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Need Analysis for The Development of Augmented Reality-Based Electronic Design Application in Secondary School Design and Technology (D&T) Subject

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ABSTRACT

Students should be introduced to computer programming in order to generate computer programming experts. However, there are many constraints in introducing students to the basics of programming and microcontrollers in Design and Technology subjects in schools. The use of the latest technology is becoming a demand in implementing the best teaching and learning and it has been an essential component of the educational process. One of the latest technologies used in education is Augmented reality which has a positive effect on students' learning. The study used a Design and Development Research (DDR) design consisting of three phases. This paper discusses the findings of the first phase (needs analysis) of the study, which was conducted to determine challenges in the implementation of the second form Design and Technology curriculum, the potential use of mobile devices in teaching and learning, as well as the need for the development of augmented reality-based Electronic Design learning applications as an aid in teaching in secondary school D&T subjects. Online surveys were employed in this study, and they were sent to second-form RBT teachers via school email. Statistical Packages for Social Science (SPSS) version 27.0 was used to perform a descriptive analysis of the study's data using the mean (M) and standard deviation (SD). Based on the analysis of survey data among 138 respondents, it was discovered that the average mean value for the challenge aspect of T&L implementation for D&T subjects was at a moderate level (M = 2.68, SP =0.52), indicating that there is still much space for improvement in this aspect. Electronic Design is the topic that is the most challenging to implement into the second-form D&T curriculum. High levels of agreement were found in a descriptive examination of the teacher's perceptions of the possible usage of mobile devices (M = 4.10, SD = 0.68). The average mean for the study of the development need of the augmented reality-based electronic design application is high (M = 3.89, SD = 0.55), indicating that it is necessary to develop it as a support material for second-form D&T courses. The findings of this study are crucial in ensuring that the design and development of a mobile application as a teaching aid for microcontroller education are put into practice and have a positive effect in enhancing secondary school students' literacy in programming.

Keywords:
TVET; Design and Technology (D&T); learning application; augmented reality; digital learning; mobile learning

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1. Introduction

The Secondary School Standard Curriculum, which replaces Living Skills with Design and Technology (D&T) subjects beginning in 2017, is being changed to align with the Ministry of Education's strategy to develop a young generation that is creative and critical-thinking in order to prepare the workforce for IR 4.0. The secondary curriculum incorporates the study of microcontrollers and programming through the topics of Electronic Design (form 2) and Mechatronic Design (form 3). Students must have a firm understanding of Electronic Design in order to comprehend the subject of Mechatronics Design. Electronic Design topic that includes learning about programming and microcontrollers require students to achieve specific learning standards, as shown in Table 1.

Table 1
Learning standards for electronic design topic in D&T

Learning Standards	Interpretation of Learning Standards
2.4.1	Specifies the meaning of microcontroller and microprocessor
2.4.2	Explains the parts in the microcontroller
2.4.3	Produce sketches of electronic circuit designs.
2.4.4	Build a simulation circuit that works with special software.
2.4.5	Makes the connection of the input circuit and the output circuit to the microcontroller
2.4.6	Writing simple programming based on the connection of input circuits and output circuits.
2.4.7	Testing and evaluating the functionality of electronic circuits.
2.4.8	Proposed improvements to the design of electronic circuits.

The application of programming skills through D&T subjects is relevant to provide students with the future employment as a source of the national workforce. This is because the programming skills and knowledge of microcontrollers are critical as they are central to robotic technology and automation, which are closely related to today's technological advances [1].

Aspects of the skills of making electronic wiring connection and programming basics a major problem in the teaching of electronics and microcontrollers causes poor mastery of students on this topic [2]. Past studies have shown there were numerous limitations on how Electronic Design concepts are taught and learned in RBT classes at schools. One of them is the lack of student knowledge of this subject, and students find it challenging to comprehend and respond to the Teaching and Learning (T&L) process of Electronic Design themes as a result of the constrained teaching time [3]. The results of the Abdul Ghani *et al.,* [4] study, which demonstrate that the topic of Electronic Design is one of the most challenging ones to apply creativity in teaching and learning due to the lack of knowledge and skills of teachers as well as the insufficient teaching aids to support teachers in implementing effective teaching can serve as further support for this [5-7]. Although there were some hardware platforms for teaching computer programming to students, but there hasn't been much comparative evaluation of them in a formal classroom setting [8]. Because of this, teachers are unable to choose the most effective teaching tool to use while implementing teaching and learning for Electronic Design topic.

