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The Effect of Exploratory Multimedia Tutorial towards the Learning Outcomes of Electrical Power Generation Based on Students' Spatial Ability Differences

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Abstract

Instructional media will determine the quality of learning outcomes. The effectiveness of multimedia is determined by teaching material's composition and delivery method based on the principles of multimedia design. In addition, the learning outcomes are also determined by the spatial ability of students, especially in learning technologies. This study proved the influence of exploratory multimedia tutorials on the students' competency of electrical power generation for the immediate post-test (I.PT/M.Rc) and the delayed post-test (D.PT/M.Rt), based on their spatial ability differences. Quasi experiments had been conducted by involving the samples of 74 students with 32 high-spatial abilities (H.SA) and 42 low spatial abilities (L.SA). The research proved that there are significant differences between the groups with high-spatial abilities (H.SA) and low spatial ability (L.SA), in which the group (H.SA) is higher than the group (L.SA). Decreasing learning outcomes (M.Rt) from (M.Rc) is also significantly different. The spatial interaction ability conducted in a test setting showed significant differences in the learning outcomes. Learning with exploratory multimedia tutorials is mostly effective for the group (H.SA) on the test (M.Rc) and is not very effective for the group (L.SA) on the test (M.Rt).

Keywords: *electrical power, exploratory multimedia, learning outcomes, spatial ability*.

A. Introduction

Technology and Vocational Education play an important role in preparing the workforce in engineering. For developing countries, the vocational education gets a special attention from the government as an effort to improve people's lives in intermediate level [1];[2];[3];[4]. The vocational education itself aims to produce graduates who are able to work in the field of engineering as a professional as well as a teacher at the vocational schools [5];[6]. The vocational education develops science and provides students with job skills in technology to be prepared for work [2]; [3]; [7].

Indonesia also has the same goal of PTK, but unfortunately the quality of graduates has not fully met stakeholders' standards. This weakness becomes a problem for graduates in the real world of work [8],[9]. Many factors have been causing why the learning process is not optimal, especially in the subject of electrical power generation. The absence of instructional media is one of the causes because the substance is considered as abstract and is conceptually difficult if the student should understand it without using visual media [8];[10];[11];[12]. The absence of the instructional media also causes the learning process to be passive, even boring [13], which further reduces the students' enthusiasm and motivation to learn [14];[15];[16]. The difference in cognitive abilities (prior knowledge) is also the cause of low student learning outcomes [17].

The problems must be overcome in order to improve the learning outcomes as well as to meet the stakeholders' standards of competence. The most appropriate effort is to develop learning by using multimedia. The use of multimedia will help students understand the teaching materials which are conceptual and abstract [18]. Komaro developed a multimedia animation (MMA) and managed to improve students' understanding of the crystal atomic structure in the technological field [19]. Learning with the electricity multimedia simulation model also proved to facilitate students in understanding the teaching materials which are conceptual and abstract [1];[20];[21].

The results of the above studies proved that the use of multimedia can improve learning outcomes. This study aims to assess the effect of using exploratory tutorial learning (ETLn) multimedia on learning

outcomes of students undertaking the subject of Electrical Power Generation, based on their spatial ability differences.

B. Literature Review

Learning outcomes are determined by many factors, one of which is the availability of multimedia learning. Multimedia learning helps students understand the learning materials more easily. Multimedia can visualize the instructional materials which are conceptual and abstract, and simplify complex things become more understandable. Information processing theory [22] became the basis of this study [23];[24]. Cognitive processes in the human brain start of the reception, processing and storage of information, and the calling back of the stored information in the brain [25].

There are two information processing theories which are Store Structure Model by Atkinson and Shiffrin, Level of Processing Model by Craik and Lockhart [26]. According to Baddeley [27] working memory has four main components, namely visuospatial sketchpad, episodic buffer, phonological loop and the central executive. In the context of learning, a person will be able to learn more easily when the materials are delivered in the forms of visual and auditory rather than just the spoken language [28]. This is consistent with the theory of dual-coding by Paivio [29], that individual would be more optimal in receiving instructional materials if it involves both visual and auditory.

