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The A-rray: Visual Animation in Learning Structured Programming

Wan Salfarina binti Wan Husain[1], Siti Hasrinafasya binti Che Hassan[2], Wan Norliza binti Wan Bakar[3]

[1,2,3] Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA Kelantan, Bukit Ilmu, Machang, Kelantan, Malaysia
[1]salfa457@.kelantan.uitm.edu.my,
hasrina581@kelantan.uitm.edu.my, wliza349@kelantan.uitm.edu.my

Abstract: In mastering computer programming language, the logical thinking skills have been proposed as a fundamental knowledge. Unfortunately, the logical reasoning among UiTM students in computer problem solving usually results in high failure rates. Thus, there is a need to find alternative solutions to improve the students' logical thinking skill in computer problem solving. The visual animation is considered to be a very promising potential to aid students in learning and understanding the algorithm concept in programming. According to the result of students' learning style by using a set of Learning Style Inventory, 54% of students are visual thinkers. Thus, this paper is proposing a conceptual model in developing an interactive multimedia courseware named *The A-rray* to reinforce the basic concepts of programming such as summation, average, counting and searching. The ADDIE model of instructional design was used to develop the application.

Keywords: Interactive Multimedia, Structured Programming, Visual Animation, Weak learners

1 Introduction

At Universiti Teknologi MARA (UiTM), Structured Programming is one of the core courses that must be enrolled by students in a Diploma of Computer Science. In this course, one of the main topics that will be covered is manipulation of single dimensional (1-D) arrays by using C++ programming language. Most of the computerized problem in the 1-D array is related to the basic mathematical operations such as summation, average, counting, and searching. Based on the informal interviews with the students who are taking this course, 80% of them have complained that the topic is quite difficult to understand and visualize its algorithm concept before it can be continued with the implementation of programming. This is because, according to [1], the programming requires problem solving and analytical thinking skill; unfortunately these skills are found to be deficient among many students pursuing computer programming courses. Therefore, the techniques that basically educators been practiced and conducted in class which is by using face to face teaching and learning can be changed to multimedia technological learning and teaching methods. The teaching of new concepts and hands on practical skills such as programming can be combined with animation and visuals to obtain the greater effect [2]. This approach is very suitable to tackle weak learners who are mostly the visual thinkers, as stated by [3] that everyone learns best with a visual presentation. The characteristics of the weak learners are students who have problems in adapting to the learning process[4] which are slow to understand concepts, unable to retain information for long and have difficulties in applying their knowledge to various situations[5]. Thus, there is a need to find alternative solutions to improve the students' logical thinking skill in computer problem solving. The visual animation is considered to be a very promising potential to aid students in learning and understanding the algorithm concept in programming.

This research is proposing a conceptual model in developing an interactive multimedia courseware named *The A-rray* to reinforce the basic concepts of programming such as summation, average, counting and searching. The design of *The A-rray* is different from the conventional approaches that require the students to follow full reading process to learn, which cause boredom to the students. According to [6], the most effective teaching methods

are those that encourage active student participation (such as role playing, simulations, etc.) and interaction with peers and lecturer (in formal or informal discussion). Thus, the aim of this application is to encourage self-regulated learning among students. There are three visual tutorials that students can explore by themselve according to the three levels of difficulty (namely; easy, moderate and difficult). The easy level is focusing on the declaration of an array with a certain size. Meanwhile, the moderate level interactively illustrates about the storage of the contents in an array according to the specific location in memory. Lastly, the difficult level shows the manipulation of an array by using four basic algorithms: summation, average, counting and searching. In each module above, a feature known as Pointer Animation with Color is applied to explain the algorithms involved in computer problem solving. The set of algorithms displayed will generate particular C++ codes based on user-friendly control button to accommodate weak learners in visualize the whole structured of programming process. The ADDIE model of instructional design was used to develop the application. In this model, there are five stages that have been conducted; Analysis, Design, Development, Implementation and Evaluation. The detailed explainations for each stage are discussed further in the Section 3.

2 Literature Review

Multimedia courseware is one of the solutions in dealing with students' differences in learning styles and knowledge background since it integrates media elements that can engage human information retrieval methods which are visual, auditory, reading and kinaesthetic [7], [8]. The discussions of visual, auditory and kinesthetic are common in educational literature, to help the teachers prepare the materials in teaching and for professional development workshops even in psychology. The theory that students learn more when 1) the content is presented in best modality such as repetition / rote learning technique, 2) teaching and learning process are supported by classroom facilities and technology which produce a dynamic atmosphere, and 3) promotes self-regulated learning according to students' learning styles.

Rote learning is a memorization technique based on repetition concept. Memorizing knowledge is essential for meaningful learning and problem solving when that knowledge is used in more complex tasks[9]. The main idea towards rote method is that the students are able to recall the learning materials more than one time, which is repeated process. Rote learning is widely used in mastering a fundamental knowledge such as in school that include reading, multiplication table and also basic formulae in science.

In learning process, the students' problem is actually related with human visualization ability[7]. In other words, the students do not have ability to see the hidden or unclear information representation in problem solving. Several studies have demonstrated positive impact of using animations on understanding complex processes and complicated task. In general educational terms, animations can be viewed as a technique of visualization [10]. With the concept of visual animation, the learning process makes it possible to prevent misconceptions in learning and can guide the students' to develop the new knowledge. According to [11], the advent of ICT eased the burden on the necessary resources for the teaching and learning processes. Nowadays, multimedia applications are used in education to transfer the knowledge effectively, and also to enhance the ability of teaching and learning processes [12]. Thus, by using the visual animation applications, the burden of face to face teaching can be reduced especially for the weak learners who are mostly the visual thinkers.