The microcontroller learning approach in Electronic Design often relies on physical hardware, which is expensive and has limitations in terms of deprivation and accessibility in the classroom. In a study of challenges in secondary school D&T subjects, discovered that, in addition to the teachers lack prerequisite knowledge in the topic of Electronic Design, constraints in providing an adequate set of microcontroller for students' use led teachers to teach only theory and not implement projects in class, resulting in students not mastering the basic skills in microcontroller learning and programming [9].

To address these issues, many forms of media and multimedia have been developed to aid in the learning process [10]. In this context, the augmented reality (AR) mobile application has emerged as a promising solution to improve the teaching and learning of microcontrollers in schools. AR apps can provide a safe and cost-effective way for students to experiment with microcontrollers without the need for physical hardware [11]. Students can visualize complex concepts, observe how microcontrollers interact with the physical world, and gain a deeper understanding of their functions. Systems for augmented reality (AR) allow users to view virtual content in their real-world surroundings, giving the impression that the content is existing in the environment. Due to the existence of devices like phones, tablets, and handheld gaming consoles over the past ten years, AR technology has swiftly become practical for commercial and academic initiatives, and relevant in a variety of disciplines, including education and simulated training [12]. This is marked by almost all children already have a smartphone [13].

Furthermore, complex concepts that are difficult to explain in microcontroller learning and programming cause teachers to have trouble implementing effective teaching in the classroom. Studies that explore teachers' teaching practices in programming teaching are still lacking in the Malaysian context [1]. Using the features of this AR application, users can more easily visualize 3D objects, and better manipulate and study them.

2. Methodology

2.1 Research Design

This study uses a Design and Development Research (DDR) approach founded by Richey and Klein [14] to design and develop systematic teaching and learning applications. The DDR approach originally had four phases which is I-Requirement Analysis Phase, II-Design Phase, III-Implementation Phase, and IV- Assessment Phase. However, the DDR approach has been modified by Saedah *et al.,* [15] to adapt it to various areas of research and not only focus on the field of instruction. This modified DDR approach has only three phases. Figure 1 shows the phases contained in the modified Design and Development Research (PRP) approach.

Fig. 1. Phases in modified design and development research (DDR) approach [15]

2.2 Respondents of the Study

Respondents involved in this study were randomly selected among teachers who taught form two Design and Technology (D&T) subject. A total of 42 schools were selected using cluster sampling from five zones (northern zone, eastern zone, central zone, southern zone and Sabah/Sarawak zone), involving 138 teachers.

2.3 Research Instrument

The study collected data using a questionnaire instrument consisting of four parts as shown in Table 2.

Table 2
Questionnaire's section

Section	Construct
A	Respondent demographic information
B	Challenges of Teaching and Learning Implementation in D&T Subject
C	Use of Mobile Devices in Teaching and Learning
D	The Need for Application Development

Five-point Likert scale was used to create questionnaire items to collect responses using questionnaire. The five-point Likert scale was used in the study questionnaires which were Strongly Agree (5), Agree (4), Uncertain (3), Disagree (2), and Strongly Disapprove (1).

Statistical Package for the Social Science (SPSS) software version 27.0, was used to analyse the data that had been gathered. Demographic data from the respondents was examined using descriptive statistics. In this survey, the following descriptive statistics were used: frequency, percentile, min value and standard deviation. The following is an interpretation Table 3 of the mean score for the responses gathered, based on Tschannen-Moran and Gareis [16].

Table 3
Min value according to five Likert scale

Min Score Value	Interpretation
1.00-1.80	Very Low
1.81-260	Low
2.61-3.40	Moderate
3.41-4.20	High
4.21-5.00	Very High

2.4 Validity of the Research Instrument

The research instrument has been reviewed and verified by four experts to verify the content and language of the questionnaire. Questionnaires are distributed to the survey respondents online via school email, after receiving permission from the schools' administration.

