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RESEARCH ARTICLE

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Virtual-laboratory based learning to improve students' basic engineering competencies based on their spatial abilities

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Abstract

This study aims to determine the effect of learning in Classic Tutorial Virtual Laboratory (CT-VLab) and Exploratory Tutorial Virtual Laboratory (ET-VLab) on student learning outcomes, that is, Immediate Memories Learning Outcomes (IM-LO) and Delayed Memories learning Outcomes (DM-LO) in essential engineering competencies. Moreover, the moderating role of spatial ability in the form of High Spatial Ability (H-SA) and Low Spatial Ability (L-SA) has been examined to assess the change in students learning outcomes. The study used a quasi-experimental approach with a 4 × 2 factorial design. Purdue Spatial Visualization Test to measure spatial abilities and learning outcomes has been applied using standard test instruments. Moreover, a two-way Manova analysis was performed. The results showed that CT-VLab was as good as ET-VLab in improving IM-LO learning outcomes, but for DM-LO, CT-VLab media was superior in maintaining learning outcomes. In addition, spatial ability showed a linear effect on learning outcomes for IM-LO and DM-LO, both in CT-VLab and ET-VLab learning. Furthermore, results revealed that for the H-SA student group, CT-VLab and ET-VLab are effective for improving IM-LO and DM-LO learning outcomes, but for the L-SA group, it is recommended to use CT-VLab.

KEYWORDS

learning outcomes, spatial ability, virtual laboratory

1 | INTRODUCTION

Technology and Vocational Education in Indonesia play a vital role in transmitting science and technology that prepares graduates to enter the secondary level [54]. However, Indonesia faces the problem of increasing the number of job seekers and open unemployment among the educated workforce. Indonesian Social Insurance Administration Organization (BPJS) data show APAK (Labor Force Participation Rate) from 69.02% in 2017 to 66.53% in 2019, which means that labor absorption is still low [1]. The Indonesian population completed high school education in 2019, amounting to 60.84%. In the last 5 years, the millennial generation has been dominated by the use of social media, 79.13%, and seeking information or news is 65.97%. The open unemployment rate for Vocational High Schools is 8.49%, with the 15–24-year age-group being 16.28%. The coronavirus disease 2019 (COVID-19) pandemic has disrupted the demand for labor because of the projected decline in economic growth. Postponement of employee recruitment until termination of employment is carried out as one of the cost-efficiency efforts undertaken by employers [4].

Moreover, in Indonesia, vocational schools produce secondary workers who face chronic problems due to the low competency of graduates. The problem of low labor competency is inseparable from the low quality of education. Research shows that most tertiary education graduates in the field of vocational technology have not reached the stakeholders' competency standards [40]. In the Industrial Revolution, 4.0, which was laden with developments and demands, caused many workers to be expelled (laid off). They were unable to adapt to the development of existing technology, especially in engineering [3].

Another problem in vocational technology education is the lack of instructional materials and multimedia. This weakness causes professional competence in technology to decrease below the standards required by stakeholders [10, 22]. It is understandable because the vocational technology field contains abstract discussion material, so it requires media for visualization, manipulation, and animation to make it easier to understand [44, 47, 53]. Besides, teaching material is abstract and conceptual and can be easily understood using appropriate media such as video, animation, and simulation [41, 43]. Competencies in Basic Engineering (CBE) involve working on a team, innovative thinking, efficiently managing projects, effectively addressing client and stakeholder needs, and basic business knowledge [35]. These competencies play an essential role in supporting students to achieve professional competence in technology and vocational education. The low competence in this field makes it difficult for students to achieve professional competence in electricity, electronics, and computer engineering [10, 44].

Moreover, basic engineering competencies have an important role in supporting students to achieve professional competence in the fields of technology and vocational education [10]. Basic engineering competencies are competencies that students must possess in vocational and technical education, especially in the Department of Electrical and Computer Engineering [58]. These include practical skills in the fields of basic electricity, basic electronics, and electrical circuits. The limitations of laboratory facilities have led to low basic engineering, so a virtual laboratory is needed as a solution to improve CBE. At the same time, basic engineering is considered very important because low competence in this field makes it difficult for students to achieve professional competence in the fields of electricity, electronics, and computer engineering [42].

Many universities in Indonesia face problems related to the lack of practicum facilities in engineering [49, 58]. Likewise, in the Western region of Indonesia, Medan State University also experienced problems with the lack of facilities for laboratory practice courses, which resulted in not achieving competency in the field of expertise [48]. It has been carrying out remedial learning to overcome this weakness, but the results of learning technology laboratory practices remain low. In addition to the lack of practicum equipment, instructor limitations also lead to ineffective remedial programs. This weakness results in an increase in the study period, and graduates' ability also to below.

To complete the practicum facility requires a substantial fee, and not all universities can complete it. One solution to overcome the limitations of practicum facilities is to develop virtual media for laboratory practicum learning [17, 51]. With a Virtual Laboratory, students can carry out practicums directly with virtual application programs in videos, animations, and simulations that illustrate the actual laboratory practice activities [16, 18]. Another advantage is that learning with virtual multimedia for studios and laboratories can increase learning motivation and learning efficiency [10, 19]. Therefore, virtual multimedia is believed to help overcome the problem of low learning outcomes for courses that require laboratory practice.

