is at high risk and cost but also in more general application, as it can reduce training time and resources significantly (Amaury Peniche et al., 2011). The use of VR improves the training process rapidly (Makransky et al., 2019). the use of technology is more effective and results in greater productivity than those who do not use it (Boothby et al., 2010). The adoption of technology in training enables operators to benefit from technological advances and increase work productivity (Sala & Silva, 2013). The use of technology in training will increase productivity if its use is adjusted to conditions and circumstances.

VR design as an alternative to training is done by creating a virtual world that considers aspects consisting of equipment accuracy, can run in real time, and interactive virtual 3D CAD modeling by adding weight and physical properties that make simulations more realistic. Training using VR is expected to increase the effectiveness of training thoroughly in PPTI 2. The concept of VR training is implemented by running a training system at a workshop directly for practice.

II. RESEARCH METHOD

Developing VR system

The VR system was developed using Unreal

Figure 1. Diagram of the VR system development process

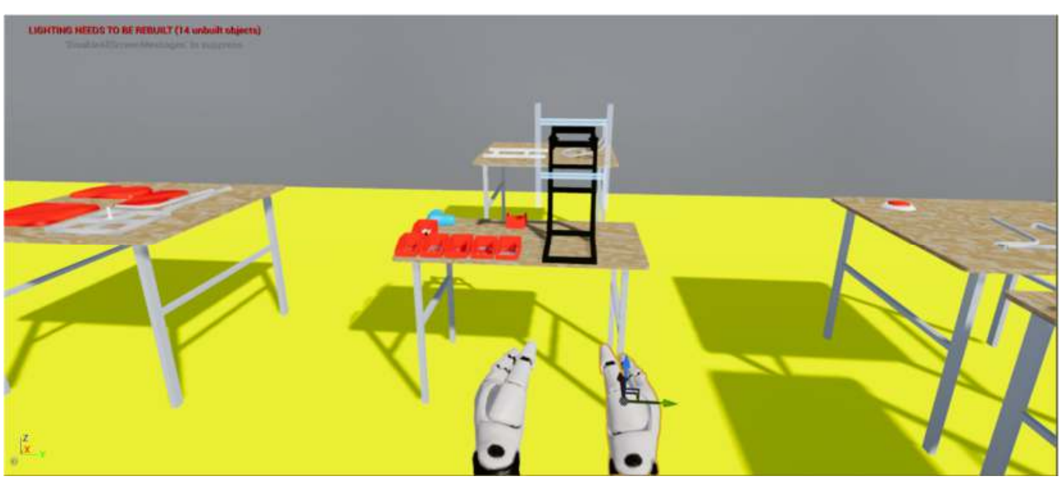

Figure 2. The results of the development of a VR system using Unreal Engine 4 after running using VR HMD

Engine 4, a game engine developed by Epic Games and which uses the C++ programing language or can also use blueprint from Unreal Editor. The creation of a VR system using Unreal Engine 4 has the function to organize all activities that will occur in the practicum chair assembly training simulation and integrate all devices used in practical chair assembly training using VR. Figure 1 describes the sequence of the VR system development process.

The first step of developing a VR system for training is by observing the real environment. after which the creation of a 3d model using Autodesk Inventor and Blender applications. From the 3d model all components of the practicum chair will be formed a virtual environment which is then programmed to create a virtual simulation using Unreal Engine 4 which will then be displayed on the VR Head Mounted Display (HMD) to run the practicum chair assembly training simulation process. The results of the development of a virtual reality system using Unreal Engine 4 can be seen in Figure 2.

Experimental Design

To validate the effectiveness of the use of VR, it is necessary to conduct a series of tests whose arrangements will be described below. All subjects selected come from industrial engineering students who have no experience in assembling practicum chairs. All subjects had an average age of 20.6 which were divided into 2 groups. Group 1 is a control group, training on assembling practicum chairs using conventional methods. Group 2 experimental group, practicum chair assembly training using VR.

At first all subjects perform the process of assembling a practicum chair with real components to determine the initials skill (pretest). Then all subjects did train on assembling a practicum chair (treatment) 7 times, which was adjusted to the groups that were followed. each after once training all subjects perform a practicum chair assembly to find out the reduction in the assembly time of the practicum chair after training (posttest). The chair which is the object of assembly in the practicum has 12 components shown in Figure 3.