2.5 Reliability of the Research Instrument

The reliability coefficient is a good indicator in showing the level of confidence and consistency of the respondents in answering the questionnaire. The stability and internal consistency of the questionnaire are considered indicators of an instrument's reliability. With a range of 0.00 to 1.00, Cronbach's Alpha can be used to calculate the questionnaire's level of reliability. A high level of reliability is indicated by a rating close to 1.00. Table 4 shows the interpretation of Cronbach's Alpha according to Hair Jr *et al.,* [17].

Table 4
Interpretation of Cronbach's Alpha reliability coefficient [17]

Cronbach's Alpha Value, α	Interpretation
> 0.90	Excellent
0.80 – 0.90	Very good
0.70 – 0.80	Good
0.60 – 0.70	Moderate
<0.60	Poor

Pilot study using questionnaire instrument aims to ensure high reliability and validity while overcoming difficulties that may arise in actual studies are available [11]. The questionnaire was administered to 30 respondents who were chosen randomly from the population. The reliability based on Cronbach's Alpha values was investigated in this pilot study. Examining Table 5 reveals that the Cronbach's Alpha for each construct is more than 0.70. High Cronbach's Alpha value index scores greater than 0.70 imply that the questionnaire is good, reliable and can be used in the actual study.

Table 5
Cronbach's Alpha reliability coefficient for each construct

Section	Construct	Number of Item	Cronbach's Alpha
B	Challenges of teaching and learning implementation	9	0.761
C	Use of Mobile Devices in Teaching and Learning	8	0.794
D	The Need for Application Development	6	0.841

3. Results

3.1 Respondents' Demographic Profile

This section discusses the general profile of the respondents, including information on each respondent's gender, age, educational level, and prior teaching experience in the field of Design and Technology (D&T). The outcomes are displayed in Tables 6 until Table 9 using frequency and percentage.

Based on Table 6, majority of the respondents were female who made up 69.7% of the total respondents. The majority of respondents (42.9%) are between the ages of 31 and 40. With 89.10%, the majority of respondents hold at least a bachelor's degree in terms of their level of education. Majority of the respondents, 52.11% had experience teaching form two D&T subjects more than 48 months or 4 years.

Table 6
Respondents' demographic information

Item	Category	Frequency	Percentage (%)
Gender	Male	40	28.99
	Female	98	71.01
	Total	138	100.0
Age	<20	2	1.45
	20-30	15	10.88
	31-40	61	44.20
	41-50	44	31.88
	>50	16	11.59
	Total	138	100
Education	SPM	1	0.72
Level	Diploma	4	2.90
	Degree	124	89.86
	Master	9	6.52
	PhD	0	0
	Total	138	100
Experience	12 month & less	10	7.25
Teaching	13 – 24 months	12	8.70
D&T	25-36 months	17	12.32
	37-48 months	26	18.84
	>48 months	73	52.89
	Total	138	100

To evaluate if the distribution of the data was normal or abnormal, a normality test using Skewness and Kurtosis was performed. Table 7 shows the value of Skewness and Kurtosis for the constructs ranged between -2.00 to 2.00, and this indicated that the data collected was in normal distribution [18].

Table 7
Results of normality test using Skewness and Kurtosis

Section	Construct	Values of normality test	
		Skewness	Kurtosis
B	Challenges of Teaching and Learning Implementation	0.464	-0.170
C	Use of Mobile Devices in Teaching and Learning	0.032	-0.437
D	The Need for Application Development	-0.389	0.141

3.2 Challenges of Teaching and Implementing Form Two D&T Subject Based on Teacher's Perception

3.2.1 Analysis of the most difficult topic in D&T subject (form two)

There are nine application technology topics in the D&T syllabus for secondary schools, with form two having the highest with six topics. Respondents were asked to select the form two D&T subject's most difficult topic according to their perspectives. Figure 2 summarises the information provided by the respondents.