An individual's capacity to understand reasons and remember the spatial relations among objects or space is known as their spatial ability [7]. Research shows that spatial ability positively influences individuals' learning outcomes, that is, design studio performance, measured by grades [13]. In addition, several studies reveal that spatial ability determines the quality of students' learning outcomes, that is, creativity, performance, information gathering, intrinsic dynamic skills, knowledge enhancement, and so on, in the areas such as immersive 3D Drawing [28], brain encoding, information technology [34], anatomy education [54], engineering education, and science learning [12], learning engineering mechanics [25]. On that basis, spatial abilities need attention to improve practical learning outcomes and support laboratory equipment. Simultaneously, extending the existing body of literature, this study examines the contingent impact of spatial ability to enhance the students' learning outcomes, that is, Immediate Memories Learning Outcomes (IM-LO) and Delayed Memories Learning Outcomes (DM-LO) in essential engineering competencies. IM-LO and DM_LO are basically learning outcomes (LO). The test instrument used is the same that was developed and has passed the validity, level of difficulty, discriminatory, and reliability tests. It is just that IM-LO is the learning result obtained by students through tests after the learning module is completed, while DM-LO is the learning result obtained by students through tests with a deadline of about 2–3 weeks after the learning module is completed [28]. Therefore, DM-LO not only tests the competence of learning outcomes but also the strength of students' memory after the deadline has passed.

Furthermore, this study focused on the Basic Engineering field, which is a continuation of relevant research in the fields of physics, power generation, and remedial learning of laboratory practicum [10, 48]. Basic engineering competencies are essential for electrical engineering and computer engineering study program students. At the same time, virtual-Lab media is believed to be the solution to overcome the lack of media and equipment to implement laboratory practices and enhance students' thinking abilities [21]. Moreover, in the condition where the actual practice is not possible, the use of Virtual-Lab media is considered appropriate for practical learning. Research also reports an enhanced level of students' interest in the virtual lab during the covid-19 pandemic, resulting in improved performance [26]. Hence, this study aims to reveal the effect of the learning model in the Classic Tutorial Virtual Laboratory (CT-VLab) and Exploratory Tutorial Virtual Laboratory (ET-VLab) on the competencies of Basic Engineering as learning outcomes, including IM-LO and DM-LO based on student spatial abilities, High Spatial Ability (H-SA) and Low Spatial Ability (L-SA).

1.1 | Research objectives and urgencies

Regarding the competency of learning outcomes, the questions are whether the learning model is useful for improving student learning outcomes. What media are used? How are the learning scenarios formed? And what supporting abilities need to be developed to achieve this competency? To answer all these questions, this study aims to develop a virtual multimedia-based learning model in virtual multimedia CT-VLab and ET-VLab to develop and improve students' basic engineering competencies, that is, IM-LO and DM-LO, based on their spatial abilities, that is, H-SA and L-SA. The study findings are expected to bring valuable insights regarding designing virtual labs to develop and improve basic engineering competencies according to students' level of spatial ability.

2 | LITERATURE REVIEW

2.1 | Multimedia-based learning

Multimedia-based learning refers to information processing theory, a derivative of cognitive learning theory. Cognitive processes begin with the reception, processing, and storage of information and recall [46]. Simultaneously, information processing occurs through the interaction of intrinsic factors with extrinsic [23]. Information enters the human cognitive system through the senses of the ear and eyes. Simultaneously, visual information reflects the images and text stored in visual form, and audio information is stored in auditory form for a short period [14]. The addition of visual and auditory elements will cause a cognitive load in visual working memory. The cognitive load consists of intrinsic cognitive load, extrinsic cognitive load, and germane cognitive load [39]. Intrinsic cognitive load can be reduced by using easily understood information, and extrinsic cognitive burden by presenting exciting material using visual, auditory, video, and animation [50]. Extrinsic cognitive load can be reduced by compiling teaching materials systematically, especially in writing formulas and examples of problem-solving. Whereas germane cognitive load must be minimized as far as possible in design and multimedia development so the students can receive information more optimally and make learning more effective [14, 33]. Referring to this multimedia information processing theory of functions to help students more readily accept and understand the subject matter so that learning outcomes, that is, IM-LO and DM-LO, can be improved.

2.2 | Virtual-Lab media

Virtual-Laboratory Media (Virtual-Lab Media) refers to the term Virtual Laboratory, a laboratory model containing interactive multimedia computer software for simulating laboratory experiments, as is the case for using equipment in actual laboratories [19]. Virtual-Lab can simulate the actual practicum work in physical laboratories by using artificial simulations based on computer program applications [51]. Thus, Virtual Lab is defined as an artificial laboratory media in a virtual form using a computer program that can simulate various practical activities in actual laboratory practice. Simultaneously, research shows the significance of laboratories as an integral part of engineering education, resulting in a multitude of studies [36].

Virtual-Lab has many advantages, including being more engaging, interactive, efficient, and useful. It enables students to carry out laboratory activities in all places, not bound by time. They can be cost-efficient, simple, easy to use, and can be done repeatedly without requiring repetitive materials and equipment. Under certain conditions, Virtual-Lab-based learning is more effective than learning in actual laboratories because it can present abstract simulations that cannot be obtained in actual laboratories [5,6]. Several studies have shown that learning using virtual-lab has proven effective in improving laboratory learning outcomes [57]. Besides that, Virtual-Lab can increase motivation, creative thinking, problem-solving thinking, and creativity [10, 19]. With this basis, it is appropriate to develop a virtual media lab as a solution to improve learning outcomes under conditions of limitations to carry out an actual practicum. The use of Virtual Laboratory in teaching solves the usual educational problem of visualization in two- and three-dimensions [20].

