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Transforming Technical Education: The Effect of the AR-MicroC Augmented Reality Learning Module on Students Achievement

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ABSTRACT

Technological advances driven by Industrial Revolution 4.0 (IR4.0) have introduced digital technologies such as Augmented Reality (AR) that are changing the approach to learning. This study aims to evaluate the effectiveness of using the AR-MicroC Augmented Reality Learning Module in improving student achievement in the Information Technology Certificate program at the Malaysian Community College. A quantitative approach with a quasi-experimental design was used, involving 66 students who were divided into two groups: a treatment group (n=32) who used the AR-MicroC module and a control group (n=34) who followed conventional teaching methods. Data was collected through pre-test and post-test for the Introduction to Internet of Things (IoT) course. The study lasted for five weeks, involving pre-test, teaching, and post-test phases. Data analysis using independent sample t-test and paired sample t-test showed a significant difference in achievement between the two groups. The results of the study prove that the AR-MicroC module is effective in improving student performance. The implications of this study suggest the use of the AR-MicroC Augmented Reality Learning Module as an innovative alternative teaching tool in the learning process, especially in transforming technical education.

Keywords:
Augmented reality, learning modules, achievements, Internet of Things (IoT), Quasi experiments

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1. Introduction

Technological progress today is greatly influenced by the new environment known as Industrial Revolution 4.0 (IR4.0). IR4.0 has revolutionized the way people live through the widespread use of digital technology. This development also has a great impact on the world of education, where the term Education 4.0 was first introduced as a response to the needs of the IR4.0 era. Education 4.0 aims to align people and technology to explore new opportunities relevant to current challenges.

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In Malaysia, the Malaysian Education Development Plan 2015–2025 (Higher Education) outlines several important shifts to strengthen the country's education system. Among them, the ninth shift emphasizes the importance of leveraging global online learning to improve the quality of teaching and learning. Digital technology provides ample opportunities for educators and students to integrate mobile devices and digital applications into the teaching and learning process [1]. The presence of generation Y and Z as the main group of students today also brings new challenges. This generation has a high technological background and advanced digital literacy, making them more inclined to technology-assisted learning [2]. Therefore, the teaching approach needs to be redesigned to be in line with the development of technology and the educational needs of the 21st century. These changes are important to ensure education remains relevant and effective in developing highly skilled human capital to face the challenges of the IR4.0 world.

21st century education emphasizes the development of skills and values needed to face increasingly complex and dynamic global challenges. The focus of education is now no longer limited to the delivery of academic knowledge alone, but also involves efforts to equip students with the ability to adapt in a world that is interconnected and driven by high technology. In this context, 21st Century Education and Technical and Vocational Education and Training (TVET) play a complementary role in preparing students to face an increasingly complex and technologically advanced world of work. As one of the stakeholders of TVET in Malaysia, Community College plays an important role in realizing the government's aspirations to empower 21st Century Education and TVET. According to the Polytechnic and Community College Strategic Plan 2018-2025, the study programs offered are adapted to the requirements of IR4.0 through a 21st century pedagogical approach. This effort aims to produce TVET graduates who are characterized as global citizens, quality, and relevant to the current needs of the industry [3].

In line with the TVET 4.0 Framework, the TVET curriculum is designed to integrate the latest teaching and learning systems that can meet the requirements of IR4.0. One of the programs offered at the Community College is the Information Technology Certificate, which aims to produce individuals who are skilled in information technology and are able to adapt to computer systems and technology networks. This program meets the country's needs in providing a workforce that is ready to face the challenges of the digital era [4]. As a step to strengthen the adaptation of IR4.0, the Department of Polytechnic Education and Community Colleges (JPPKK) implemented the 4IR Flagship initiative by introducing new technology in the curriculum and co-curriculum. IR4.0 elements such as the Internet of Things (IoT) are used as effective learning modules to help students master the latest technology [5]. This effort ensures that TVET education remains relevant in producing competitive and innovative human capital to support the country's economic development.