Multimedia learning theory can be divided into two levels, namely low level and high level. The low level is related to psychological theories, including memory systems and cognitive processes, while the highest level is related to multimedia design principles, including text, graphics, audio, animation and video [30]. Theories which are relevant to the lower level are dual-coding theory hypothesized by Paivio and memory models proposed by Baddeley. While the theories which are relevant to the high level are Sweller's cognitive load theory and cognitive theory of multimedia learning [27];[29].

Multimedia learning will be effective if it is developed according to the rules of learning, such as cognitive theory of multimedia learning which is a combination of cognitive load theory by Sweller, dual-coding theory by Paivio, and working memory model by Baddeley [31]. The combination of text, picture and audio make multimedia learning not only improves the learning achievements, but also increases enthusiasm, passion and motivation [32]. Mayer described an information processing flow in the cognitive theory of multimedia learning model in the Figure 1.

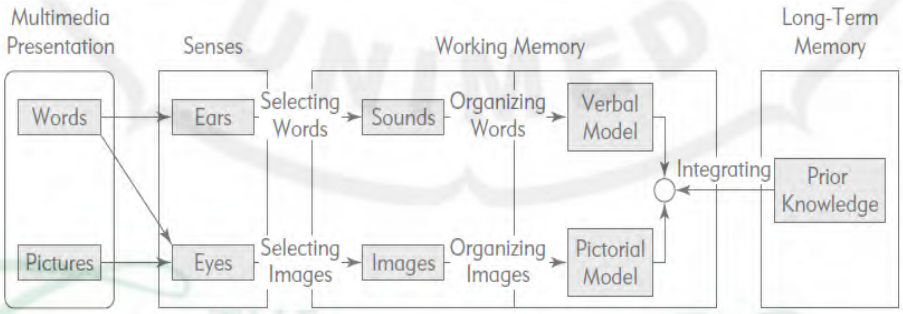

Figure 1. Cognitive theory of multimedia learning

The theory confirms four principles in the process of cognitive science studies which are Dual Channel, Limited capacity, Active processing, and Transfer. Cognitive load theory becomes the basis of the learning process because instructional designs have to consider the cognitive load [18];[33]. The cognitive load on the working memory is caused by three sources: (1) intrinsic cognitive load; (2) extrinsic cognitive load, and (3) German cognitive load [34];[35]. The cognitive load can be reduced in the process of learning with multimedia, developed with the principles of multimedia design [28].

Multimedia is a tool to make the process of learning achieve optimum results. Multimedia containing teaching materials compiled into a module are easy to understand by the students [36]. Multimedia used in this study is Exploratory tutorial learning models [37];[38]. This model applies a principle that the teaching

materials are compiled into a module with the principle of completeness and flexibility for students to access the materials in the link-access to a database as drawn in the Figure 2.

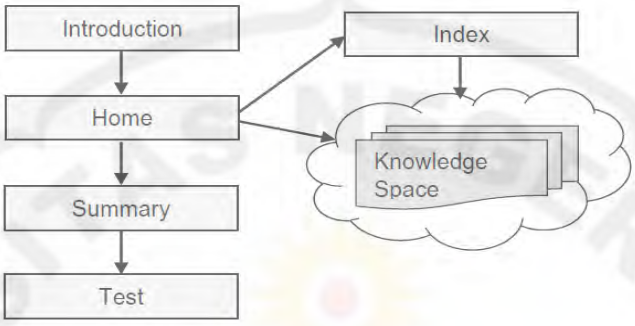

Figure 2. Structure of Exploratory tutorial learning process

The development of courseware multimedia needs to consider the principles of how the cognitive of human's brain work. Mayer stated the 10 principles, namely: (1) Multimedia principle; (2) Split-attention principle; (3) Modality principle; (4) Redundancy principle; (5) Signaling principle; (6) Coherency principle; (7) Spatial contiguity principle; (8) Temporal contiguity principle; (9) Segmenting and pre-training principle; and (10) Personalization principle [28].