The development of Virtual-Lab media must follow applicable rules [33]. In this study, Virtual-Lab media was developed in two types: Classic-tutorial and Exploratory tutorials [27, 52]. Media form CT-VLab is a learning media developed according to the rules of laboratory tutorial learning. The presentation of teaching materials is sequentially and hierarchically, starting from the objectives, presentation of teaching materials and examples, simulations, and evaluations. Practical material is compiled from easy to difficult and from concept to application. At the same time, the form of ET-VLab media was developed according to the rules of a parallel tutorial. In which the teaching materials in groups or classifications or without classifications can be freely accessed [27, 52]. Both the CT-VLab and ET-VLab media were developed with the same content of teaching materials in terms of scope, level of difficulty, and questions and assignments. The only difference is the presentation of CT-VLab in series while ET-VLab in parallel.

2.3 | Spatial ability

Spatial ability is the ability to manipulate objects in several spatial perspective rotations [9, 34]. Spatial ability is also interpreted as a component of one's intelligence in performing operations rotating and manipulating 2-D and 3-D objects, including spatial visualization, spatial orientation, and spatial relationships. This ability becomes the basis for visualizing the thought process that determines the process of recalling information (memory recall) and memory retention through visual manipulation, rotation configuration, and object transformation. Simultaneously, the determination of spatial ability level is based on test results using the Purdue Spatial Visualization Test instrument [9]. The total ideal score is 100, and the ideal mean is $100/2 = 50$. Where the score <50 presents the L-SA group and the score >50 presents the H-SA group. In engineering, the spatial ability is needed to rotate and analyze an object in several dimensions through visual media [55, 56]. Several factors determine the success of learning using multimedia, and spatial ability is one of them. Therefore, spatial ability becomes an ability that determines the success of learning in multimedia-based engineering.

2.4 | Learning outcomes

Learning outcomes can be divided into several taxonomies, one of which is Bloom's taxonomy, which divides into three domains: (1) Cognitive, Affective, and Psychomotor [8]. The cognitive domain consists of six levels, namely: (1) knowledge, (2) comprehension, (3) application, (4) analysis, (5) synthesis, and (6) evaluation. Bloom's cognitive domain received a response from education experts. It produced a development version of the dimensions of knowledge and dimensions of cognitive processes with changes to Remember, Understand, Apply, Analyze, Evaluate, and Create [2]. Learning outcomes in this study use the cognitive domain [2] with higher order thinking skills (HOTS), namely, application, analysis, evaluation, and creation.

The learning outcomes in this study use Bloom's cognitive domain, divided into two groups, namely, immediate memory, direct memory, and delayed memory [45]. Immediate memory is achieved through the posttest conducted when the learning process is finished. In contrast, the delayed memory capability is achieved through the posttest with a delay of 3 weeks after the learning process is finished. A 3-week delay is considered to affect one's ability to remember significance. The strength of student memory is expressed by the small decrease in the ability score after a certain period (delayed memory) from the previous ability (immediate memory).

The subject of this research study focused on the primary fields of engineering (basic engineering) that are abstract and conceptual, and difficult to understand for students, namely, atomic theory, active components of electronics, and electrical load circuits [48]. Basic technical competencies are needed as a basis for students to study and improve professional competency in the fields of electricity, electronics, and computer engineering [49]. This research expects to strengthen the superiority of Virtual-Lab media to help students more easily understand teaching materials and eventually be able to improve their learning outcomes.

3 | METHODOLOGY

3.1 | Research variables and design

This study has three variables. The learning model as an Independent Variable consists of learning based on CT-VLab and learning based on ET-VLab. The second variable is Spatial Ability as a moderator variable, consisting of two groups: H-SA and L-SA. At the same time, Dependent Variables are learning outcomes consisting of IM-LO and DM-LO. IM-LO is the learning outcome obtained by students shortly after the learning process is completed, while the DM-LO is obtained after one cycle 3 weeks after the learning process is finished. The study used a quasi-experimental design with a factorial design of 4×2 [15].

3.2 | Research respondents

This research was conducted at the State University of Medan, Indonesia, in the Electrical Engineering Education study program and Information and Computer Technology Education. Research respondents are first-year students who take the Basic Engineering course, which consists of two groups based on the learning media used, namely, CT-VLab and ET-VLab. The sample of 122 students was randomly determined; 64 students came from the CT-VLab group and 58 from the ET-VLab group. Respondents in each learning group differed based on the level of spatial ability, namely, H-SA and L-SA, so the study sample consisted entirely of four groups. The Virtual-Lab media-based learning process groups were guided via tutorial self-learning scenarios in CT-VLab and ET-VLab.

