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PAPER

Application of Gamification Models with Virtual Reality for Learning Plant Cultivation Techniques

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ABSTRACT

The aim of this research is to assess the effectiveness of implementing gamification models with virtual reality (VR) for plant cultivation techniques in constructing hydroponic circuits. The purpose of this study is to examine the significant differences in effectiveness between the control group and the intervention group when using gamification with virtual reality. The data used consists of test results from 50 respondents, divided into two groups: a control group of 25 students and an intervention group of 25 students. The trial was divided into two different groups. Group 1, the control group, received conventional treatment, which involved lecturers explaining the assembly of hydroponic circuits in class, followed by students practicing the assembly. Group 2, the intervention group, received self-learning treatment that involved the practice of assembling hydroponic circuits using a gamification model with VR. An independent t-test was conducted to determine whether there was a significant effect of applying plant cultivation techniques on assembling hydroponic circuits. The results of the t-test revealed a significant effect of applying the gamification model with VR compared to the conventional model. The application of the gamification model with VR to assemble hydroponic circuits has shown significant effectiveness, with an N-Gain value of 62.47%, whereas the conventional treatment has demonstrated lower effectiveness, with an N-Gain value of 28.24%.

KEYWORDS

application of gamification, virtual reality (VR), learning plant cultivation techniques

1 INTRODUCTION

1.1 Research background

The traditional learning model is used to introduce conventional plant cultivation techniques, as explained by the lecturer during class. The lecturer highlighted the limited availability of teaching aids in the classroom for effectively conveying theoretical concepts. Incorporating teaching aids not only demands additional time

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but also incurs cost for lecturer preparation. The onset of the COVID-19 pandemic posed a challenge to enhance the interactivity of online learning, leading to the integration of gaming and virtual reality (VR) until 2022. This study seeks to investigate whether there exists a significant disparity of comprehension between the traditional method of theoretical learning in a classroom setting and the use of gamification with VR to comprehend plant cultivation techniques. The focal point of the study is on assembling simple hydroponic systems as part of the broader topic of plant cultivation techniques.

1.2 General purpose and specific purpose of research

The main objective of this research is to develop an effective learning model and assess the impact of gamification with VR on plant cultivation techniques. The specific objective of this research is to identify an effective and significant learning model for constructing hydroponic systems in the field of agricultural cultivation engineering.

Food is a fundamental necessity derived from agriculture and can be obtained through various crop cultivation techniques. There is a need for information on how to cultivate crops that are essential to the community in order to boost crop yields. The rapid development of information technology has led to the introduction of digital farming to the public through online information on the web or via mobile phone applications. To effectively communicate information about plant cultivation techniques, it is essential to adapt the delivery of information using technology to meet the needs of people facing challenges in this area. Using delivery techniques can involve incorporating games and educational elements in non-game contexts, a practice commonly referred to as gamification, or employing the concept of games for teaching, known as serious games [1]. Educators and researchers have highlighted issues such as poor education. For this reason, some studies have utilized gaming models in education as a means to address issues in educational interactions [2]. A study by Research [33] that aimed to introduce plants using augmented reality technology tools did not produce significant changes, while research [34–35] showed a significant effect. VR is widely utilized in the field of education, and the trend of its use is increasing. The use of VR for sign language has had a significant impact [36–38].

1.3 Research limitations

The limitation of this research is that only one set of tools for the hydroponic circuit was used, as the hydroponic tools are quite expensive if provided in large quantities. This only affects a limited number of respondents, specifically 50 students. The scope of this research is limited to the field of hydroponic plant cultivation techniques due to their broad range of applications.

The limitations of using gamification in this study include the reliance on scores, interaction with hydroponic circuit objects, information buttons, score displays, themed levels, and coin sound effects. The VR assets include music soundtracks, rotating hydroponic 3D assets, a 3D room atmosphere, and players who can walk, observe the surroundings from a 360-degree angle, and interact with the hydroponic objects. The research utilized a set of hydroponic circuit tools, cellphones, cardboard VR, Blender software for creating 3D assets, Unity 3D software to create VR gamification, and Visual Studio for scripting based on the C# programming language.

