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Immersive Visualization of Python Coding Using Virtual Reality

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***Abstract*— The main goal of this study is to develop a mobile Virtual Reality (VR) application to conduct basic Python coding skills for university students who are struggling to learn to code. This study employs a quasi-experimental method to examine the difference in the efficiency of VR and traditional learning methods by evaluating the students' performance. Thirty students between 18 to 22 years old participated. The participants were divided into two control groups, in which one group used the conventional python learning method while another implemented the VR application in python learning. Unity 3D was used as the application development tool with Mobile Application Development Lifecycle (MADLC). The developed VR application was employed using Google cardboard to create an immersive VR experience. Usability tests, hypothesis tests, Presence Questionnaires (PQ) and system usability scale (SUS) are used as evaluation tools. Findings illustrated how learning through VR has yielded better performance than the conventional learning method. In hypothesis testing, the VR learning method suggested more effective learning with *t*_statistic value of 4.992, a more considerable value than t_critical=2.76. 73% of the participants rated above 68 out of 100, which indicated high levels of satisfaction with the use of the mobile VR application to learn Python. In short, the VR method is perceived to be useful and convenient to help students learn at any place and time.**

***Keywords*— Education; immersive virtual reality; programming learning; Python coding.**

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I. INTRODUCTION

Learning to code using Python is a struggle for many students enrolled in technology-based courses in universities and institutes [1]-[3]. Globally, coding skills are in high demand, and it is increasingly becoming an essential skill for multiple industries in the 21st century [4]-[7]. According to a 2018 Pew Research Centre survey, since 1990, jobs in science, technology, engineering, and mathematics have grown by 79 percent [8]. They are expected to increase to an additional 13 percent by 2027. The ability to associate and adapt to the solving skills can be enhanced through various teaching and learning techniques suitable to the students [9]-[14]. The idea of creating a virtual reality (VR) environment as a new learning media was formed [15]. Applying mobile VR to language learning is promising because it is affordable, engaging, and less likely to be explored in Malaysia yet, and VR at this stage could be a useful tool for visual communication in a true-to-scale environment [16]-[19].

Virtual reality, also known as Virtual Environment, Artificial Reality, Virtual Worlds, and Artificial Worlds, provides a 3-dimensional interface for displaying and controlling the interactive computer graphic. VR typically refers to a simulated environment creator with the help of high-performance computer technology in which its virtual environment simulation is getting indistinguishable from the real world [20]-[22]. Over the past decade, many researchers have widely studied it in various aspects [23]-[26]. "VR is the biggest brain tool that we have," says Kevin Kelly, founding editor of Wired magazine [27]. An artificial environment created by this emerging technology immerses into many fields, especially education and training [28]-[32]. For instance, VR can be used in medical studies to help the students better understand the structure of the human body or in scientific studies to facilitate the scientist for research analytics [33]-[36].

Based on the statistical analysis done by Emsi, a labor market insight company from January 2016 until February 2017, there were 115,058 software developer recruitments each month. Still, the average monthly hires were only

33,579, which only fills up around 30% of the job posting [37]. The data indicated that the demand for software developers outweighs the supply. To put into context, research by Etherington [38], as shown in Fig. 1, demonstrated the obstacles in learning programming. The study indicated how computer programming is difficult to learn. The findings from the study explained that the motivation of the students in learning programming is affected by the lacking of practical tools to resolve the problems mentioned in the same study [39].

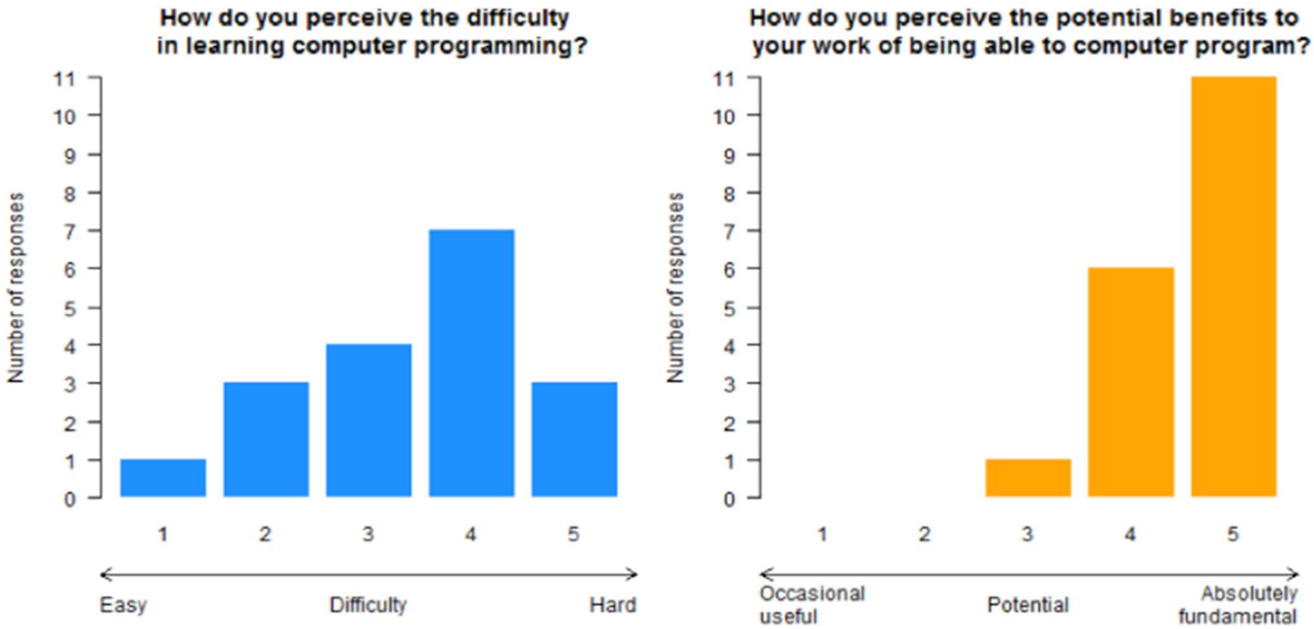

Fig. 1 Results of the perspective of novice towards learning programming [38]