3.3 | Instruments and data analysis techniques

There are two research instruments: the learning achievement test instrument and the instrument to measure spatial ability. The learning achievement test instrument uses items of standard cognitive domains on

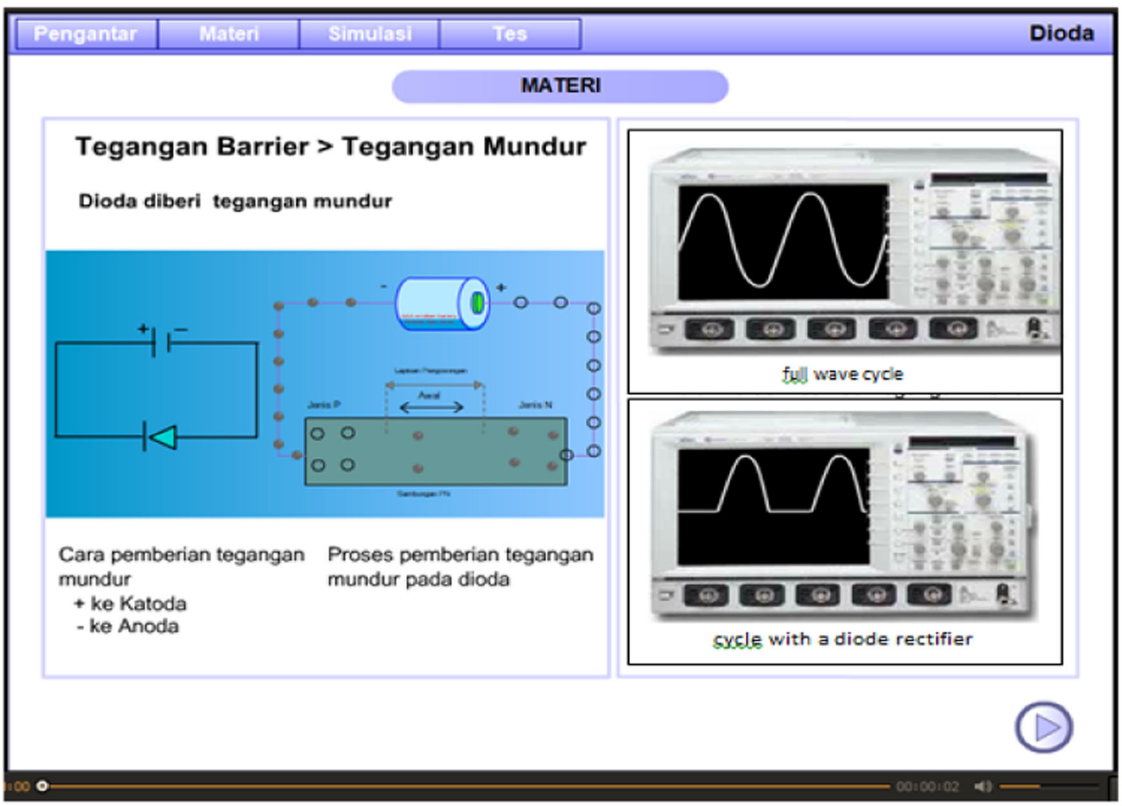

FIGURE 1 Diode virtual-lab displays

higher thinking abilities [2]. There are two learning outcomes test packages arranged in parallel: to measure IM-LO and DM-LO, which state the strength of students' memory. The examination time interval between IM and DM is set at 3 weeks [56]. Meanwhile, to determine students' level of spatial ability, a standard instrument Purdue Spatial Visualization Test, was used [9].

4 | RESULTS AND DISCUSSION

4.1 | Results

Learning content for learning in Virtual-Lab media includes electronics circuits, the load of direct current, and alternating current. An example of the Virtual-Lab display is shown in Figures 1 and 2.

The Virtual-Lab media-based learning process is carried out independently by students through web learning with guided tutorial self-learning scenarios, namely, CT-VLab and ET-VLab. Student learning outcomes, both IM-LO and DM-LO, are described in each learning group. The results showed that the CT-VLab-based learning group H-SA got the highest average learning outcomes for IM-LO and DM-LO compared with L-SA group students. It indicated the spatial ability of the linear effect on student learning outcomes in virtual laboratory-based learning. Similarly, ET-VLab media learning proved spatial ability, determining student learning outcomes for both IM-LO and DM-LO. Complete data on the results of statistical processing are shown in Table 2.

Table 1 states that overall learning outcomes for IM-LO (mean score: 37.33) are higher than DM-LO (mean score: 33.53). Overall, student groups' learning outcomes

TABLE 1 Factorial design research

		Learning outcomes	
	Spatial ability	IM-LO	DM-LO
Virtual-Lab			
CT-VLab	H-SA	xx.xx	xx.xx
	L-SA	xx.xx	xx.xx
ET-VLab	H-SA	xx.xx	xx.xx
	L-SA	xx.xx	xx.xx

Abbreviations: CT-VLab, Classic Tutorial Virtual Laboratory; DM-LO, Delayed Memories learning Outcomes; ET-VLab, Exploratory Tutorial Virtual Laboratory; H-SA, High Spatial Ability; IM-LO, Immediate Memories Learning Outcomes; L-SA, Low Spatial Ability.