In addition to multimedia, another factor that determines the learning outcome is the students' spatial ability. The spatial ability is defined as the ability to manipulate objects in a spatial rotation perspective [39], which is a component of human intelligence in performing the rotation operation, manipulate and construct two- and three-dimensional objects. This ability includes spatial visualization, spatial orientation and spatial relationship. Basic spatial visualization ability can be meant as the ability for making retention process and recalling the configuration rotation and transforming objects in 2D and 3D perspectives [40]. Spatial abilities can be grouped into two categories, which are egocentric or allocentric [41].

The spatial ability is a part of individual difference characteristics that influences the success of multimedia learning [28]. To understand the learning materials of electrical power generation, it requires visual capabilities, manipulation and animation information [1];[6];[42];[43]. The materials of the electrical power generation subject contain concepts involving 3D structures. Therefore, it encourages the student 's ability to understand abstract concepts. To achieve optimum learning results, students must have visual abilities.

Spatial abilities can support students' achievement in the subject of electrical power generation, which is an applied science [1];[6];[44];[45]. Initial ability will also determine the students' academic achievement [36]. Spatial ability was assessed by using the instrument of Purdue Spatial Visualization Test / Test of Rotation (PSVT / ToR) by Bodner and Guay [46]. Spatial ability showed the characteristics of individual differences that influence on multimedia learning.

Learning outcomes are classified in a taxonomy. The study uses Bloom's taxonomy to discuss about the cognitive domain of learning outcomes encompassing six levels, namely (1) knowledge; (2) understanding; (3) application; (4) analysis; (5) synthesis; and (6) assessment [47]. Learning outcomes can be divided into two capabilities, which are memory recalling and memory retention [48];[49]. This study examines the two kinds of learning outcomes. Memory recalling is the ability of students to recall what obtain in the class soon after the learning process (immediate post-test), while the memory retention is the students' ability to do the test after following the learning process for two weeks (delayed post-test) [50]. Both tests are measured by using the same test instrument, but it is different in the order of items and answer options.

C. Methodology

The purpose of the study was to analyze the effect of learning with exploratory multimedia towards learning outcomes in the subject of electric power generation. The independent variable of this research was learning with exploratory multimedia, and the dependent variable was the learning outcomes called as

Memory Recall (M.Rc) as measured by the Immediate Post-Test (I.PT) and Memory Retention (M.Rt) as measured by Delayed Post-Test (D.PT), while the moderating variable was a spatial ability divided into two groups: High Spatial Ability (H.SA) and Low Spatial Ability (L.SA).

The samples were 74 students divided into two groups. Both groups were consisting of H. SA and L.SA, given the same learning materials by using exploratory multimedia. Two weeks before the treatment, a pre-test was carried out. The treatment had been done for 5 meetings / week, and I. PT was conducted after the learning process in each week while D. PT was carried out two weeks after the I.PT. This study used pre-test and post-test models [51];[52] with 2 x 2 factorial experiment design.

The research instruments consisted of multimedia feasibility test, spatial ability test and achievement test. Exploratory multimedia was developed to test the feasibility of alpha and beta with the indicators following the theory of Alessi & Trollip [53]. Achievement test instruments were developed in parallel to measure the results of pre-test and post-test (M.Rc/I.PT) and (M.Rt/D.PT). Pre-test instruments, M.Rc/I.PT and M.Rt/D.PT had the same content, level of difficulty and discriminatory power, but they were different in terms of item and answer option orders. The test instruments were developed by the researcher, and had been tested its validity and reliability, difficulty index and discriminatory power. Related to the spatial ability, it was measured by using an instrument of Purdue Spatial Visualization Test/ToR [46]. The data were analyzed by using descriptive statistics and inferential statistics, i.e. One way ANCOVA [54];[55]. The test was performed using a significance level $\alpha = .05$.

D. Results and Discussion

The treatment has been conducted for 5 weeks by involving 74 students divided into two classes. The results of the achievement test are presented in the Table 1.