2 LITERATURE REVIEW

2.1 Theoretical foundation of gamification model

Before delving into gamification, it is important to first explore the origins and relationship between games and gamification. There are numerous theories about games that have been defined by previous researchers. However, this study will adopt the definition of the game based on the summarized results from each researcher. A game is a system with rules in which players compete by making strategic decisions. Individuals or players controlled by a computer participate in four categories of interactive digital entertainment, encompassing interactive systems, puzzles, contests, and games [16]. In general, gamification is defined as the use of game elements to encourage user engagement and actions within a non-game context [17]. Meanwhile, gamification refers to the use of game design elements in non-game contexts. According to Stamatios J. Papadakis [30], the application of gamification to learning shows promising results in motivating students and increasing student engagement [29], [31–32]. VR is generally the result of processing using special electronic equipment to create a three-dimensional environment that simulates information, appearing very real to those who experience it [18].

There are two models for the game approach: serious game models and gamification models. The serious game model is designed for entertainment, while the gamification model incorporates an educational approach by using game elements and educational themes, but it is not purely a game. The use of games in education aims to engage users. While serious games are designed solely for entertainment purposes [3]. The gamification-based model [4] incorporates design elements such as player ranking boards, teams, challenges, voting, prizes, and exploration (source). The demand for information technology development is significantly increasing, with predictions that by 2020, half of organizations will incorporate gamification into their internal systems and processes [5]. The implementation of gamification principles using an accessible technology platform has great potential to enhance the agricultural industry [6]. The method of gamification motivates students and promotes a high level of student involvement in learning [7]. Scopus statistical data shows that gamification is an attractive way for researchers to present their research, with 650 papers accounting for 40.9% of all documents on the topic [8]. The study yielded generally positive results regarding the effectiveness of gamification [9].

2.2 Theoretical foundation of virtual reality

Virtual reality is a component of artificial intelligence technology that uses computer-generated simulations and supporting equipment to simulate vision and hearing, creating an experience similar to being in the real world [10]. Using VR requires physical elements such as cardboard, a cellphone, a headset, and a joystick. This research exclusively utilizes cardboard and cellphones, as it leverages the more affordable Google Cardboard version. Software tools used to create 3D assets, such as 3D modeling software such as Blender, AutoCAD, and 3Ds Max. The 3D assets are processed to create VR using Unity 3D. Meanwhile, the components required to create a VR environment include world elements, which are the elements of a three-dimensional world environment. Furthermore, there is an immersive element, specifically an atmosphere that simulates the real world with sound and three-dimensional objects. The next element is the presence of sensors that allow users to walk, see a 360-degree atmosphere, and hear sounds. The interactive elements in the next VR include touching and throwing objects.

2.3 State of the art

The following section provides an explanation of the relevant findings from previous studies, highlighting the differences and advantages of the current research in comparison to the previous studies. The application of virtual reality technology for learning in a study found that the results showed that students who took data structure lectures using virtual reality technology scored an average of 12% higher on tests compared to students who used traditional learning methods [11]. The research briefly describes similar studies on the application of gamification and virtual reality in various fields of science, including architecture, medicine, artificial neural networks, rice plants, agronomics, and agriculture [12–15]. However, this research has not provided much explanation about the implementation of gamification with VR. These studies have not utilized gamification in virtual reality.

2.4 How this research differs from and betters previous works

Previous studies only focused on the success of implementing gamification without involving VR, or the success of applying VR without incorporating gamification. This research has advantages and unique features, specifically the integration of gamification with VR in the field of plant cultivation techniques, particularly for the implementation of hydroponic circuits.

So, based on the explanation above, this study aims to explore plant cultivation techniques using gamification methods to offer effective solutions and enhance cultivation practices through VR gamification. Research on gamification models has been conducted in the field of education to motivate students to learn plant cultivation techniques. While there is ample evidence of research using gamification to engage students interested in plant cultivation techniques, there is limited evidence of research utilizing VR as a gamification tool. This research aims to explore the role of VR in the gamification model. This study aims to determine the percentage of the impact of gamification with VR on the practice of assembling hydroponics.

2.5 Research novelty

The integration of gamification and VR in plant cultivation techniques represents a novel approach to creating a new gamification model, offering users fresh challenges. The literature explanation above demonstrates the presence of VR as an independent entity, separate from gamification within VR. This research introduces a novel approach to education by integrating gamification and VR to enhance the effectiveness of assembling hydroponic circuits for plant cultivation engineering.