The chair assembly consists of 1 sub assembly and 12 assemblies. Assembly of the front backrest on the main frame (A1), backrest cover assembly (A2), H-frame assembly (A3) union jack assembly (A4), round connector assembly (A5), leg frame assembly (A6), L shaped frame assembly (A7), seat assembly (A8), Bottom shelf assembly (A9), end cap assembly (A10) Table arm assembly (A11), sub assemly table plate with table board (SA1), and table assembly on the main frame (A12). The sequence of assembly steps (assembly chart) is shown in Figure 4.

Figure 3. Practicum chair

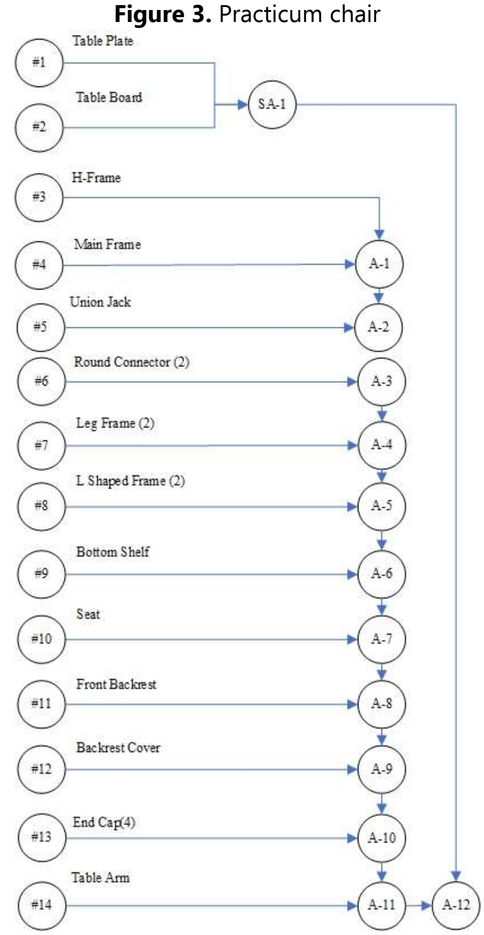

Figure 4. Assembly chart

Figure 5. Training of assembling practicum chairs using conventional method

Figure 6. Training of assembling practicum chairs using VR

III. Result and Discussion

The Results of Testing the Practicum Chair Assembly Training Method

Both groups were tested by taking the time of assembling the practicum chair after previously being trained. The results of testing the practicum chair assembly training using conventional methods and using VR are shown in Table 1 and Table 2.

The results of testing the practicum chair assembly training method using the conventional method obtained an average initial skill time of 1759.8 seconds. The average time for the first assembly after training is 1481 seconds and the average assembly time after 7 trainings is 833.8 seconds.

The results of testing the practicum chair assembly training method using VR obtained an average initial assembly time of 1817.8 seconds. The average time for the first assembly after training is 1395 seconds and the average assembly time after 7 trainings is 684.2 seconds.

Table 1. Conventional method assembly training test results (sec)

	Subject	Initial test	Train 1	Train 2	Train 3	Train 4	Train 5	Train 6	Train 7
Conven-tional	1	2076	1473	1332	1197	1135	1008	911	841
	2	1514	1334	1158	1110	1107	1006	943	823
	3	1722	1535	1384	1229	986	979	922	862
	4	1656	1567	1298	1215	1092	1045	919	812
	5	1831	1496	1316	1183	1121	986	883	831

Table 2. Assembly training test results using VR (sec)

	Subject	Initial test	Train 1	Train 2	Train 3	Train 4	Train 5	Train 6	Train 7
Virtual Reality	1	1801	1220	1154	882	814	705	685	687
	2	1685	1392	1125	1116	786	747	734	692
	3	2026	1564	1022	978	766	626	618	631
	4	1856	1457	1051	973	798	723	720	709
	5	1721	1342	1062	1005	762	682	690	702