Table 1 Description of Learning Outcomes

		Pre-Test	I.PT (M.Rc)	D.PT (M.Rt)
N	Valid	74	74	74
Mean		8.01	33.62	29.88
Median		8.00	34.00	29.00
Mode		8.00	39.00	34.00
Std. Deviation		3.13	5.89	6.00

The Table 1 presented that there is an increase in learning achievement with a mean score of 25.61 in I.PT (M.Rc) compared with the results of Pre-Test, whereas the mean score decreases (3.74) in D.PT (M.Rt) compared with I.PT (M.Rc). This proved that the use of exploratory multimedia learning can improve learning outcomes significantly. This can be seen from the increase of the mean score of 25.61, and in the retention test (D.PT) performed after two weeks it shows the decrease in the mean score of 3.74 compared with the recall test (I.PT).

To prove whether there are differences in learning outcomes of Memory Recall (M.Rc) in the group of students H.SA and L.SA, one-way ANCOVA was performed. Levene's Test of Equality of Error Variances, F=.009; p=.923 has met the test requirements. The results of one-way ANCOVA test by controlling the Pre-Test scores are shown in Table 2.

Table 2 Tests of Between-Subjects Effects

Dependent Variable: Memory Recall (M.Rc/I.PT)

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	4106.64	1	4106.64	250.86	.00
Pre-Test	605.07	1	605.07	36.96	.00
Spatial Ability	86.74	1	86.74	5.30	.02
Total	86186.00	74			

One-way ANCOVA results in the Table 2 (F=5.30; p=.02) presented significant differences of the mean score in the groups of M.Rc, H.SA, and L.SA. It can be concluded that there is a positive impact on learning outcomes of spatial ability (M.Rc), with the significance level α = .05. Therefore, spatial abilities affect the results of the Memory Recall linearly. Furthermore, estimated marginal mean can be seen in Table 3.

Table 3 Estimate of Mean Marginal for M.Rc with Pre-test controlled

Dependent Variable: Memory Recall (M.Rc/I.PT)

Spatial Ability	N	Relative	Mean Estimate with Pre-Test Score controlled			
		Mean	Mean	Std.Error	Lower Bound	Upper Bound
H.SA	32	37.31	35.12	.80	33.52	36.71
L.SA	42	30.81	32.48	.68	31.12	33.84

α=.05

In relative terms, the H.SA mean score is 37.31 and the L.SA mean score is 30.81, but after controlling for pre-test scores there has been a change in the mean score of H.SA, which is 35.12 and the mean score of L.SA which is 32.48. This means that the pre-test provides a greater contribution to the group of L.SA because after controlling for pre-test scores the mean score of H.SA decreases 2.19, while the mean score of L.SA increases 1.67 of the relative mean. It can be concluded that learning with exploratory multimedia give a positive linear effect on learning outcomes of both groups H.SA and L.SA. Differences in the relative mean score of H.SA group which is 6.50 is higher than L.SA group due to the influence of the Pre-Test scores. However, after the Pre-Test Scores have been controlled, the difference is only 2.64.

Furthermore, to test differences in learning outcomes of Memory Retention (M.Rt) in a group of students of H.SA and L.SA, one-way ANCOVA was performed. The results of Levene's Test of Equality of Error Variances have met the test requirements, namely F=.02 and p=.90. The results of one-way ANCOVA test are presented in Table 4.

Table 4 Tests of Between-Subjects Effects

Dependent Variable: Memory Retention (M.Rt/D.PT)

Source	Sum of Squares	df	Mean Square	F	Sig.
Intercept	3065.19	1	3065.19	202.66	.00
Pre-Test	566.98	1	566.98	37.49	.00
Spatial Ability	164.54	1	164.54	10.88	.00
Total	68689.00	74			

Based on the Table 4, it is presented that F=10.88; p=.00 which proves the significant difference of the mean score in learning outcomes (M.Rt) of the group H.SA and L.SA. This means that there is an influence of positive spatial abilities on learning outcomes of Memory Retention (M.Rt) in learning using exploratory multimedia, and the effect is significant at the level α =.05. Thus, it can be concluded that spatial abilities will determine the success of learning linearly. Further, to control the Pre-Test scores, the estimated marginal mean can be seen in Table 5.