3 MATERIAL AND METHOD

3.1 Research design

The research method was implemented to obtain measurable results by initially gathering references related to this study. Next, develop a gamification application using VR technology. The completed application was tested to assess the impact of gamification with VR compared to traditional teaching methods involving lecturers providing explanations in class. The topic is how to set up a hydroponic system. The primary participant in gamification with VR is a player who assumes a role as if they were in the real world, exploring the room to observe and interact with the hydroponic components in order to earn points and experience the hydroponic panorama within the room. The VR tool used is the VR Box because it is affordable for students from the lower middle class. Software for implementing gamification with VR using Unity 3D is compatible with a Google Cardboard-style viewer and VR Box. The three-dimensional hydroponic system design was created using Blender software and exported as an fbx file for import into the Unity 3D editor. The 3D assets created include a hydroponic table frame, gully pipes for planting, paralon pipes for water channels, water hoses for water flow into the bucket, and aquarium pumps to lift the water through the pipe channels.

Figure 1 illustrates the flow and stages of the research, starting with the collection of relevant research reference data. The collection of related research reference data includes concepts, designs, and materials for creating 3D modeling assets. Next, the stage involves creating gamification with VR by assembling the gamification and 3D assets that have been developed. Next, we need to conduct internal testing to ensure that the results align with the design plan. The final step is to conduct experiments involving students.

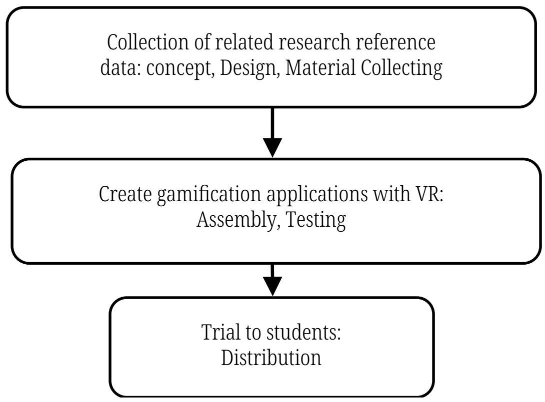


Fig. 1. Research methods to get research results

3.2 Sampling method

The population was drawn from one of the 5th-semester courses in the information systems department, consisting of students who lacked understanding of hydroponic plant cultivation techniques. The class has a population of 98 students, with an average age of around 21 years. The Slovin formula is used to obtain a sample with a permissible sampling error of 10%, as deemed acceptable by Slovin, particularly for a limited dataset. Consequently, a sample of 50 students was obtained. Subsequently, a simulation trial will be executed involvng the participation of these 50 students, as outlined in the study [19], with the cohort divided into two groups. The control group will consist of 25 students who will undergo simulation in the traditional manner, while the intervention group will comprise 25 students participating in simulation trials with VR gamification.

$$\mathrm{n} = \frac{N}{1 + N e^2} \tag{1}$$

Formula 1 above explains the Slovin's formula, where n represents the sample size, N is the population size, and e is the acceptable margin of error, set at 10% according to Slovin.

3.3 Respondent background

The control group is the group that does not receive treatment and consists of 5th semester students majoring in information systems, with an average age of 21 years. The control group lacks knowledge of hydroponic cultivation techniques. The control group did not receive any treatment in this study. The control group received the standard treatment before the pre-test, following the lecturer's traditional teaching methods, which included in-class explanations using a laptop, LCD projector, and slides. Post-tests were then administered to assess the practice of assembling hydroponic circuits. The intervention group consisted of 5th semester students majoring in information systems, with an average age of 21 years, who had no prior knowledge of hydroponic cultivation techniques. The intervention group received treatment in the form of a pre-test after self-study using a gamification model with VR, followed by a post-test to assemble the hydroponic circuit.

3.4 Research instrument results with statistical analysis

The samples from two groups of students were analyzed using the independent T-test statistical technique to identify significant differences between the control group, which did not receive treatment, and the intervention group, which received treatment. To determine whether there is a difference in effectiveness, the N-Gain test is used to assess the impact of the two groups on effectiveness. Prior to undertaking the T-test and N-Gain test, preliminary measures were implemented to assess the validity and reliability of the survey questions. This step was taken to ensure that the responses provided by the students were both valid and reliable for the subsequent analyses. The following are the results of the validity and reliability tests in Tables 1 and 2.