The use of technology in education is growing along with the progress of the digital era. Mobile devices are now an important medium in teaching, acting as a catalyst to connect teachers, students, peers, and learning materials virtually through websites or educational applications [6]. Activities such as sharing learning materials, downloading notes, and completing assignments can be done easily through smartphones, making the learning process more flexible than using a personal computer [7,8]. Furthermore, students can access learning materials online, increasing the accessibility and effectiveness of learning. Lecturers also found that the use of mobile devices in the delivery of education can attract students' interest and increase their level of understanding [9, 10]. The development of mobile technology has sparked the Augmented Reality (AR) revolution, which introduces a new dimension in teaching and learning [11,12]. AR technology combines virtual and real-world elements, resulting in a more interactive and enjoyable learning experience [8]. According to [13], the use of AR in the classroom shows increased student motivation and a positive effect on learning achievement. AR-based learning is not only interesting, but also stimulates students' technical skills in a more effective way. This finding is in line with the study of [14] and [8], who found that AR technology helps create a flexible and more effective learning environment. Therefore, AR emerges as a promising medium to strengthen the teaching and learning process, especially in training TVET students to face the challenges of the IR4.0 era world.

Despite the proven potential of Augmented Reality (AR) in enhancing motivation, understanding, and technical skills among students, its integration into the teaching and learning process in the context of Technical and Vocational Education and Training (TVET) remains limited. Specifically, there is a lack of comprehensive studies and practical implementations focusing on how AR can be effectively utilized to address the unique challenges faced by TVET students, such as mastering complex technical concepts and skills required in the IR4.0 era. This gap highlights the need for further exploration and development of AR-based learning modules tailored to TVET education, particularly in equipping students with industry-relevant competencies in an engaging and efficient manner.

1.1 Problem Statement

The course Introduction to the Internet of Things (IoT) is a compulsory course for Community College Information Technology Certificate students in the third semester. This course aims to provide exposure to the basics of IoT as well as the skills to develop IoT applications. One of the main topics is Microcontrollers, which requires students to master visualization and creativity skills to understand concepts, assemble electronic circuits, and write programming code. However, this topic is often considered challenging because it involves aspects of programming and assembly of complex electronic circuits [15,16]. Difficulty in understanding the topic of Microcontroller causes students to face problems in achieving the set learning outcomes. In addition, the lack of teaching aids that are able to clearly visualize the function of circuits and electronic components also complicates the learning process [17]. Lecturers face a big challenge to deliver this topic effectively because they need to master innovative teaching techniques as well as provide comprehensive guidance.

With the development of today's technology, teaching and learning methods need to change to meet the needs of the modern generation of students. Technology-based approaches such as Augmented Reality (AR) offer great potential to improve student understanding through interactive and immersive learning experiences [18,19]. Learning using AR technology can not only stimulate students' interest but also improve their achievement [20-22]. Furthermore, students now prefer if lecturers use the latest technology in teaching because it can improve achievement [23].

1.2 Objectives, Research Questions and Hypotheses

In general, this study aims to evaluate the effect of using the AR-MicroC Augmented Reality Learning Module in the Microcontroller topic on Information Technology Certificate students at Community Colleges. To achieve that goal, several objectives have been built, namely:

i. Determine the mean difference in pre-test scores between the control group and the treatment group.
ii. Determine the mean difference in post-test scores between the control group and the treatment group.
iii. Determine the mean difference of the pre-test and post-test scores against the control group.
iv. Determine the mean difference of the pre-test and post-test scores of the treatment group.

To achieve these objectives, the research questions that need to be answered to guide this study are:

i. Is there a difference in mean pre-test scores between the control group and the treatment group?
ii. Is there a difference in mean post-test scores between the control group and the treatment group?
iii. Is there a difference in the mean scores of the pre-test and post-test compared to the control group?
iv. Is there a difference in the mean pre-test and post-test scores of the treatment groups?

The results of the data analysis will determine whether the null hypothesis is rejected or accepted. The hypotheses for this study will be linked to the research questions which are:

H_{o1}: There is no significant difference between the mean pre-test scores of the control group and the treatment group.
H_{o2}: There is no significant difference between the mean post-test scores of the control group and the treatment group.
H_{o3}: There is no significant difference between the mean pre-test and post-test scores for the control group.
H_{o4}: There is no significant difference between the mean pre-test and post-test scores for the treatment group.