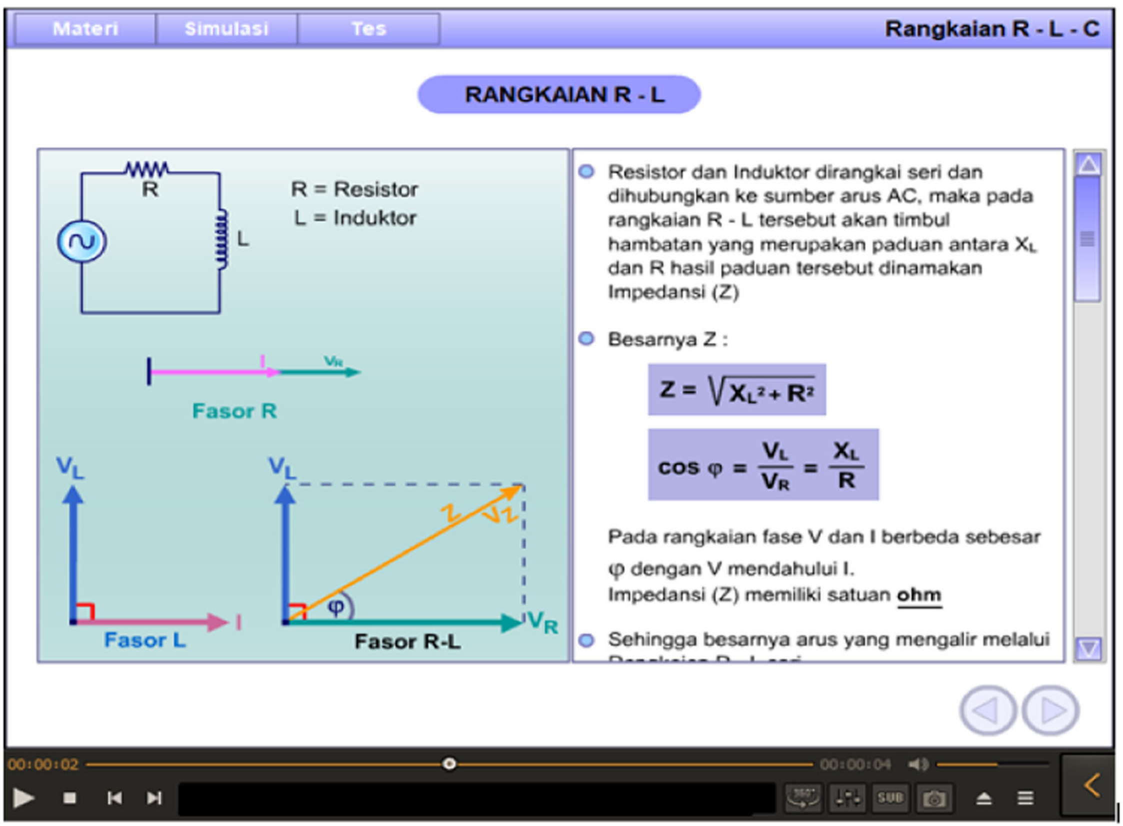

FIGURE 2 Simulation of R, L, and C used virtual-lab

using CT-VLab get a mean score of 37.87 and ET-VLab group 36.74 on IM-LO. In DM-LO, the CT-VLab group got a mean score of 35.81 and the ET-VLab group 31.01. It means that student learning outcomes using CT-VLab media are higher than ET-VLab media groups for both IM-LO and DM-LO. Likewise, the comparison of student learning outcomes based on the level of spatial ability is directly proportional to the achievement of learning outcomes. A statistical test was conducted to examine the significance of differences in learning outcomes based on each cell of the Virtual-Lab tutorial model and the spatial ability for IM-LO and DM-LO, namely, two-way analysis of variance (ANOVA).

TABLE 2 Descriptive statistics on learning results based on virtual-lab media and spatial ability

Learning outcomes	Virtual-lab media	Spatial ability	Mean	Std. deviation	*N*
IM-LO	CT-VLab	H-SA	38.42	3.51	38
		L-SA	37.07	2.85	26
		Total	37.87	3.30	64
	ET-VLab	H-SA	37.45	4.27	35
		L-SA	35.65	2.96	23
		Total	36.74	3.88	58
	Total	H-SA	37.95	3.89	73
		L-SA	36.40	2.96	49
		Total	37.33	3.62	122
DM-LO	CT-VLab	H-SA	37.60	3.41	38
		L-SA	33.19	3.83	26
		Total	35.81	4.17	64
	ET-VLab	H-SA	33.37	4.08	35
		L-SA	27.43	3.41	23
		Total	31.01	4.79	58
	Total	H-SA	35.57	4.28	73
		L-SA	30.49	4.62	49
		Total	33.53	5.07	122

Abbreviations: CT-VLab, Classic Tutorial Virtual Laboratory; ET-VLab, Exploratory Tutorial Virtual Laboratory; DM-LO, Delayed Memories learning Outcomes; IM-LO, Immediate Memories Learning Outcomes.

All data groups are normally distributed, and the Box's Test of Equality of Covariance Matrices (by SPSS) shows a significance of $p > .05$ to meet the hypothesis test requirements. Moreover, a summary of the multivariate test results is shown in Table 3.

The equality test shows significance for both dependent variables, as shown in Table 4.

In statistics, Levene's test has been used as inferential statistics to examine the differences in the equality of the constructs' variances in two or more groups [30]. Hence, if the results of two or more groups depict the similarity of variance between the groups, then the null hypothesis is rejected. In connection to that, the results of testing the dependent variable both show similarity invariance ($p > .05$) to meet the requirements for hypothesis testing. From processing statistical data using factorial 4×2, the test results' statistical value is shown in Table 5.

In tests of between-subjects effects, each term in the model, plus the model as a whole, is tested for its ability to account for variation in the dependent variable Hypothesis testing can be performed after fulfilling the test requirements and data processing results presented in Tables 2–5. As presented in Table 5, the results revealed the significant impact of virtual-lab media on IM-LO and DM-LO ($p < .05$). Also, the impact of spatial ability is significant on both IM-LO and DM-LO ($p < .05$). In addition, the interactive effect of virtual-lab media and H-SA is significant on IM-LO and DM-LO, that is, ($p < .05$). In contrast, the interactive effect of virtual lab media and L-SA on IM-LO and DM-LO is insignificant ($p > .05$). It further reflects the importance of H-SA in developing and enhancing the students' memory outcomes in virtual lab settings. Moreover, there are 13 hypotheses proposed in this study, with the results summarized in Table 6.