Table 1. Control group (traditional) and intervention group (gamification VR) validity test results

Questions	Control Group (R Table = 0.396)		Intervention Group (R Table = 0.396)	
	Pre Test R Count	Post Test R Count	Pre Test R Count	Post Test R Count
q1	0.747	0.961	0.822	0.765
q2	0.873	0.957	0.787	0.765
q3	0.739	0.926	0.921	0.711
q4	0.808	0.919	0.697	0.817
q5	0.828	0.929	0.656	0.867
q6	0.845	0.941	0.820	0.957
q7	0.862	0.912	0.726	0.706
q8	0.827	0.911	0.825	0.715
q9	0.929	0.908	0.803	0.780
q10	0.861	0.909	0.709	0.661

Table 1 shows that the results of the validity test for the control group and intervention group were greater than the critical T value of 0.396, which was obtained from 25 respondents. The T-table value was 0.396 [23]. Based on Table 1, the results of the pre-test and post-test questionnaires for the control group and intervention group were deemed valid because they exceeded the T-table value of 0.396.

Table 2. Control group (Traditional) and intervention group (Gamification VR) reliability test results

Questions	Cronbach's Alpha > 0.6 Control Group		Cronbach's Alpha > 0.6 Intervention Group	
	Pre Test R Count	Post Test R Count	Pre Test R Count	Post Test R Count
	0.951	0.981	0.927	0.915

Table 2 shows that the Cronbach's alpha for pre- and post-test questions in both the control group and intervention group is above 0.6 [23], indicating that the pre- and post-test questions in both groups are reliable.

Figure 2 illustrates that the gamification application with VR consists of two levels or two parts. The player can choose between level 1, or part 1, and level 2, or part 2, of the game. In level 1, the player completes missions to locate hydroponic elements and earns points by interacting with them. After reaching a point at level 1, you can return to the main menu to select level 2. In level 2, players can access information and panoramas of the installed hydroponics. The gamification features include a level 1 scoreboard, background music, and a menu for navigating the main options. In the VR scenario, the player can walk into the room and interact with the rotating hydroponic components, indicating that the object is interactive when touched.

3.5 Application flowcharts

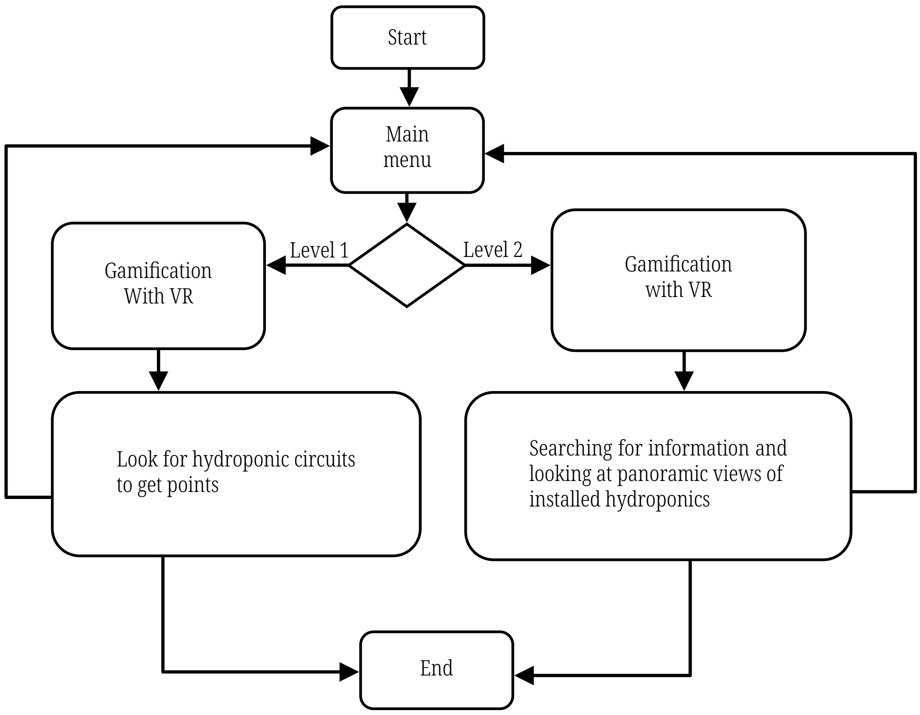


Fig. 2. Gamification model with VR to learn to assemble hydroponics

When the object is touched, a sound will indicate the point, and the score will appear automatically. Once you have finished interacting with all the hydroponic elements, the player can navigate to the main menu to select level 2. In level 2, the scenario allows the player to view the panorama of the room and the installed hydroponic system, serving as a reminder of the hydroponic circuit that will be implemented for practical use in the real world. In gamification with VR at level 2, players can access information in the room by directing their view to the buttons, causing information about hydroponics to automatically appear.