Moreover, Utilizing VR capabilities for software programmers have not been properly examined [40]. According to Bamodu and Ye [41], the three major types of VR are non-immersive, semi-immersive, and immersive. Among the three types of VR, Immersive VR is more user-friendly and economically accessible [42]. An immersive VR system can provide the highest level of immersion in which the user is isolated from the real world, increasing task efficiency [19], [43]-[48]. Still, at the same time, it is the most expensive option among the three systems. The graph in Fig. 2 shows the number of papers in Computer Science related to Head Mounted Device (HMD) education published per country. Although computer science has widely used the HMD in education, most published work originated in the United States. VR in Malaysia education is still promising [49]-[52].

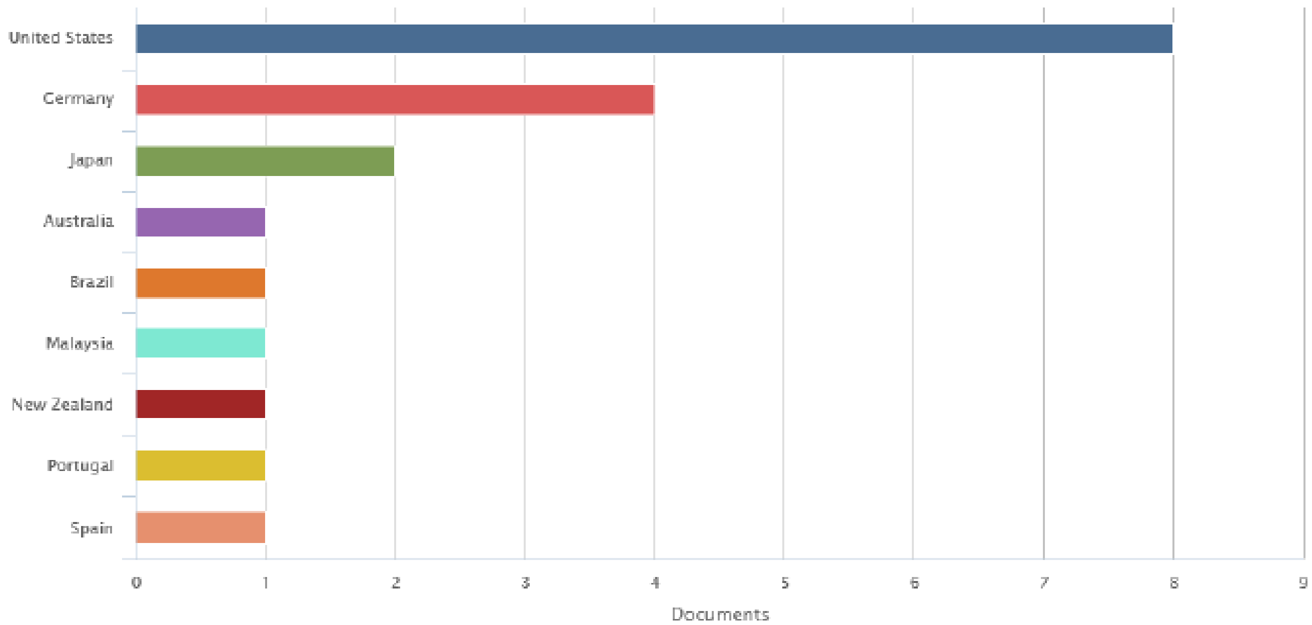

Fig. 2 Number of computer science paper about HMD education published per subject area [42]

VR in education and learning refers to the use of the VR environment to learn academic concepts [19], [45], [53]-[55]. VR technology is said to increase the interest and understanding of students in learning scientific concepts [56]. Vicher (Virtual Chemical Reaction module) developed by the University of Michigan Chemical Engineering Department was used in chemical reaction engineering courses to enhance their education system [57]. The exam scores of the Vicher users were used to analyze the effectiveness of this module. The results indicated that VR could help students visualize situations and concepts. Another study on the interaction effect of immersive VR in the classroom was done. The findings showed that higher improvement scores were obtained by utilizing VR-based learning [58]. Furthermore, a low-cost, scalable, and portable VR learning system for the US Army has been developed. The researcher randomly assigned the participants into control and investigational groups. They accessed learning outcomes from existing questionnaires' pre-test and post-test scores and the VR system usability.

Learning programming through VR has been done [59]. Chandramouli et al. [60] introduced a fun-based VR interaction system to teach engineering students programming concepts. VRML97 was used to model the scene, resulting in lower graphics quality and interaction. The built system was not immersive and did not specify on a programming language. Meanwhile, VR-OCKS is also used as a virtual reality learning game for basic programming concept [61], which is targeted at adults and children use. The system is implemented in HTC VIVE, a relatively expensive mobile VR. Both pieces of research above focused on general programming concepts instead of Python language. Although VR-OCKS is an immersive VR, the users were unable to explore the virtual environment because its static moment is set.