1.3 Conceptual Framework

The conceptual framework shows the relationship between each study variable as well as the relationship of the variable with the chosen theory, model or phenomenon [24]. The independent variable involved in this study is the AR-MicroC Augmented Reality Learning Module used on respondents. This AR-MicroC Augmented Reality learning module is developed based on Behaviorism Theory, Mayer's Cognitive Theory of Multimedia Learning and the SAMR Model (Substitution, Augmentation, Modification, Redefinition). This learning module is also developed based on the m-ADDIE design model. The dependent variable for this study refers to the assessment of student achievement after using the developed module. The conceptual framework of this study is shown in Figure 1 below.

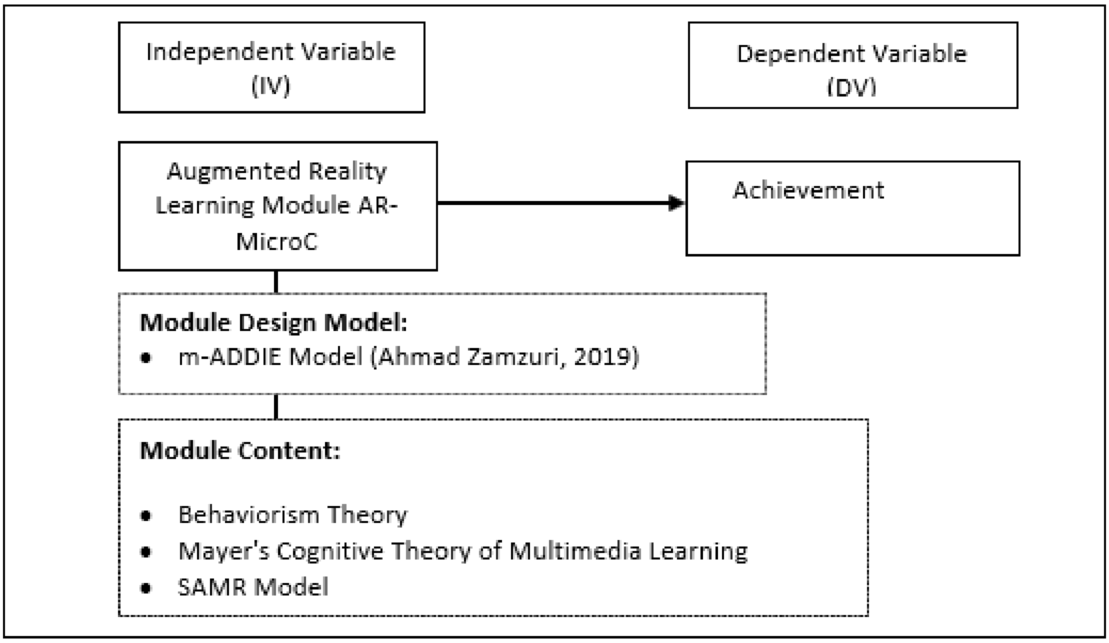

Fig. 1. Conceptual framework

2. Methodology

This study was conducted based on a quantitative approach. While the research design used is a quasi-experimental design to develop and evaluate the achievement of the AR-MicroC Augmented Reality learning module for the Information Technology Certificate program at the Malaysian Community College. A quasi-experimental study is used to test the hypothesis of a comparison or significant difference between an experimental group and a control group or between two independent variables (treatment group) and a dependent variable (control group) based on at least one or more hypotheses that state the cause between the two variables [25].

Table1
Quasi experimental design [25]

Group	Pre Test	Teaching Method	Post Test
Treatment Group	O^1	X	O^2
Control Group	O^1		O^2

2.1 Population and Sample

The population in this study consisted of students from Community Colleges offering Information Technology Certificate programs. The number of colleges that have been involved in this study is as many as 14 Community Colleges. All these students have been made into a population in this study and can be selected as a study sample through a cluster random sampling technique. Cluster sampling is sampling that involves the selection of groups or clusters instead of individuals [26,27]. The number of samples for this study is a total of 66 students from four selected Community Colleges. The sample consisted of 32 students in the treatment group and 34 students in the control group.