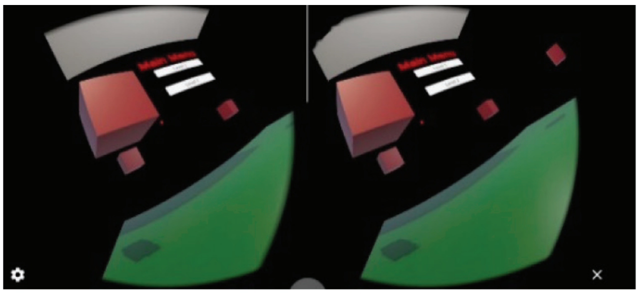
4 RESULTS AND DISCUSSIONS

The study aimed to assess the impact of using gamification with VR on the assembly of hydroponics with a group of 50 students. The sample size was determined based on the total number of students majoring in information systems, which is approximately 98. Using the sample formula [19], a sample of 50 students was obtained. The background sample (respondents) consists of students majoring in information systems who do not yet have an understanding of hydroponics. The samples were divided into two groups: group 1, comprising 25 students who assembled hydroponics based on the model and the lecturer's explanation provided in class, and group 2, consisting of 25 students who assembled hydroponics based on self-study gamification models with virtual reality.

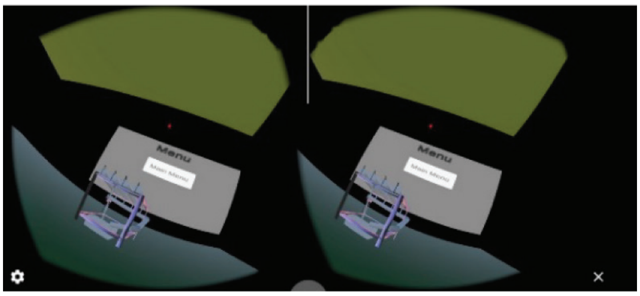
4.1 Gamification design result

The gamification design with VR includes scenarios with three scenes: scene 1 for the main menu theme, scene 2 for the level 1 theme, and scene 3 for the level 2 theme. Scene 1 only shows the main menu. While scene 2 explores the theme of gamification. In Scene 2, the gamification theme is depicted as the player's gamification tool interacts with the hydroponic instrument object, resulting in the acquisition of a point value. Another gamification technique involves displaying a scoreboard every time the player touches an object. Another gamification element that is evident is the background music, which creates a more relaxed atmosphere.

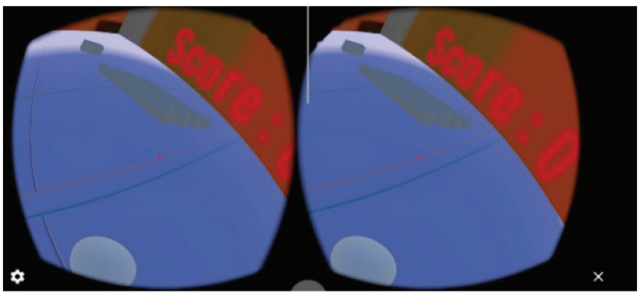
Figure 3 depicts three scenes in the Unity editor, with scene 1 representing the main menu (a), scene 2 representing level 1 (b), and scene 3 representing level 2 (c). Scene 1 only features the main menu, which the player can select using the GvrReticlePointer.



a) Main menu



b) Level 1



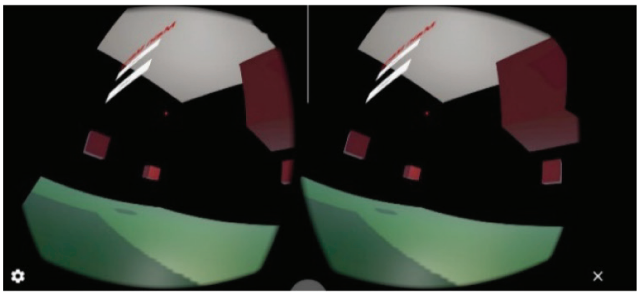
c) Level 2

Fig. 3. Shows gamification (a) Scene 1 is the main menu, (b) Scene 2 is Level 1, and Scene 3 is Level 2

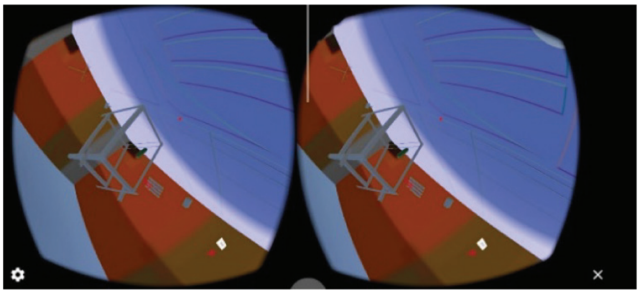
In Scene 2, the player engages in gamified activities by walking and interacting with hydroponic instruments to earn points, which are then displayed on the scoreboard. Meanwhile, in Scene 3, the player is able to walk and see the complete hydroponic circuit that has been installed. At level 2, another activity is for the player to be able to select a button to return to the main menu.