Among the HMDs that are used to view VR content, Google Cardboard is the cheapest and easiest to function. This tool allowed users to experience immersive virtual reality learning with the related apps using their phones. Dascalu et al. [62] agreed that cardboard VR is an affordable tool for immersive learning. There is no difference in immersion level between traditional HMD (Oculus Rift) and mobile-based VR headsets. A comparison between the three famous VR content development tools was made in Table I.

TABLE I
COMPARISON BETWEEN UNITY 3D, UNREAL ENGINE4 AND CRYENGINE.

Development Software	**Unity 3D**	**Unreal Engine 4**	**CryEngine**
Languages Supported	C#, Boo, Unity Script	C++ only	C++, Flash, ActionScript, and Lua
Platform Supported	Support almost all platforms such as Mac OS, Android, iOS, Windows	Support almost all platform	Support major platforms, but mobile support is still under development
Supported Device	Support major HMDs such as Gear VR and Google Cardboard	Support major HMDs	Support major HMDs
Price	Free for the personal version, $35 for the plus version, and $125 for a pro version	Very cost-effective. Free to use, with a 5% royalty on gross product revenue	Free but takes 5% of the revenues generated for each built game (revenue> $5000)
Learning Curve	Flat learning Curve. Suitable for beginners and professionals.	Steep learning curve. It is suited mostly for professionals.	Steep learning curve. Required strong command of related programming language

The comparison results show that Unity 3D is the best option. Unity 3D is also a tool used by Wang [63] to create an immersive environment in their research. A study by Peters et al. [64] proved that Unity 3D is the most cost-effective, sustainable, and flexible tool for developing VR or AR applications.

In summary, there is an increase in studies focusing on learning through virtual reality. However, there is still a dearth of local studies in this field. Few works of literature have tried to utilize the concept of learning programming through VR. Most of the research has limitations as they were non-immersive, where the users could not interact with the 3D simulation environment. Moreover, most of these systems only involved general concepts of programming. Users are unable to learn a specific computing language. Some of the built systems have low graphics quality which can be improved to enhance the learning experience.

To address the gaps discussed above, this study aims to develop an immersive VR system that provides an interactive environment for the participants to learn the program, specifically Python, as it is one of the most demanded languages in 2020 and plays a vital role in data analytics [65-68]. The main goals of this study are as follows:

- To design a virtual reality environment focused on python coding skills for university students.
- To create a virtual reality environment focused on python coding skills for students.
- To evaluate the performance of the virtual reality system after the implementation.

II. MATERIALS AND METHODS

The research design used for this study, shown in Fig. 3, consists of seven phases: a) identification; b) design; c) development; d) prototyping; e) testing; f) deployment and g) maintenance.

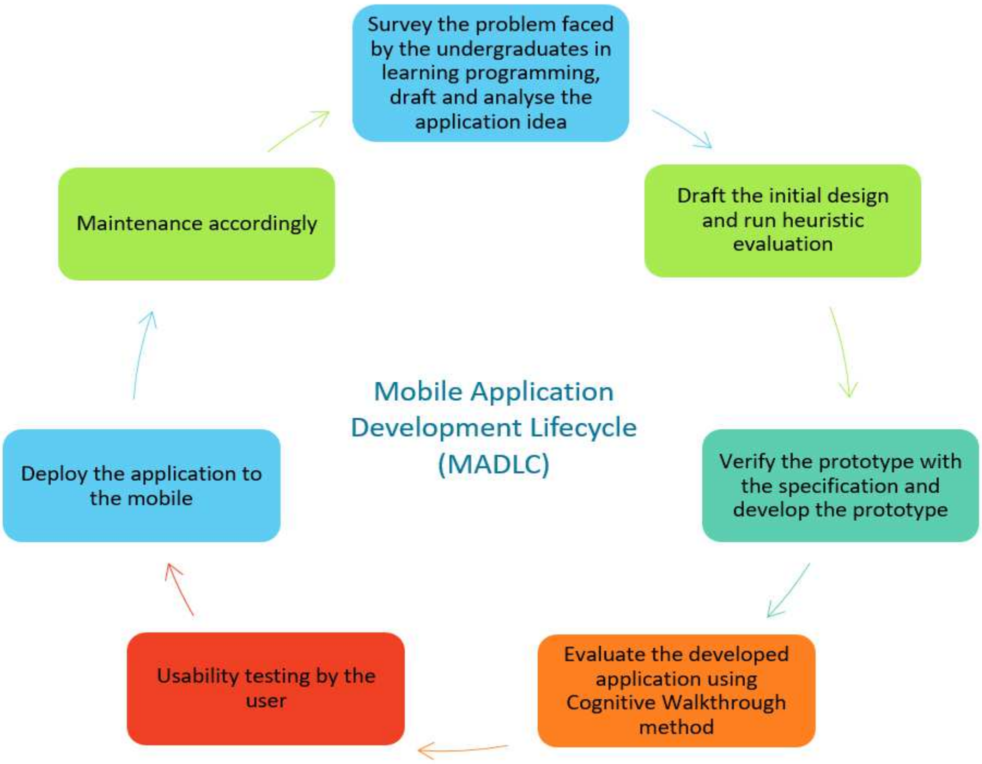

Fig. 3 The research designs

A. Application Development Lifecycle (MADLC)

1) Identification Phase: A survey was administered to a class of Cognitive Science majors who study programming as part of their core subjects. The survey intended to find learning and comprehension problems undergraduates face in learning programming, such as Python. The questions asked in the study are shown below and the results collected are illustrated in the graph in Fig. 4.