2.2 Instrument

The research instrument used is an achievement test consisting of a pre-test and a post-test. In the context of this study, instruments were given to students from both the control and treatment groups before the treatment and after the treatment was implemented. Tests are given to students within one week before the treatment is implemented. After three weeks of treatment, again the same test was given to the students a week after treatment. This test is designed to assess student understanding of the topics Introduction to the Internet of Things and Electrical Components, Device Connection, and Programming. A set of questions was developed to measure overall student achievement. The formulated questions are guided by the Test Specification Table (JSU) by referring to the Taxonomy domain set in the syllabus. The set of questions along with the formulated scheme has also been reviewed, evaluated and verified (vetting) by the Evaluation Committee at a Community College. The pre-test and post-test were implemented with the support of researchers and lecturers who are experienced in teaching Information Technology Certificate programs at Community Colleges. The validity of the instrument is carried out against the language and content aspects of the instrument. The test instrument was evaluated by 3 appointed experts as shown in Table 2.

Table 2
Profile of instrument evaluation experts

Expert	Profile and Experience
Expert 1	Senior Lecturer and Head of General Studies Unit, Kolej Komuniti. Curriculum Developer for the National Language Curriculum under the Department of Polytechnic and Community College Education (JPPKK). Holds a bachelor’s degree in education (Teaching Malay as a First Language, UPM) 15 years of teaching experience.
Expert 2	Head of the Information Technology Program at Kolej Komuniti. Holds a Bachelor’s Degree in Information Technology. 15 years of teaching experience.
Expert 3	Deputy Director of Academics, Kolej Komuniti. Holds a Master’s Degree, UiTM. 12 years of experience in curriculum and JSU

The validity of the achievement test instrument was ensured through a comprehensive vetting process. This process not only focused on identifying technical and linguistic issues in the test items but also emphasized generating content validity to maintain the quality and relevance of the evaluation questions [28,29]. During the vetting sessions, all experts unanimously agreed on the reviewed items, though they provided constructive suggestions for improving the answer schemes. These suggestions were carefully noted, and necessary adjustments were made by the researcher. The validation process employed the Achievement Test Vetting Form, a standard tool used across Malaysian Community Colleges. The assessment of the instrument’s validity, based on the consensus of three experts, revealed that the validity level was commendable.

The reliability of pre- and post-achievement tests was analyzed using the Kuder-Richardson (KR-20) reliability method, which is suitable for dichotomous data. The value of the reliability coefficient (Cronbach's Alpha) for the achievement test instrument is .704, indicating that the set of test questions is at a good and acceptable level [30]. In addition, the reliability of the achievement test is also confirmed through a moderation process, where two experts evaluate the test that the respondents have answered. This method is in line with the observer's reliability approach or inter-rater reliability. After the scoring by the two experts was completed, their scores were compared, and the value of the Pearson correlation coefficient (r), was calculated to determine the strength of the reliability of the pre- and post-tests [31]. Based on Table 3, the Pearson correlation value obtained is ($r = .996$), which is significant at the ($p < .05$) level, showing a very strong relationship between the scores of the two experts. These results prove that the constructed achievement test has a high level of reliability.

Table 3
Correlation coefficient scores, r for pre- and post-achievement tests

Rater	Correlation	Rater 1	Rater 2
Rater 1	Pearson Correlation	1	.996**
	Sig. (2-tailed)		<.001
	N	29	29
Rater 2	Pearson Correlation	.996**	1
	Sig. (2-tailed)	<.001	
	N	29	29

**Correlation is significant at the 0.001 level (2-tailed)

2.2 Research Procedure

The implementation procedure of this study is divided into three main phases: the analysis phase, the design and development phase, and the implementation and intervention effectiveness evaluation phase. Figure 2 provides a summary of the procedures in the implementation and evaluation phases using the quasi-experimental method. Before the teaching and learning sessions begin, both groups will undergo a pre-test. Subsequently, both groups will be taught using the prescribed methods. The treatment group will be taught using the Augmented Reality (AR) AR-MicroC module, while the control group will be taught using conventional methods. After three weeks of instruction, both groups will take a post-test. This experiment spans a total duration of five weeks. The scores of both groups will then be compared to evaluate the effect of teaching using the AR-MicroC Augmented Reality module on students' achievement.