4.2 Virtual reality design result

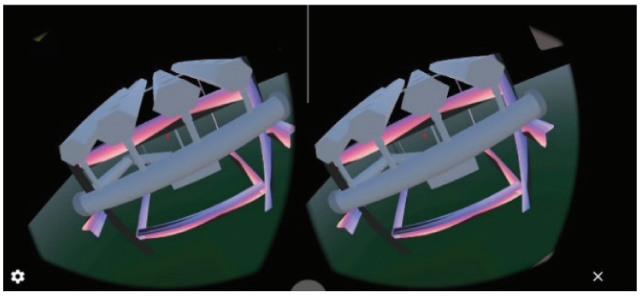
The VR design for scene 1 features a panorama with level 1 and level 2 buttons for selection. The player can move around the room as if it were the real world to access the main menu, which displays the level 1 and level 2 dashboards.



a) Panoramic scene 1



b) Panoramic scene 2



c) Panoramic scene 3

Fig. 4. Shows VR panorama (a) Scene 1 is the main menu, (b) Scene 2 is Level 1, and (c) Scene 3 is Level 2

The VR design for scene 2 features a panoramic view of the room, including a rotating hydroponic instrument designed to attract the player's attention. When approached and touched, it will produce a coin-sound reaction, and the score will appear on the dashboard. The VR design for scene 3 on level 2 showcases a complete panoramic view of the installed hydroponics and an information dashboard. Players can take a walk around the room to observe the installed hydroponic circuit and enjoy the panoramic view. Players can also access information on the dashboard by tapping the information button. This level 2 allows players to further observe the hydroponic arrangement that has been installed while walking around and observing the hydroponic system, which will later be implemented in the greenhouse area. Figure 4a depicts the VR panorama in scene 1, which represents the room for the main menu theme. While Figure 4b depicts the VR panorama in scene 2, specifically level 1, which is set in the room for the gamification theme with VR. Figure 4c is a VR panorama of scene 3, specifically level 2, showing the installed hydroponic circuit. The gamification in scene 3 involves viewing a series of hydroponic systems and learning about hydroponics.

4.3 Test result

The gamification application with VR that has been developed is currently being tested on information systems students who lack knowledge about hydroponic plant cultivation. The total student population is 98, so a sample of 50 is obtained from the age range of [19–22].