- Q1: What is your opinion on programming? (Usefulness)
- Q2: How do you feel when you learn python language in the lab? (Difficulty)
- Q3: How well can you focus, understand, and involved in the lab session?
- Q4: How willing you will try on a new learning technology?

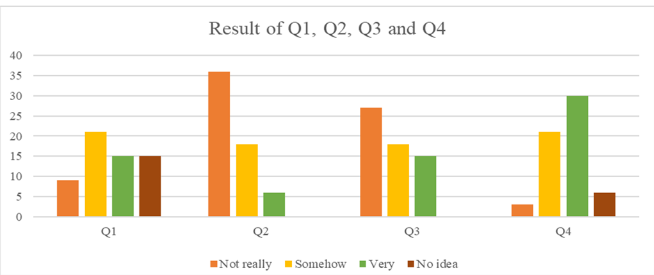

Fig. 4 Results obtained from the survey

80% of the students mentioned that they do not understand the content of lectures in Programming courses, and they generally found the lecture sessions were uneventful. The remaining 20% reported that the practical hands-on component in the course was too complicated to follow. With the information collected from the survey above, an initial idea to develop a VR mobile application learning was mooted. Based on an analysis of product dimensions proposed by [69] (presented in Table II*),* it was determined that the python scopes for the application would encompass four topics which are a) string; b) tuple; c) if-else; d) statement and loops.

TABLE II
SEVEN PRODUCT DIMENSIONS OF APPLICATION.

Product Dimension	**Details**
User	Cognitive Science majors
Interface	3D Visual interface, touch, audio
Action	Moving, triggering, and visual model supplement
Data	Scope of python contents stored in the system
Control	Clickable button, gaze interaction
Environment	In study room
Quality Attribute	Content design guide and evaluation by the expert

2) Design Phase: In the design phase, the first design of the application is sketched based on the idea proposed in the first stage, as shown in Fig. 5. Four rooms have been drafted to allocate four different topics. Learning materials are designed at different locations in each room. Meanwhile, a maze was designed as a tutorial session to allow the participants to practice the programming knowledge they learned in the earlier room. The heuristic evaluation proposed by [70] was done with the expert to evaluate and improve the design. A few concerns were raised in the assessment, such as a) Is the size of the text appropriate?; b) Is the button reasonably to click on?; c) Has the user have reasonable control of the interface?; d) Is the font used easily to read?; e) Are the common words used understandable?; f) Is the color used appropriately?; g) Is the information presented in a logical order without surprise?; h) Is the layout user-friendly?

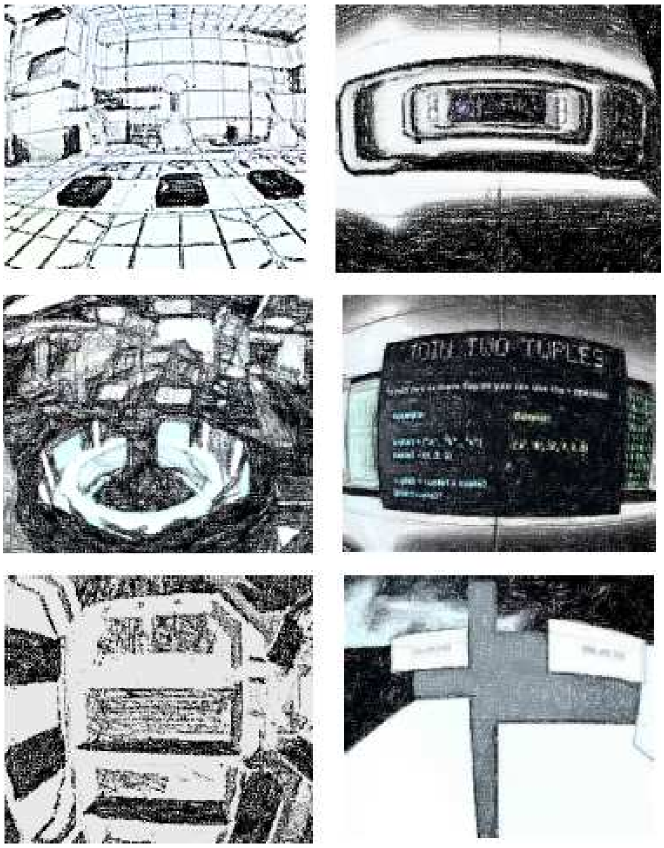

Fig. 5 Draft design of the application

3) Development and Prototyping Phase: The goal of constructing the Mobile VR application was to generate an interactive VR model and VR scene using Unity 3D and program the model into an Android device. The technology stacks used to develop the application are listed below:

- Unity 3D v 2019.2.5f1
- Android Software Development Kit (SDK)
- Native Development Kit (NDK)
- Microsoft Visual Studio 2017
- C-Sharp language

There are several functions included in the application. First, users can randomly explore the virtual environment and trigger the learning material placed in the room by looking down, as shown in Fig. 6 and Fig. 7. Furthermore, users can click the button on the Google Cardboard or the button in the scene to trigger action upon instruction. Fig. 8 shows the clickable button in one of the scenes in this application using gaze interaction. After exploring all rooms containing learning materials, they can enter a maze designed to be the tutorial session of this learning. In the maze, users must choose the correct path based on the answer to the question to escape from the maze and end the learning, as shown in Fig. 9. An expert did cognitive Walkthroughs proposed by Polson, et al. [71] to check the fulfillment of requirement before forwarding to the users.