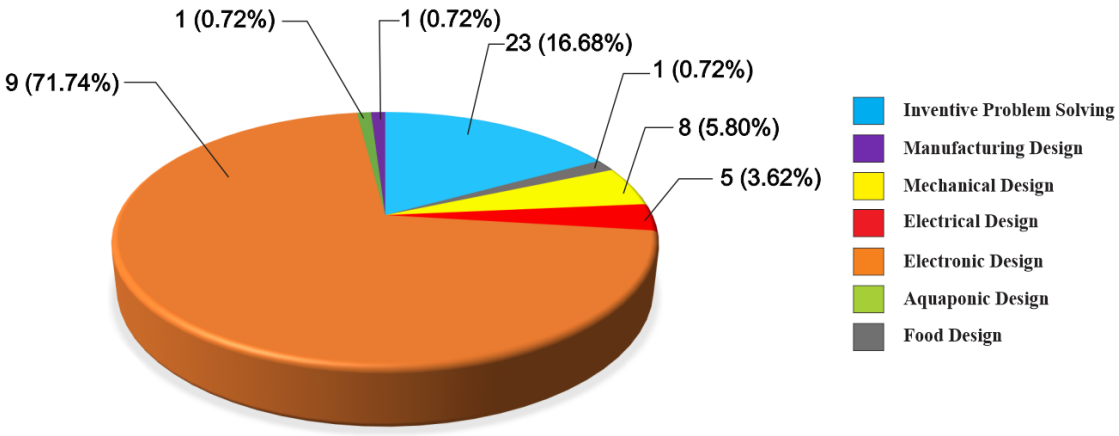

Fig. 2. The most difficult topic in form two D&T subject

3.2.2 Challenges of teaching and implementing form two D&T subject

In the second section of the questionnaire, there were nine items constructed to determine the teachers' perceptions on the challenges faced in implementing teaching and learning in D&T subject. Table 8 displays the results of descriptive statistics of 138 teachers and their perceptions.

The findings revealed that the value of overall mean score was 2.68, which was in the moderate level. Analysing each item, there are five items in the low mean score. The items include B5 (Mean = 2.41& SD = 0.58), B6 (Mean = 2.49 & SD = 0.70), B9 (Mean = 2.33 & SD = 0.87), B10 (Mean = 2.42 & SD = 0.72). Four items were in the moderate mean which are B3 (Mean = 2.83& SD = 0.69), B4 (Mean = 2.67 & SD = 0.76), B7 (Mean = 2.80 & SD = 0.86), B8 (Mean = 2.81 & SD = 0.84). Only one item has a high mean value which was item B2 (Mean = 3.38 & SD = 0.69). The findings for part B of this questionnaire show that there are several aspects that present significant challenges in the implementation of form two D&T subject especially in Electronic Design topics, and need to be addressed well.

Table 8
Challenges of teaching and implementing form two D&T subject

Item Code	Item	Mean	SD	Interpretation
B2	I mastered the topic well in theory.	3.38	0.69	High
B3	I am good at guiding students to carry out projects for the topic.	2.83	0.69	Moderate
B4	Students are able to master the topic well despite the complex content of the syllabus.	2.67	0.76	Moderate
B5	The training provided for the teacher are sufficient to help me master the topic well.	2.41	0.58	Low
B6	Teaching aids for the topic are sufficient to facilitate the students' understanding.	2.49	0.70	Low
B7	Digital teaching resources aligned with the curriculum standards are easily available.	2.80	0.86	Moderate
B8	Project implementation guidance for the topic is provided to help teachers guide students in carry out projects.	2.81	0.84	Moderate
B9	The tools/equipment in the workshop are sufficient for all students to implement the project.	2.33	0.87	Low
B10	The time allocated in the curriculum standards for the topic is sufficient.	2.42	0.72	Low
	Overall	2.68		Moderate

3.3 Use of Mobile Devices in Teaching and Learning

In the third section of the questionnaire, eight items were designed to assess teachers' perception on the use of mobile devices in D&T teaching and learning. The results are presented in Table 9. The analysis indicated that the min score of that particular feature was 4.10. Based on the interpretation Table 3 by Tschannen-Moran and Gareis [16], the respondents' acceptance in using mobile devices in D&T teaching and learning recorded a high level [19]. Five items recorded high mean scores which are C1 (Mean = 4.01, SD = 0.65), C4 (Mean = 4.19, SD = 0.52), C5 (Mean = 3.88, SD = 0.51), C6 (Mean = 3.97, SD = 0.60), and C7 (Mean = 4.03, SD = 0.66). The rest three items show a very high mean value which are items C2 (Mean = 4.30, SD = 0.61), C3 (Mean = 4.22, SD = 0.68), C8 (Mean = 4.23, SD = 0.53).