Table 5 Estimate of Mean Marginal for M.Rt, with Pre-test controlled

Dependent Variable: Memory Retention (M.Rt/D.PT)

Spatial Ability	N	Relative	Mean Estimate with Pre-Test Score contolled			
		Mean	Mean	Std.Error	Lower Bound	Upper Bound
H.SA	32	34.06	31.94	.77	30.39	33.47
L.SA	42	26.69	28.31	.66	27.00	29.62

The relative mean score of the H.SA group is 34.06 while the L.SA group is 26.69. This proves that the H.SA group have obtained a higher learning achievement than the L.SA group so that it can be concluded that spatial abilities have a positive influence on learning outcomes. Furthermore, after controlling for the pre-test scores, the mean score of the H.SA group is 31.94 and the mean score of L.SA group is 28.31. The H.SA group experiences a decrease in its M.Rt mean with the score of 2.12 compared with the mean relative. On the contrary, the M.Rt mean score of the L.SA group increases, which is 1.62 compared with the relative mean. The difference of the relative mean score of the H.SA group is higher than the L.SA group due to the influence of the pre-test scores. Meanwhile, after controlling the pre-test scores, the difference is only 3.63.

The statistical test has proved that there is a significant difference between the learning achievement of the H.SA and L.SA groups in terms of memory recall (M.Rc) as well as memory retention (M.Rt). The detailed results of the statistical test can be seen in the Table 6.

Table 6 Summary of Learning Outcomes for Spatial Ability Differences

Multimedia Learning	Spatial Ability	N	Pre-Test		I.PT (M.Rc)		D.PT (M.Rt)	
			Mean	Diff*	Mean	Diff*	Mean	Diff*
Exploratory tutorial (ETLn)	H.SA	32	10.00	3.50	37.31	6.50	34.09	6.40
	L.SA	42	6.50		30.81		26.69	
	Total	74	8.01		33.62		29.88	
Differences (Pr.T-I.PT)		:				25.61	:	
Differences (I.PT-D.PT)					:			3.74

**Different (H.SA-L.SA)*

The table 6 shows the summary results of learning using exploratory multimedia. It has been proved that spatial abilities have a significant effect on learning outcomes. The scores of students in the H.SA group are higher than those in the L.SA group. In the pre-test, the difference of the mean score is 3.50; and in I.PT (M.Rc) the difference of the mean scores is 6:50; whereas, in D.PT (M.Rt) the difference is 6.40. This is consistent with the studies conducted by Cheryl, et al. [56]; Sanches & Wiley [44]; Haynie [50]; Black [45]; Sun & Sun [57].

In the immediate post-test (M.Rc), there has been an increase in the mean score of 25.61 for the pre-test's mean score. However, the study results in the delayed post-test (M.Rt) after two weeks of the immediate post-test (M.Rc) show a decrease in the mean score of 3.74. The mean score differences are significant at α =.05 level. These findings coincide with Sun and Sun [57]; Pavlova [6]; Romanas [42]; Wouters[18]; Gilbert [1]; and Komaro [19].

E. Conclusions and Suggestions

Learning using multimedia exploratory has been proven to improve students' learning outcomes. It was found to have an increase in the mean score of 25.61 in memory recall (M.Rc/I.PT) than in the Pre-Test. After two weeks, memory retention test was conducted and it showed a decrease in the mean score (M.Rt/D.PT) of 3.74 than (M.Rc/I.PT). The study also proved that spatial abilities have a positive effect on learning outcomes of both M.Rc and M.Rt. The H.SA group proved to have higher abilities than the L.SA group with the mean differences in the Pre-Test score of 3.50. This result is different from the Immediate Post-Test (M.Rc) which is 6.50 and Delayed Post-Test (M.Rt) which is 6.40. The effect of exploratory learning with multimedia relatively proves greater influences to H.SA, but after controlling the Pre-test scores it was found that the greater impact happened on the L.SA group.

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