Fig. 6 Learning material displays after prompts are triggered by users

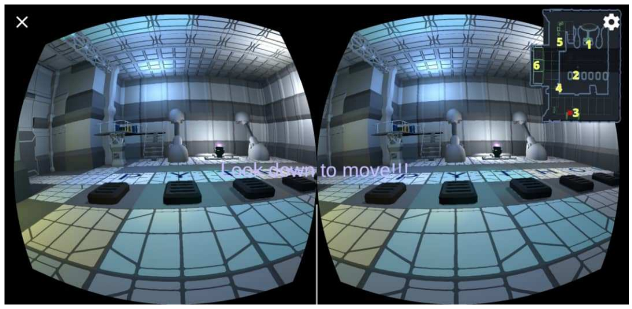

Fig. 7 Hint to instruct users to look down to move in the application

Fig. 8 Using gaze interaction to click buttons

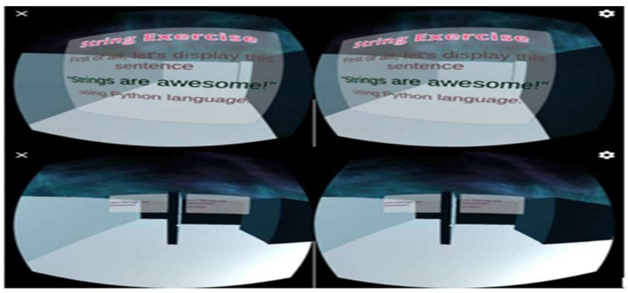

Fig. 9 Question displayed and answered to choose from in the maze.

4) Testing, Deployment, and Maintenance: The application has been tested using usability testing. Below are the tasks given to the user during the unguided test. The time used to complete a task, error detection and ability to complete the task served as the main usability evaluation checkpoint.

- Task 1: Read the welcome notes and enter the first learning room.
- Task 2: Search for the first information in the room.

- Task 3: Trigger all the learning materials in the first room and enter the next scene.
- Task 4: Click the button using gaze interaction.
- Task 5: Finish all the learning processes in the application.

After collecting final feedback from the users, the application has been installed on users' mobile for user consumption. This learning method is targeted to all python coding lab lessons as it is proven efficient. In the meantime, maintenance is the ongoing process that responds, based on the user performance, to develop accordingly.

B. Data Collection Procedures

This study employs a quasi-experimental method to examine the difference in the efficiency of VR and traditional learning methods by evaluating the students' performance. Thirty participants were divided into two control groups, in which one group used the conventional python learning method while another implemented the VR application in python learning. The flow of the data collection procedure is shown in Fig. 10. The data collection procedures started by choosing the targeted respondents and was split into two groups: traditional and VR group. The traditional group uses the traditional tutorial learning style in acquiring knowledge about the scopes of the Python set, as shown in Fig. 11. Likewise, the VR group used the developed VR learning application with HMD for learning, as shown in Fig. 12. The Python learning materials used in the learning method are identical.

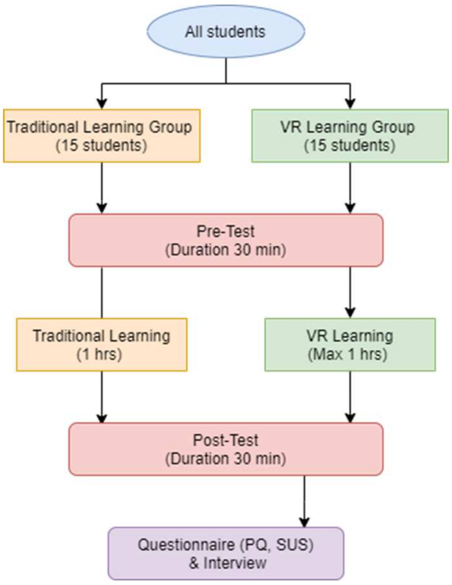

Fig. 10 Flowchart of data collection procedures

The participants are given a pre-test before the learning process to examine their pre-knowledge in python coding and a post-test to evaluate the participants' improvement. Both identical tests are given 30 minutes to answer, and the test paper consists of 40 structural and multiple choices questions. Next, the participants continued with the respective learning method in which the length of the study session was set to one hour as a limit.

Fig. 11 Participants learning session using traditional learning method

Fig. 12 Participants learning how to use VR learning method

Meanwhile, direct observation is implemented during user testing, and questionnaires are distributed to the participants after the application is used. The instrument adopted in this research is the Presence Questionnaires (PQ) by Witmer and Singer [72], which were revised by U.C. Lab [73] to measure the degree of Presence of the user. In addition, System Usability Scale (SUS) questionnaires created by Brooke [74] have been utilized for usability measures. Finally, a series of interviews were conducted with each participant to seek insights, ask in-depth questions, and evaluate their learning pathways from various perspectives.