A multivariate analysis of variance (MANOVA) analysis presents the impact of two factors or a group of two factors (independent variables) on dependent constructs. It further reflects all the categories of each dependent factor group. In the context of this study, comparative test results of learning outcomes were based on periods (Hypothesis 1). The test results give the decision to reject Ho, which means there are differences in the learning outcomes of IM-LO with DM-LO. Student learning outcomes tested after the learning process get an

TABLE 3 Summary of multivariate tests

Effect		Value	*F*	Hypo. *df*	Error *df*	Sig.
Intercept	Pillai's Trace	0.991	6.43E3[a]	2	117	.000[a]
Spatial_Ab	Pillai's Trace	0.447	47.36[a]	2	117	.000[a]
VL_Media × SA	Pillai's Trace	0.017	1.03[a]	2	117	.360

average score of 37.33, while the learning outcomes after the next 3 weeks are 33.53. This finding proves IM-LO is higher than DM-LO, which indicates a score reduction of 3.80 after 3 weeks from the first test. Thus, the Virtual-Lab media developed could inhibit the rate of memory loss to 10.17% within 3 weeks. It can be linked with the previous studies in various contexts; for instance, Othman & Lua [38] reported a 19.4% decrease in delayed memory after a 20-min gap of immediate memory among schizophrenia patients. It further reflects.

In contrast to previous findings, Larson et al. [31] compared learning using Video Games and Reading media with an unusual finding that memory recall in delayed memory reading media groups decreased by 22.32% but conversely in groups using video games media increased by 1.46% of immediate memory. From this discussion, a conclusion drawn was that memories would generally decrease over time. However, in particular content, these reductions can be overcome or even enhanced through video games, especially in content involving the affective domain. The use of visual media (reading media) decreases memory even higher, reaching 22.32% [31].

A comparison of learning outcomes based on periods on Classic Virtual-Lab Media (Hypothesis 2) proved significant differences between the two groups. In the group of students who used CT-VLab media, the average score was 37.87 in the IM-LO and 35.81 in the DM-LO. It proves that IM-LO is higher than DM-LO, with a score difference of 5.43% after 3 weeks. The same comparison in Exploratory Virtual-Lab (Hypothesis 3) also applies, where the average score at IM-LO is 36.74 and on DM-LO is 31.02. These results revealed that student learning outcomes decreased by 15.57% in the DM-LO from the IM-LO learning outcomes 3 weeks earlier. This fact proves that the Classic Virtual Laboratory (CT-VLab) media is superior to the Exploratory Virtual Laboratory (ET-VLab) media in maintaining student memory in learning basic engineering. These results are in line with Sriadhi's research, which states that the Classic Tutorial media is superior to Exploratory Tutorial media. The strength is the sequence of instructional materials intended hierarchically according to the development of students' thinking abilities in the learning process. The same was also stated by Horton [27], Thomas [52], and Othman & Lua [38].

A comparison of learning outcomes based on the type of media (Hypothesis 4) shows no difference between groups of students using CT-VLab and ET-VLab for immediate memory learning outcomes. Although the two different learning outcomes, IM (CT-VL) with a mean score of 37.87 and IM (ET-VL) at 36.74, the difference is not significant, so the learning outcomes of the two groups are stated equally well to achieve IM-LO. That is, CT-VLab media is as good as ET-VLab media in achieving IM-LO learning outcomes. Nevertheless, this is not the case for learning outcomes of DM-LO memory strength as the test results (Hypothesis 5), where groups of students using CT-VLab media get a mean score of

TABLE 4 Levene's test of equality of error variances

	F	df1	df2	Sig.
Immediate LO	1.654	3	118	.181
Delayed LO	0.531	3	118	.662

Abbreviation: LO, learning outcome.

TABLE 5 Summary of between-subjects effects test

Source	Dependent variable	Type III sum of squares	*df*	Mean square	*F*	Sig.
Intercept	Immediate LO	161401.804	1	161401.804	1.293	.000
	Delayed LO	126579.939	1	126579.939	9.215	.000
Virtual-Lab Media	Immediate LO	41.700	1	41.700	23.341	.050
	Delayed LO	729.587	1	729.587	53.112	.000
Spatial Ability	Immediate LO	72.477	1	72.477	5.806	.018
	Delayed LO	782.844	1	782.844	56.989	.000
Virtual-Lab media × High Spatial Ability	Immediate LO	1.552	1	83.623	42.145	.000
	Delayed LO	16.968	1	61.192	33.235	.004
Virtual-Lab media × Low Spatial Ability	Immediate LO	1.552	1	1.552	0.124	.725
	Delayed LO	16.968	1	16.968	1.235	.269

Abbreviation: LO, learning outcome.