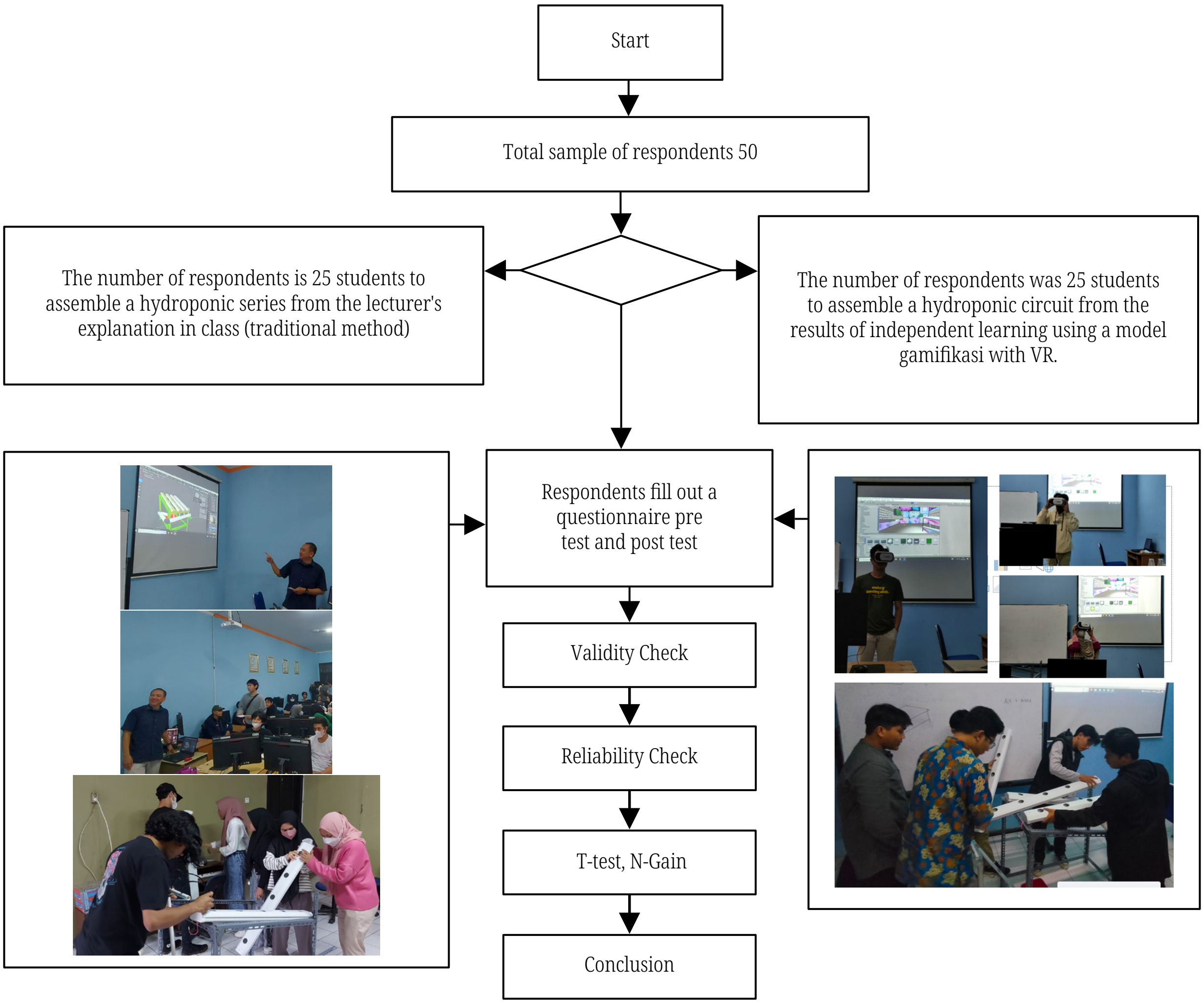


Fig. 5. The flow of the results of the hydroponic assembling test process with two traditional models and gamification with VR

After obtaining a sample of student respondents, they were divided into two groups. Group 2, consisting of 25 students, was tasked with assembling a hydroponic circuit based on the lecturer's explanation in class. Group 1, consisting of 25 students, constructed a hydroponic circuit based on their independent learning using a gamification model with virtual reality.

4.4 Test results using independent T-Test

The table below shows the results of a questionnaire completed by Group 1, comprising 25 students. The scenario involved students receiving an explanation from the lecturer in class on how to assemble hydroponics. Fill in the questionnaire by selecting numbers 4 (Strongly Agree), 3 (Agree), 2 (Disagree), and 1 (Strongly Disagree). Group 2, or the control group, was assessed with a pre-test and a post-test. Validity and reliability calculations were conducted prior to determining the results of the Independent T-Test. The questions from the pre-test and post-test are considered valid and reliable because they have been tested with Cronbach's alpha post-test and conventional pre-test values of 0.96. The validity and reliability of the pre-test and post-test are confirmed by a Cronbach's alpha value of 0.94, which exceeds the critical value of 0.396 [23–26]. An independent t-test was conducted to determine whether there is a significant effect of applying the gamification model with VR to assemble hydroponic circuits. The pre-test and post-test results for two groups, the experimental and control groups, were analyzed using IBM SPSS version 26. Before conducting the independent T-test, a normality test was first performed to determine whether the data were normally distributed. The results of the normality test obtained a p-value of 0.22, which is greater than 0.05. This indicates that the data is normally distributed [26].

The results of the independent T-test indicate a significance value of less than 0.05, suggesting a significant effect of implementing the gamification model with VR for both the experimental and control groups. If the results of the independent T-test yield a significance value greater than 0.05, it indicates that there is no significant effect of implementing the gamification model with VR for the experimental group compared to the control group.

Table 3. Independent T-test results of experimental class and control class

		Levene's Test for Equality of Variances	T-test for Equality of Means	
		Sig.	Df	Sig. (2-tailed)
Score	Equal variances assumed	0.236	48	0.0001
	Equal variances not assumed		45.586	0.0001

Table 3 explains the significance value of "Sig." The p-value is 0.0001 (2-tailed), indicating that the significance level is less than 0.05. The significance value of 0.0001 is less than 0.05, indicating a significant effect of the gamification model with VR on the experimental group compared to the conventional control group. The conclusion drawn from the independent T-test suggests a significant impact of applying hydroponic circuit assembly through the gamification experiment group with VR in comparison to conventional methods, when contrasted with the conventional control group.