C. Data Evaluation

Quantitative and Qualitative data analyses are used in this study. The results obtained from the pre-test and post-test for everyone are analyzed to determine whether there is any improvement through the traditional and VR learning experience. The VR learning method's validation showed significantly superior improvement compared to the traditional learning method. Meanwhile, qualitative data is used for quantitative data analysis of triangulation. The qualitative data obtained from the observation and interview methods were used to support the findings.

1) Dependent Sample t-test: Dependent samples t-test or paired samples t-test is used to determine if there is any improvement in the test results before and after learning Python via traditional and VR learning methods. The hypothesis testing is performed in the next four steps.

Step1: Stating the hypotheses

$$\text{Null hypothesis, } h_0: \mu_d = 0$$

$$\text{Alternative hypothesis, } h_1: \mu_d > 0$$

Where μ_d is the pairwise difference between the pre-test and post-test after conducting the learning session.

Step2: Formulating the analysis plan

Typical significance levels are 0.1, 0.05, and 0.01. In this research, the significance level of 0.005 is selected so that the evidence of the samples is strong enough with a confidence of 99.95% to reject the null hypothesis. This can be correlated with the research done [75], where the significance level of 0.005 can increase the study's reproducibility.

Step3: Analyzing the sample data

The t-score can be calculated using the following formula based on the sample data.

$$t_{statistic} = \frac{(\sum_{i=1}^{N} d_i)/N}{\sqrt{\frac{\sum_{i=1}^{N} d_i^2 - \frac{(\sum_{i=1}^{N} d_i)^2}{N}}{(N-1)N}}} \quad (1)$$

Where

d_i is the i[th] difference of the post-test and pre-test.

N is the sample size.

Step4: Interpreting results

Based on t-distribution table with the selected significant level of 0.005, and the $(N-1)$ degree of freedom, the critical value of t-distribution, $t_{critical}$ can be determined.

- If $t_{statistic} > t_{critical}$, the results provide sufficient evidence to reject the null hypothesis. It indicates that there is improvement of the post-test compared to pre-test after conducting the learning through traditional or VR method.
- If $t_{statistic} < t_{critical}$, the results do not provide sufficient evidence to reject the null hypothesis. This indicates that there is no improvement of the post-test compared to pre-test after conducting the learning through traditional or VR method.

2) Independent Sample t-test

Independent samples t-test, or unpaired samples t-test is utilized to determine if the VR learning method has a more significant improvement compared to the traditional learning method. Assumptions applied for the independent samples t-test are as follows:

- Assumption of independence, two independent, categorical groups represent the independent variable. In this research, the independent groups are the traditional and VR learning methods.
- Assumption of normality, the dependent variable, which refers to the improvement of the results based on pre-test and post-test, is assumed to be normally distributed.
- In the assumption of homogeneity of variance, the variances of the dependent variable are assumed to be equal.

The hypothesis testing is performed as follows:

Step1: Stating the hypotheses

Null hypothesis, h_0: $\mu_2 - \mu_1 = 0$

Alternative hypothesis, h_1: $\mu_2 - \mu_1 > 0$

Where μ_1 is the mean of improvement results via traditional learning method, μ_2 is the mean of improvement results via VR learning method. These hypotheses constitute a one-tailed evaluation, as it is to verify whether the VR learning method has a more significant improvement compared to the conventional learning method.

Step2: Formulating the analysis plan

Typical significance levels are 0.1, 0.05, and 0.01. In this research, a significance level of 0.005 is selected. Therefore, the evidence of the samples is strong enough with a confidence of 99.95% to reject the null hypothesis. An independent samples t-test is carried out using the collected data.

Step3: Analyzing the sample data

The t-score can be calculated using the following formula based on the sample data.

$$t_{statistic} = \frac{\bar{X}_2 - \bar{X}_1}{\sqrt{\frac{\left[\sum_{i=1}^{N_1} X_{1,i}^2 - \frac{(\sum_{i=1}^{N_1} X_{1,i})^2}{N_1}\right] + \left[\sum_{i=1}^{N_2} X_{2,i}^2 - \frac{(\sum_{i=1}^{N_2} X_{2,i})^2}{N_2}\right]}{N_1 + N_2 - 2}\left[\frac{1}{N_1} + \frac{1}{N_2}\right]}} \quad (2)$$

Where

$X_{1,i}$ is the i[th] improvement result through the traditional learning method.

$X_{2,i}$ is the i[th] improvement result through the VR learning method.

$\overline{X_1}$ is the sample mean of the improvement results through the traditional learning method.

$\overline{X_2}$ is the sample mean of the improvement results through the VR learning method.

N_1 is the sample size from traditional learning method.

N_2 is the sample size from VR learning method.

Step4: Interpreting results

Based on t-distribution table with the selected significant level of 0.005, and the $(N_1 + N_2 - 2)$ degree of freedom, the critical value of t-distribution, $t_{critical}$ can be determined.

- If $t_{statistic} > t_{critical}$, the results provide sufficient evidence to reject the null hypothesis. The results indicate that the VR learning method has a more significant improvement of the results compared to the traditional learning method.
- If $t_{statistic} < t_{critical}$, the results do not provide sufficient evidence to reject the null hypothesis. The results indicate that the VR learning method has no significant improvement of the results compared to the traditional learning method.

III. Results and Discussion

A. Results of Usability Testing

As mentioned in Section II.A.4, three main concerns were examined in the usability testing phase - time taken to complete a task, error detection, and ability to complete the tasks. The results of usability testing are presented in Table III.