Table 9
Use of mobile devices in teaching and learning

Item Code	Item	Mean	SD	Interpretation
C1	I have the skills to use a mobile device when teaching D&T subjects	4.01	0.65	High
C2	The use of mobile devices can save the time of preparation of teaching materials.	4.30	0.61	Very High
C3	The use of mobile devices can improve my students' understanding of the topics taught.	4.22	0.68	Very High
C4	The use of mobile devices allowed me to implement T&L more creatively and interestingly.	4.19	0.52	High
C5	The use of mobile devices is suitable for students to use for the purpose of learning in the classroom.	3.88	0.51	High
C6	The use of mobile devices can maintain the focus of students in the classroom on the topics taught.	3.97	0.60	High
C7	Mobile devices can be used for various purposes in T&L	4.03	0.66	High
C8	The use of mobile devices in PdP can improve students' efficiency in ICT	4.23	0.53	Very High
	Overall	4.10		High

The findings of this section show that all items regarding mobile device usage are well accepted among D&T teachers, which indicates that teachers are willing to take advantage of mobile devices in teaching and learning sessions [20].

3.4 The Need for Application Development

3.4.1 The types of microcontrollers used the most in electronics design teaching and learning

Table 10 summarises the information provided by the respondents about the types of micro controller used the most among the respondents. According to the results, there was no big difference between D&T teachers using Arduino and Magnetcode microcontrollers in schools, with 54.35% of teachers using Arduino boards and another 45.65% using Magnetcode board in T&L.

Table 10
The types of microcontrollers used in electronics design T&L (d1)

Microcontroller	Frequency	Percentage (%)
Arduino	75	54.35
Magnetcode	63	45.65
Others	0	0
Total	138	100.00

3.4.2 The need for application development

Seven questions were included in the questionnaire's fourth section to access the teachers' perception on the need of an Augmented Reality (AR)-based Electronic Design application for the D&T curriculum. Table 11 shows the findings of the results.

Table 11
The need for application development

Item Code	Item	Mean	SD	Interpretation
D2	For the Electronic Design topic, modern teaching methods using technological tools are more suitable for compared to conventional teaching methods.	4.09	0.74	High
D3	Electronic Design Applications based on Augmented Reality (AR) should be developed as the realistic use of digital resources can improve students' understanding on the topic.	3.88	0.63	Very High
D4	The Augmented Reality (AR)-based Electronic Design app should to be developed as it allows students' learning regardless time and place limitations.	3.51	0.80	Very High
D5	The Augmented Reality (AR)-based Electronic Design Application should be developed as a support source for implementing effective T&L.	3.95	0.76	High
D6	The Augmented Reality (AR) application complete with the implementation guide of the Electronic Design project should be developed to save teachers' preparation time in implementing T&L.	4.03	0.76	High
D7	The use of Augmented Reality (AR)-based Electronic Design application can makes T&L sessions more enjoyable.	3.86	0.63	High
	Overall	3.89		High

4. Conclusions

The study's conclusions have supported the need for developing a digital learning application which integrates Augmented Reality as a teaching aids resources for the Electronics Design topic in Design and Technology (D&T) subject in Malaysia. The development of a mobile learning application of Electronic Design in Design and Technology subject provides an opportunity for the students to better acquire the knowledge about microcontroller and the skills in programming. Based on the findings in this need analysis, the topic in Form 2 D&T subject, Electronic Design perceived to be the hardest topic to be taught and learnt by students, based on the perception of the teachers. In conclusion, there is a need to develop an Augmented Reality (AR)-based Electronic Design application as a teaching aid in class. Based on the findings of this study, it was found that teachers can receive the use of mobile devices in teaching and learning sessions in the classroom to help the teachers to plan and conduct a more successful teaching session to promote meaningful learning among students.

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