Results: The mean for the intervention group was 62.47%, indicating that the intervention was highly effective in implementing gamification with VR for plant cultivation techniques in the context of assembling hydroponic circuits. In comparison, the control group had an average of 28.24%, suggesting that their approach was ineffective for practicing the assembly of a hydroponic circuit for plant cultivation techniques. The intervention group showed a significant effect in the T-test, with a value of less than 0.05. This indicates that the intervention group had a significant impact on the application of plant cultivation techniques in the context of practicing assembling hydroponic circuits.

4.5 Effectiveness test results

The N-Gain test was carried out to see how effective it is to assemble a hydroponic circuit using the gamification model experiment method with VR and the conventional model control group. The level of effectiveness can be seen in Table 2. Table 4 explains the level of N-Gain, or it could also be the level of effectiveness according to [2], [3], consisting of four ranges, namely the range $g > 0.7$ is very effective, $0.3 \leq g \leq 0.7$ is quite effective, $0 \leq g \leq 0.3$ is less effective, and $g \leq 0$ is not effective.

$$g = \frac{Spost - SPre}{ideal\,score - SPre} \tag{2}$$

Formula 2 is used to calculate the N-Gain score, which is the post-test score minus the pre-test score, divided by the ideal score minus the pre-test score.

Table 4. Table of N-gain criteria

Average	Criteria
$g > 76$	Effective
56–75	Effective enough
40–55	Less effective
< 40	Ineffective

The results of the N-Gain test in the N-Gain table are analyzed in advance to determine whether the data is normally distributed, as the N-Gain test requires the data to be normally distributed. The results of the Kolmogorov-Smirnov normality test indicated that the control group had a significant value of 0.054, while the intervention group had a significant value of 0.200. According to [19], if the p-value is greater than 0.05, it can be concluded that the data is normally distributed, and the N-Gain test can proceed.

The N-Gain score was calculated to be 62.47, representing the mean value for the experimental group, which used the gamification model with VR. The control group, when using the conventional method, achieved an N-Gain score with a mean value of 28.24. Based on Table 2, the N-Gain score of 62.47 falls within the fairly effective range, whereas the conventional control group's N-Gain score of 28.24 is in the ineffective range. It can be concluded that the assembly of a hydroponic circuit using a gamification model with VR is quite effective, with an efficiency level of 62.47. The conventional method is ineffective for assembling hydroponic circuits, with an efficiency level of 28.24.

Table 5. N-gain score test results

	Class	N	Mean	Standard Deviation	Standard Error Mean
NGain Persen	Experiment	25	62.47	22.11	4.42
	Conventional	25	28.24	31.37	6.27

Table 5 above explains that N represents the number of experimental samples and conventional samples, with each group consisting of 25 samples. The average N-Gain score for the experimental group is 62.47, while the average N-Gain score for the conventional group is 28.24. The standard deviation for the experimental group was 22.11, while for the conventional group, it was 31.37. The mean standard error for the experimental group is 4.42, whereas the conventional group has a mean standard error of 6.27.

4.6 Implications, comparisons, and research results

The implications of this research differ from previous relevant studies. When VR technology is used alone for learning, the success rate is 12% compared to traditional methods [11]. When compared to this study, there is a notable difference: the application of the gamification model with VR has a significant and effective impact, with a 62.47% applicability rate. Therefore, it can be concluded that the integration of gamification with VR in the field of plant cultivation techniques, particularly in assembling hydroponic circuits, is highly effective.

5 CONCLUSION

This study concludes that the use of plant cultivation techniques, particularly in setting up hydroponic circuits, has a significant impact when employing a gamification model with VR, as opposed to conventional methods where students learn from lecturers who explain in front of the class. The implementation of the gamification model with VR for assembling hydroponic circuits is 62.47% effective, whereas the conventional model is only 28.24% effective for the same purpose.

Recommendations for future research include utilizing a more interactive Oculus VR headset and incorporating more dynamic gamification to further enhance the gamification effect with VR. Additionally, it is recommended to develop the technology for the metaverse.

The limitation of this research is that the hydroponic circuit tools are only available in a single set, so when used for practice, there is a need to queue. So, the limitations of this tool only affect the small number of respondents who participate in the practice.

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