TABLE III
RESULTS OF USABILITY TESTING

Task	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
Read the welcome notes and enter the first learning room	0:30, No error, complete	0:35, No error, Complete	0:22, No error, Complete	0:30, No error, Complete	0:34, No error, Complete
Search for the first information in the room	0:20, No error, Complete	0:33, No error, Complete	0:60, 1 error, Complete	0:38, No error, Complete	0:35, No error, Complete
Triggered all the learning materials in the first room and enter the next scene	7:43, No error, Complete	9:33, 1 error, Not Complete	10:12, No error, Complete	8:30, No error, Complete	9:06, No error, Complete
Click the button using gaze interaction	0:21, No error, Complete	Undefined, 1 error, Not Complete	0:14, No error, Complete	0:26, No error, Complete	0:24, No error, Complete
Finish all the learning processes in the application	44:54, No error, Complete	30:11, 4 errors, Complete,	38:20, 2 errors, Complete	54:06, No error, Complete	52:37, No error, Complete

From the results presented above, the overall outcome is at the optimum level as there is not much error detected and the time used to complete this task is optimum. One error was detected when Participant 3 was performing Task 2 in which he triggered the information in the room in an incorrect order. The findings indicated that he had not noticed the function of the minimap designed in the application before he started to explore the room. However, the problem has been solved after tweaking. A similar error was made by Participant 2 in Task 3. The time taken for the participants to complete Task 2 is all within 40 seconds, except for one participant who made an error. In addition, the time taken to complete Task 3 to Task 5 varied by person since each task required participants to read the assigned learning materials.

The speed of reading would affect their task's completion time. However, in the experiment, Participant 2 was unable to complete Task 4 as he had missed out, triggering the learning material to be displayed. Task 5 encapsulated the participants' overall time to finish the learning process. From the result, all participants had successfully completed the learning, but two participants had performed some mistakes during the process. Comparing the time used to complete task 5 and the error performed in each task, an assumption of the participants is more likely to make mistakes if they finish the learning process in fast pace. Their less completeness may have caused this in exploring the virtual environment in the application.

B. *Results of Proposed Learning Method*

Of the 30 participants, 20 are females and ten males. About 60% know other programming languages, but none in Python. Only 30% of the participants have experience in immersive VR technology, but none have ever tried VR for language learning. The pre-test and post-test results collected from traditional and VR learning methods are presented in Fig. 13 and Fig. 14, respectively.

By substituting the results into the t-score formula stated in Section II.C.1, the $t_{statistic}$ obtained was 8.767 and 8.958, respectively. Meanwhile, Based on t-distribution table with the selected significant level of 0.005 and degree of freedom of 14, the critical value of t-distribution, $t_{critical} = 2.98$. the $t_{statistic}$ (8.767) falls at the right-hand side of the t-distribution graph and is much greater than $t_{critical}$ (2.98). The results provide sufficient evidence with a confidence level of 99.95% to reject the null hypothesis. This indicated the improvement of the post-test compared to the pre-test after conducting the learning through the traditional learning method. The same result was obtained by the VR learning method, which the $t_{statistic}$ (8.958) fall at the right-hand side of the t-distribution graph and is much greater than $t_{critical}$ (2.98). Based on the hypothesis testing, the student has a better understanding of the fundamental knowledge of Python through the VR learning session.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					99.5% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	PostTest - PreTest	4.90000	2.16465	.55891	3.04123	6.75877	8.767	14	.000

Fig 13. Results of pre-test and post-test via traditional learning method

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					99.5% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	VR2 - VR1	12.30000	5.31776	1.37304	7.73369	16.86631	8.958	14	.000

Fig. 14 Results of pre-test and post-test via VR learning method

The proposed VR learning method was validated using the independent samples t-test mentioned in Section II.C.2. The improvement results for learning Python programming via both traditional and VR learning methods are presented in Table IV.

TABLE IV
IMPROVEMENT RESULTS FOR BOTH TRADITIONAL AND VR LEARNING METHOD.

Sample	Improvement via traditional learning, X_1	X_1^2	Improvement via VR learning, X_2	X_2^2
1	3	9	12	144
2	4	16	12.5	156.25
3	7	49	7	49
4	4.5	20.25	0	0
5	2.5	6.25	10	100
6	5	25	13	169
7	4	16	19	361
8	4	16	16.5	272.25
9	1	1	17	289
10	8	64	9	81
11	6	36	11	121
12	9.5	90.25	22.5	506.25
13	5	25	12	144
14	6	36	9.5	90.25
15	4	16	13.5	182.25
Total	73.5	425.75	184.5	2665.25

By substituting the results into the formula stated in Section II.C.2, the $t_{statistic}$ obtained was 4.992. Based on t-distribution table with the selected significant level of 0.005, and degree of freedom of 28, the critical value of t-distribution, $t_{critical} = 2.76$. the $t_{statistic}$ (4.992) falls at the right-hand side of the t-distribution graph and is much greater than $t_{critical}$ (2.76). The results provide sufficient evidence with a confidence level of 99.95% to reject the null hypothesis. This indicated that the VR learning method has a more significant improvement in the results compared to the traditional learning method.

From the analysis of the results presented above, it can be concluded that VR learning method is better than the traditional learning method in terms of students' performance. VR learning can increase the interest and curiosity of the students to attempt to understand the lecture content through exploring the new environment. Students can be easily distracted from the lecture content in the lecture hall, but they are less distracted in VR learning because they have been immersed in the virtual environment. In addition, the 3D simulating lecture content is more attractive than the wording on the whiteboard or slides reported by the participants.