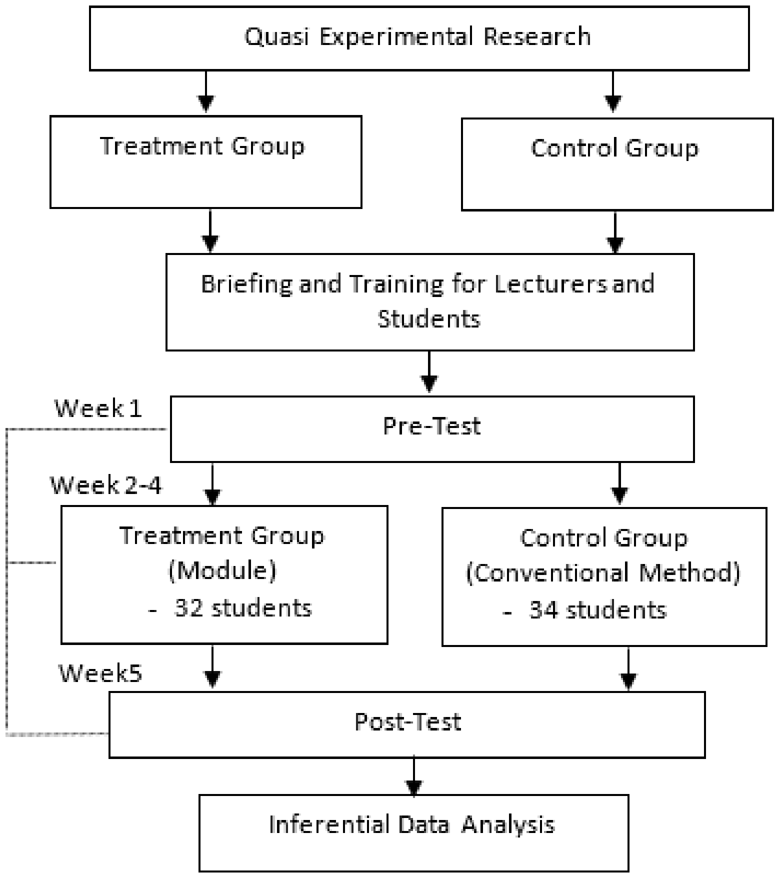

Fig. 2. Summary of research procedure

Aspects of internal and external variable control play an important role in implementation and evaluation. This control is necessary to ensure that the effect on the dependent variable occurs as a result of variation in the independent variable. If the external variable cannot be controlled, it will affect the dependent variable and can threaten the results of the study. In this experimental study, internal validity and external validity have been identified Extraneous variables that are known for sure, are history, maturity, pre-test procedures, instrumentation, mortality and statistical regression. While the internal threats are Population Validity, Treatment Interference, and the Hawthorne Effect. Controls for each threat were implemented in this research.

3. Results

3.1 Normality Test

The normality test is one of the basic conditions for inferential statistics such as the t-test whose data is normally distributed. To determine whether the distribution of the obtained data is normally distributed or otherwise, the normality test was conducted for that purpose. Based on Table 4, it shows that all the student achievement data obtained for this study is normally distributed. This is because the obtained Skewness and Kurtosis values range from -2.00 to +2.00 [32]. [33] also stated that the data is normally distributed when both the Skewness and Kurtosis values are between -1.96 and +1.96. Therefore, the data obtained meets the conditions to continue with inferential analysis.

The findings of the AR-MicroC Augmented Reality learning module effects, were interpreted using both descriptive and inferential analysis. Descriptive analysis involves mean and standard deviation, while inferential analysis involves t-test based on the constructed research questions.

Table 4
Normality test of student achievement for control group and treatment group

Group	Pre-Test		Post-Test	
	Skewness	Kurtosis	Skewness	Kurtosis
Control	0.381	-0.565	0.282	-0.491
Treatment	-0.122	0.211	-0.799	0.753

Research Questions 1
Is there a difference in mean pre-test scores between the control group and the treatment group?

The results of the independent sample t-test analysis for the comparison of the pre-test mean for the control group and the treatment group, it was found that the significant value [t(64)= 1.947, p=0.056] p is greater than 0.05 ($p > 0.05$). From those results (Table 5) where the p value is greater than 0.05 indicates that there is no significant difference for the pre-test mean between the control and treatment groups. Therefore, hypothesis H_{o1} is accepted, that is, there is no significant difference in mean pre-test scores between the treatment group and the control group. This means that there is no difference in the mean pre-test scores obtained by students of the control group and the treatment group.