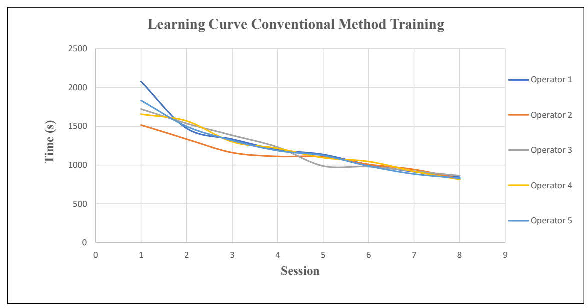

Figure 7. Learning Curve Training Using Conventional Method

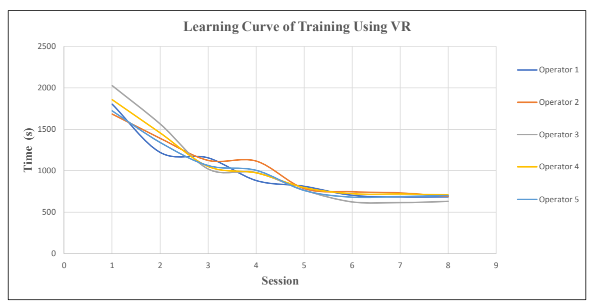

Figure 8. Learning Curve Training Using VR

Comparison of Learning Curve Practicum Chair Assembly Training Method

After all training sessions and data retrieval from the subject are completed, then plot the data to create a learning curve. Figure 7 shows the learning curve of subjects trained using conventional training methods and Figure 8 shows the learning curve of subjects trained using VR.

The experimental group's curves appear to be remarkably similar to the control group's curves at first inspection. Both samples were statistically compared using a independent T-test to see if the virtual reality training method is more effective then traditional methodology.

Independent T-test

The comparison phase of the effectiveness of the lecture chair assembly training using the independent sample t-test was carried out to determine the effect of using the results of the virtual reality system design on the PPTI 2 practicum chair assembly training.

Before the independent sample t-test was conducted, the first step was to test for normality. Normality test was conducted to determine the distribution of the data obtained was normally distributed or not. Normality testing was carried out using the Kolmogorof-Smirnov test method.

The maximum count value is 0.2 while the value in the table with $\alpha = 0.05$ is 0.56, so the value of L count < the value of L table. From the calculation results it can be concluded that the data is normally distributed, as shown in Table 3.

Independent sample t-test was conducted to compare the difference in the mean of the two sample groups with normally distributed data. Testing independent sample t-test using $\alpha = 0.05$ with 95% confidence level. The hypothesis used in the independent sample t-test can be explained as follows:

$H_0 : \mu_1 = \mu_2$, there is no significant difference between practicum chair assembly training using conventional methods and practicum chair assembly training using VR.

$H_1 : \mu_1 \neq \mu_2$, there is a significant difference between practicum chair assembly training using conventional methods and practicum chair assembly training using VR.

The variable that is compared is the time reduction of both samples. The first group with training using the conventional method had an average reduction time of X = 756 seconds. The second group with training using VR had an average time reduction of X = 1121.2 seconds. The conclusion of the hypothesis test is that there is a significant average difference between the two samples in other words the use of VR for practicum chair assembly training is more effective than training using conventional methods. Test results with independent T-Tests shown in Table 4.

Table 3. Normality of Time Reduction data from the results of the practicum chair assembly training

Training methods	L count	L table	Ho	Conclusion
Conventional	0.15	0.56	Accept	Normal
Virtual Reality	0.20	0.56	Accept	Normal

Table 4. Independent Sample T-test Results

Training Method	Average	Standard Deviation	T value α=0.05	
			T count	T table
Conventional	756	218.58	2.934	2.036
VR	1121.2	172.35		

IV. Conclusion

From the initially proposed objectives, and considering the results it is possible to conclude: (1) Interaction devices are critical in virtual reality training systems to attain a high level of immersion, since they allow for a more natural interaction with the system and hence more suitable skill transfer, (2) Highly immersive systems are nearly as successful for training as traditional approaches; as a result, they can replace a significant portion of the training process, removing the majority of the drawbacks associated with traditional methodologies, and (3) The results of the VR system design for practicum chair assembly training can increase the effectiveness of practicum chair assembly training with an average difference in practicum chair assembly time after training using VR by 48.3% faster than training using conventional methods.

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