C. *Results of Questionnaires*

PQ was conducted to evaluate the degree of Presence of the participants while using the application. The mean and standard deviation score for each criterion of the PQ is presented in Table V. The results showed that the proposed application has a high performance in terms of realism, possibility to act and examine, quality of interface and self-evaluation of performance. The sound effect is also satisfactory in the application.

TABLE V
MEAN AND STANDARD DEVIATION FOR EACH CRITERION OF PRESENCE QUESTIONNAIRE

Criterion	Mean	Standard Deviation
Realism	40.800	5.256
Possibility to act	23.533	2.941
Quality of interface	13.400	4.484
Possibility to examine	17.600	2.274
Self-evaluation of performance	11.533	2.334
Sounds	17.933	2.380

This study utilized the Cronbach alpha employed by Juan, et al. [76] and Tcha-Tokey, et al. [77] to evaluate the consistency and reliability of the questionnaire. The calculated Cronbach alpha is 0.909, which shows that the instrument used is highly reliable. The majority think that the virtual environment looks realistic but few of them think that it cannot compare with the traditional learning method because they cannot ask questions, and there is no physical interaction between the lecturer and the students. Most of the participants' feedback in self-evaluation is that the interactive description and examples in the application provide a better understanding of the python content.

Furthermore, SUS was conducted to evaluate the system usability scale of the application rated by the participants. The score classification is presented in Table VI, and the results are illustrated in the pie chart in Fig. 15.

TABLE VI
GENERAL SUS SCORE CLASSIFICATION

SUS Score	Grade	Adjective Rating
> 80.3	A	Excellent
68 – 80.3	B	Good
68	C	Okay
51 – 68	D	Poor
< 51	F	Awful

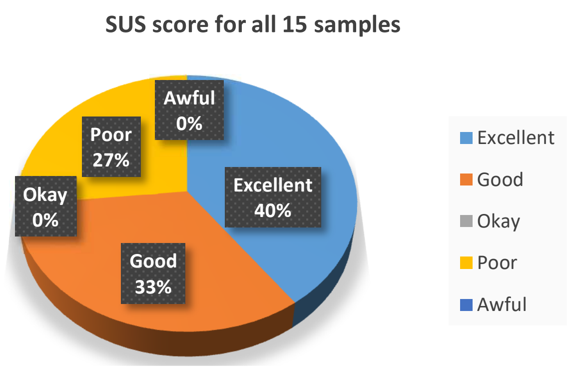

Fig. 15 Pie chart of the SUS score

From the results, 11 participants represented 73% of the participants rated above 68 out of 100. Overall, they are satisfied with the application used to learn Python. Reviewing the questionnaire responses, some participants would like to be aided while using the application. This response shows that the application's affordance information is insufficient to enable the participants to play alone.

Enhancement of the application on this issue is required in the maintenance phase. However, short interviews are conducted with the participants to understand their criteria for rating. Many of them reported that it was the first time they experienced immersive VR, so they had felt they needed to be assisted as they did not know where the button on the HMD that needed to be clicked, how to navigate and what can they do in the VR environment.

10 out of the 15 participants reported the application's disadvantage is that it is unsuitable to use for too long because they started to feel dizzy, uncomfortable, or tired after a period. Cybersickness is one of the well-known disadvantages of VR, which is a type of motion sickness that may face by

some people during or after VR play, with symptoms including dizziness, nausea, and imbalance [78].

The phenomenon happened because of a variation in what the human eye informs the brain and what the human body feels. For example, when one of the participants was walking in the virtual environment, but he was not physically walking in reality. Since Google Cardboard does not have any camera sensor for motion capture, the participants were unable to physically move in real life and thus may be resulted in dizziness.

IV. Conclusion

VR is currently widely used in multiple industries, and several studies have shown that it can effectively improve efficiency and inefficiencies. Therefore, this study employs VR in Python language learning. Through the finding, the proposed VR method is convenient and a modern tool for learning anywhere. It provides valuable experience and an interesting method for participants to learn. Moreover, this system not only can have used for programming but in other fields as well. However, there is insufficient evidence to show that VR can completely replace the traditional learning method because there are still some limitations as physical interaction between lecturer and student. Physical interaction is considered one of the main factors in providing efficient and effective learning experiences. Therefore, a better way is to implement both learning methods to increase learning effectiveness. Nevertheless, the system is a good approach to be used as a system to aid the learning process.

The main findings from this study:

- In usability testing, the overall outcome was optimum as there was not much error detected, and the time used to complete this task was optimum too.
- In hypothesis testing, the suggested VR learning method was more effective learning with $t_{statistic}$ value 4.992, which is much larger than $t_{critical} = 2.76$.
- Based on the 0.909 Cronbach alpha value obtained from PQ, the questionnaire was highly reliable.
- From figure 15, 73% of the participants rated above 68 out of 100, which indicated that the participants are satisfied with the user application to learn Python

It is recommended to extend the present work using a mobile VR or other HMD with higher or more extensive specifications. This recommendation could help the user experience to be significantly enhanced. More interactive applications can be developed if HMD with gesture interaction, such as Oculus Go, is adopted. A study considering larger sample size may yield higher confidence and reliability values. Finally, it is recommended that the cybersickness due to a long period of usage can be minimized by shortening the learning session or using better HMD.

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