Table 5
t-Test for comparison of pre-test means of control group and treatment group

Group	N	Mean	Standard Deviation	t	df	Significant Value
Control	34	31.91	7.497	1.947	64	0.056
Treatment	32	28.56	6.390			

*significant value at p = 0.05

Research Questions 2
Is there a difference in mean post-test scores between the control group and the treatment group?

The results of independent sample t-test analysis show that the significant value [t(59.986)= -10.334, p0.001] p is smaller than 0.05 ($p < 0.05$). From those results (Table 6) where the p value is smaller than 0.05 indicates that there is a significant difference for the post-test mean between the control and treatment groups. Therefore, hypothesis H_{o2} is rejected. This means that there is a significant difference in the post-test effect of students who use the AR-MicroC Augmented Reality Learning Module compared to students who are taught using a conventional approach. Thus, this shows that the total post test scores obtained by students in the treatment group are higher than those in the control group.

Table 6
t-Test for Comparison of Post-Test Means of Control Group and Treatment Group

Group	N	Mean	Standard Deviation	t	df	Significant Value
Control	34	54.76	9.608	-10.334	59.986	0.001
Treatment	32	75.97	6.916			

*significant value at p = 0.05

Research Questions 3
Is there a difference in the mean scores of the pre-test and post-test compared to the control group?

The study found based on Table 7 that the paired t value for the pre- and post-test results for the control group is equal to t (33) = -11.987 and the level of significance is equal to p=0.001 which is smaller than 0.05 ($p < 0.05$). From those results where the p value is smaller than 0.05 shows that there is a significant difference for the mean of pre-test and post-test for the control group. So, hypothesis H_{o3} is rejected. This is because the findings show that there is a significant difference between the pre-test mean and the post-test mean for the control group students.

Table 7
t-Test for pre and post test mean comparison of the control group

	N	Mean	Standard Deviation	t	df	Significant Value
Pre-Test	34	31.911	7.497	-11.987	33	0.001
Post-Test	34	54.765	9.608			

*significant value at p = 0.05

Research Questions 4
Is there a difference in the mean scores of the pre-test and post-test compared to the treatment group?

The paired t value for the pre and post test results in Table 8 for the treatment group is equivalent to t (31) = -36.195 and the significance level is equivalent to $p < 0.001$ which is smaller than 0.05 ($p < 0.05$). From the results where the p value is smaller than 0.05 shows that there is a significant difference for the mean pre-test and post-test for the treatment group. So, hypothesis H_{o4} is rejected. This is because the findings show that there is a significant difference between the pre-test mean and the post-test mean for students taught using the AR-MicroC Augmented Reality Learning Module.

Table 8
t-Test for pre and post test mean comparison of the treatment group

	N	Mean	Standard Deviation	t	df	Significant Value
Pre-Test	32	28.56	6.390	-36.195	31	0.001
Post-Test	32	75.97	6.916			

*significant value at p = 0.05

4. Conclusions

The results show that the AR-MicroC Augmented Reality Learning Module is significantly effective in improving the achievement of understanding the concept of Microcontrollers in the Introduction to Internet of Things course. The mean score of the achievement test for both groups increased linearly from the pre-test to the post-test. This finding confirms that the AR-MicroC Augmented Reality Learning Module is effective in improving the achievement of Microcontroller concepts in the STM30273 Introduction to Internet of Things course at Community College. Overall, there was a positive change in the effect of the AR-MicroC Augmented Reality Learning Module on the respondents. The findings of this study are in line with the findings of previous studies on the effects of learning modules based on electronics and microcontrollers, such as studies [34-37].

Future research could benefit from considering a larger and more diverse sample to enhance the validity and reliability of the findings. Additionally, adopting a longitudinal approach would provide valuable insights into the long-term impact of the AR-MicroC module on student learning outcomes and knowledge retention. This approach would help to further validate its effectiveness and identify areas for refinement to ensure sustained benefits in teaching and learning processes.

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