TABLE 6 Summary of hypothesis test results with two-way MANOVA

No	Hypothesis zero	Test result		Decision
1	IM(VL. Media) = DM(VL. Media)	IM (VL. Media)	37.33	Ho rejected
		DM (VL. Media)	33.53	
		$F(1,117)$	49.50	
		p	.00	
2	IM(CT-VL) = DM(CT-VL)	IM (CT-VL)	37.87	Ho rejected
		DM (CT-VL)	35.81	
		$F(1,118)$	49.50	
		p	.00	
3	IM(ET-VL) = DM(ET-VL)	IM (ET-VL)	36.74	Ho rejected
		DM (ET-VL)	31.02	
		$F(1,118)$	49.50	
		p	.00	
4	IM(CT-VL) = IM(ET-VL)	IM (CT-VL)	37.87	Ho accepted
		IM (ET-VL)	36.74	
		$F(1,118)$	49.50	
		p	.07	
5	DM(CT-VL) = DM(ET-VL)	DM (CT-VL)	35.83	Ho rejected
		DM (ET-VL)	33.53	
		$F(1,118)$	53.11	
		p	.00	
6	IM(H-SA) = IM(L-SA)	IM (H-SA)	37.95	Ho rejected
		IM (L-SA)	36.40	
		$F(1,117)$	5.08	
		p	.00	
7	IM(CT-VL)(H-SA)=IM(CT-VL)(L-SA)	IM (CT-VL)(H-SA)	38.42	Ho rejected
		IM (CT-VL)(L-SA)	36.07	
		$F(1,118)$	5.08	
		p	.01	
8	IM(ET-VL)(H-SA)=IM(ET-VL)(L-SA)	IM (ET-VL)(H-SA)	37.45	Ho rejected
		IM (ET-VL)(L-SA)	36.65	
		$F(1,118)$	5.08	
		p	.01	
9	DM(H-SA) = DM(L-SA)	DM (H-SA)	37.60	Ho rejected
		DM (L-SA)	33.19	
		$F(1,117)$	56.98	
		p	.00	
10	DM(CT-VL)(H-SA)=DM(CT-VL)(L-SA)	DM (CT-VL) (H-SA)	38.42	Ho rejected
		DM (CT-VL)(L-SA)	36.07	
		$F(1,118)$	56.98	
		p	.00	

(Continues)

TABLE 6 (Continued)

No	Hypothesis zero	Test result		Decision
11	DM(ET-VL)(H-SA) = DM(ET-VL)(L-SA)	DM (ET-VL)(H-SA)	33.37	Ho rejected
		DM (ET-VL)(L-SA)	27.43	
		F(1,118)	56.98	
		p	.00	
12	IM (VL. Media) × IM (SA)	F(1,117)	0.12	Ho accepted
		p	.72	
13	DM (VL. Media) × DM (SA)	F(1,117)	1.23	Ho accepted
		p	.26	

Abbreviations: CT-VLab, Classic Tutorial Virtual Laboratory; ET-VLab, Exploratory Tutorial Virtual Laboratory; DM-LO, Delayed Memories learning Outcomes; IM-LO, Immediate Memories Learning Outcomes; MANOVA, multivariate analysis of variance.

35.83 and ET-VLab group 33.53. The difference is statistically significant at $\alpha = .05$, so it can be said that the CT-VLab learning media is superior in maintaining student memory compared with ET-VLab. It is in line with the concept of preparing content in instructional multimedia [43]. The form of virtual laboratory media has also proven its superiority in improving learning outcomes [29, 37, 44].

Regarding spatial abilities, generally, learning outcomes are linearly influenced by spatial abilities (Hypothesis 6). Learning outcomes for IM-LO obtained a mean score of 37.95 for groups of students with the H-SA, while the L-SA group got 36.40. The difference in score of 1.55 was proven significant, so that enough reason to declare spatial ability had a positive effect on IM-LO learning outcomes. The higher the spatial ability of students, the higher the learning outcomes of immediate memory.

Moreover, in terms of virtual laboratory media and spatial ability, immediate memory learning outcomes are higher in students with high spatial abilities (Hypothesis 7). The results of data analysis showed IM (CT-VL) (H-SA) got a mean score of 38.42 while IM (CT-VL) (L-SA) was 36.07. With F (1.118) 5.08 and $p = 0.18$, it is sufficient to declare the spatial ability to determine the achievement of learning outcomes of immediate memory compared with the type of virtual laboratory media used. The same fact also occurs in the use of Exploratory Virtual Laboratory media. Spatial ability is more dominant in determining learning outcomes than virtual media (Hypothesis 8). It is evident from the results of the data analysis that the mean score of IM (ET-VL) (H-SA) is 37.45, while IM (ET-VL) (L-SA) is 36.65. Because the value of $p < .05$, the difference is significant, so it is sufficient to state the learning outcomes of IM-LO groups of students who use ET-VLab are more determined by students' spatial ability. The result is in line with other studies on the dominance of spatial abilities in learning science and technology practicum [24]. This study's results have significantly proven the dominance of spatial abilities on the learning outcomes of immediate memory for practicum virtual laboratories in science and technology and basic engineering in this study.

Spatial abilities still dominate delayed learning outcomes that indicate the strength of student memory after the learning period as a determinant of their success (Hypothesis 9). Statistical data showed that the H-SA group on learning outcomes of delayed memory DM (H-SA) got a mean score of 37.60 while the DM group (L-SA) 33.19. With $p < .05$, it is sufficient to state that the high group's spatial ability is superior in achieving delayed memory learning outcomes to the L-SA group. Likewise, CT-VLab media and spatial ability have a dominant positive influence that determines learning outcomes of delayed memory (Hypothesis 10). The mean score of delayed memory learning outcomes for the DM (CT-VL) (H-SA) group was 38.42, while DM (CT-VL) (L-SA) 36.07, a significant difference. The same thing is evident in the use of exploratory virtual laboratory media (Hypothesis 11) that the DM group (ET-VL) (H-SA) gets a mean score of 33.37 while the DM group (ET-VL) (L-SA) gets 27.43. The difference in learning outcomes is significant ($p < .05$), so it is said that high spatial abilities are more effective in memory learning outcomes compared with L-SA in both groups. It reinforces the results of previous studies such as those conducted by Castro-Alonso & Uttal [11] and Marrero et al. [32].

Of the three hypotheses, namely, Hypotheses 9, 10, and 11, both overall and partially based on the type of virtual media used, groups of high spatial students are superior in achieving DM-LO learning outcomes than the L-SA group. This fact supports the results of research in general that have proven the strong influence of spatial ability on student learning outcomes. The advantages of spatial ability are not only in learning outcomes in practicum technology but also in technical skills, science, and technology [24] and based on gender, working memory, and strategy variables [56].

The interaction of virtual laboratory media types with spatial abilities (Hypothesis 12) is not enough reason to accept them. The statistical test results get an F value (1.117) of 0.124 with $p = .725$. There is no significant interaction between the types of virtual laboratory media used with students' spatial abilities in achieving Immediate Memory learning outcomes. The same results also occurred in the Delayed Memory learning outcomes test, where the statistical test results (Hypothesis 13) obtained an F value (1.117) of 1.235 with $p = .269$. It concluded that there was no significant interaction between types of virtual laboratory media with spatial abilities in achieving results in learning delayed memory. This fact is different from some studies in general, such as Marrero et al. [32]. Learning results in the form of laboratory practicums obtained through virtual experiment activities are to be the main reason that makes the findings in this study different from other research results for actual real laboratory practice.

5 | CONCLUSION

From the research and hypothesis testing results, at least 13 conclusions can be drawn as follows.

1) Student learning outcomes for immediate memory are higher than delayed memory for the entire virtual media used.
2) CT-VLab-based media learning has an advantage in achieving immediate memory learning outcomes over delayed memory, with a decrease of 10.18% in the past 3 weeks.
3) In ET-VLab-based media learning, the results of immediate learning memory are superior to delayed memory, with a decrease of 15.57% after 3 weeks.
4) Immediate memory learning outcomes did not differ in the two groups using CT-VLab media and ET-VLab media.
5) The delayed memory learning result is higher in the CT-VLab-based media learning group than in the ET-VLab media. It means that the CT-VLab media retain memory (ability) based on periods more than the ET-VLab.
6) In general, spatial ability has a linear effect on the achievement of learning outcomes of immediate memory.
7) In CT-VLab-based media learning, immediate memory learning outcomes are strongly influenced by spatial ability. The H-SA group achieves higher immediate memory learning outcomes than the L-SA group in CT-VLab-based media learning.
8) In media-based learning, ET-VLab spatial ability greatly determines student learning outcomes in immediate memory. The H-SA group has higher immediate memory learning outcomes than the L-SA group in ET-VLab-based learning.
9) Generally, learning outcomes in delayed memory differ based on students' spatial ability. The H-SA group has higher learning outcomes than the L-SA group.
10) Learning Outcomes of delayed memory in CT-VLab-based learning differ in two groups of students based on spatial ability. The H-SA group is higher than the L-SA group.
11) Learning Outcomes of delayed memory groups of students with H-SA are superior in CT-VLab media-based learning achievement than student groups with L-SA.
12) There is no interaction between the types of virtual media and students' spatial abilities in the acquisition of immediate memory learning outcomes.
13) Learning outcomes of delayed memory are not determined by the interaction between the types of virtual media used and students' spatial ability.

Based on the research findings, there are three findings of rejection of the hypothesis (Ho); there is no difference in the immediate memory learning outcomes in two virtual media-based learning models, namely, CT-VLab and ET-VLab. Furthermore, there is no interaction between the types of virtual media and students' spatial abilities in the immediate memory and delayed memory learning outcomes. Both learning models based on CT-VLab and ET-VLab have the same superiority in improving immediate memory and delayed memory learning outcomes, but not so in delayed memory learning outcomes, where CT-VLab media are better at maintaining memories in learning outcomes over some time. Therefore, both types of virtual media are equally good in efforts to improve learning outcomes of immediate memory for both groups of spatial abilities, but for delayed memory learning outcomes, groups of students with low spatial abilities should use CT-VLab media to maintain learning outcomes over a more extended period. CT-VLab and ET-VLab effectively improve immediate memory and delayed memory learning outcomes for the high spatial ability student group. Still, for the L-SA group, it is recommended to use CT-VLab.

5.1 | Limitations and future research directions

In addition to several strengths, this study has a few limitations, which can bring valuable insights for educational institutions and practitioners if addressed in the future. The study settings in this study are two different virtual media, that is, CT-VLab and ET-VLab. However, the traditional reading media has been ignored, so in the future, a comparative study can be conducted where students' learning outcomes, that is, IM-LO and DM-LO, can be assessed in the presence of virtual and traditional reading media. Moreover, this study is based on a quantitative methodology utilizing quasi-experimental settings where two different groups are assessed on their learning outcomes and spatial abilities. In contrast, a mixed-method approach can be utilized to conduct interviews among the students to understand better their memory-based learning outcomes, that is, IM-LO and DM-LO, via utilizing various media in the learning process. Finally, this study has assessed the contingent impact of spatial abilities in terms of low and high levels to assess the students' learning outcomes. At the same time, the moderating role of students' gender can be examined to find the predictive differences in their learning outcomes in two different virtual media, that is, CT-VLab and ET-VLab.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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