The evolution from teacher controlled learning environment to self directed learning education has highlighted the need for students of all ages to develop self-regulated learning skills. Self-regulated learning (SRL) emphasizes the autonomy and control by the individuals who direct, monitor, and regulate learning to achieve their goals and expertise[13]. Self-regulated learning also involve with students manage their own emotions, cognition, behavior[14] and the context during learning process such as good time management and the ability to select the most efficient problem solving strategies. It has become a common theme in education field which plays a vital role during the learning process, and when the students start practicing their expertise in the real world.

The purpose of developing an instructional model based on the visual animation is to help educators ensure that they are teaching the appropriate materials in a correct way.The ADDIE model is one of instructional design model that very famous in multimedia design and suitable to be applied in education field. The phases of this model include analysis, design, development, implementation, and evaluation[15][16]. Each phase of the model has an important element of constructing the instructional design process. In each phases, the instructional designer makes the decisions that are critical for ensuring the effectiveness of the instructional experience.

In reality, not all visual animation software is suitable for all users. Hence, to design good software, the developers and designers need to study the effectiveness and the usability of the software that match with the learning styles. Refer to effectiveness meaning, the goal of the software need to be clear before designing tasks. Reflecting with this, a good usability testing need to be done. The usability testing is the key importance in human computer interaction which is the basic elements used to verify the user interface quality [17].

3 Method

This conceptual model is designed for an interactive multimedia courseware named *The A-rray* that integrates with visual animation for learning structured C++ programming language. The ADDIE instructional design that was introduced by Dick & Carey in 1978, was used as a guideline to provide step-by-step methods that assists in developing the application coursware. Its components are as follows: Analysis, Design, Development, Implementation, and Evaluation. These five development phases are summarized in **Figure 1**.

A Analysis

Analysis phase identifies the actual instructional needs or learning problems among the weak learners. In this initial phase, the developers gathered 1) the specific scope of the critical topics that need to be focused, and 2) the necessary techniques and approaches used to tackle the weak learners in attaining and perserving the learning process. Hence, several methods have been used to obtain the above information such as formal and informal interviews about educators' experiences in teaching weak learners in programming course, and observations of students' learning and performance in the classroom.

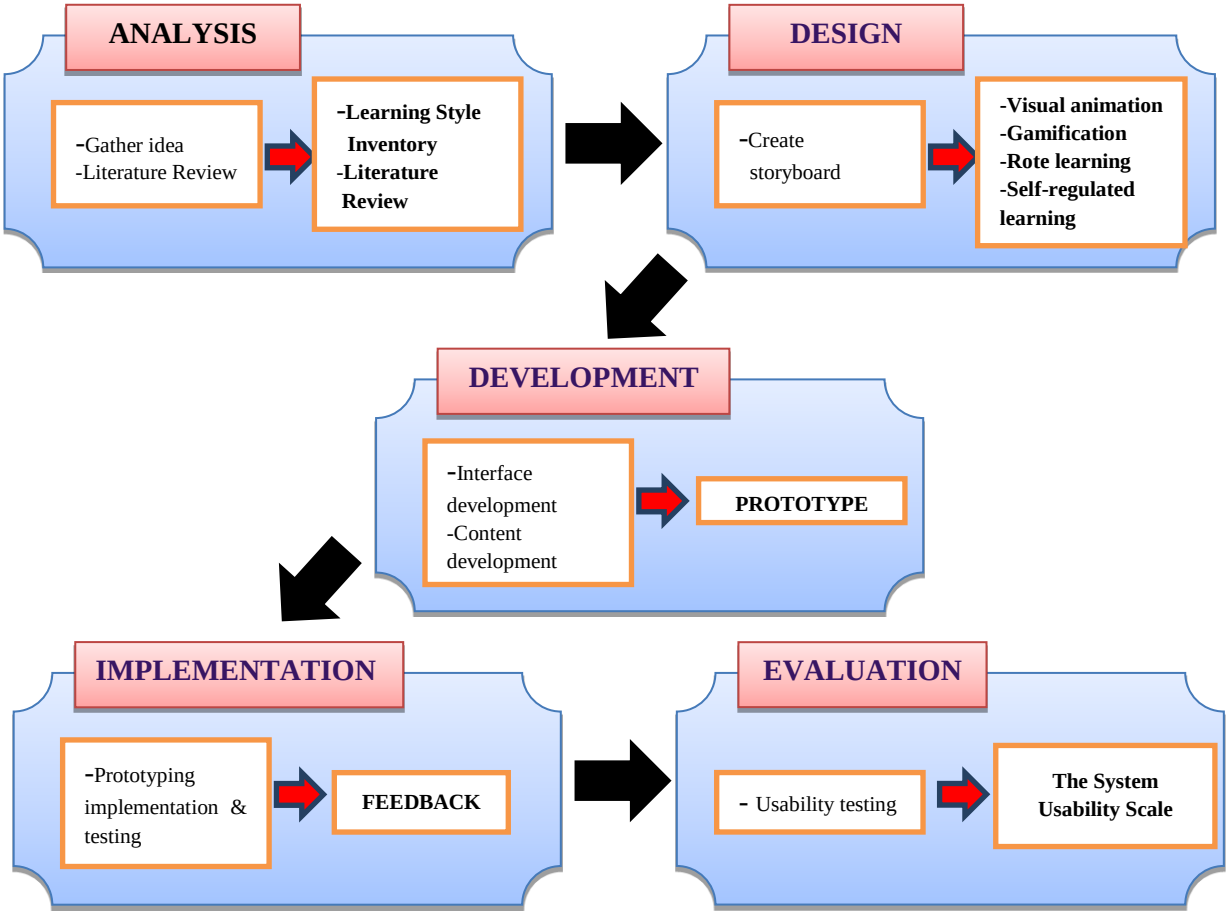

Figure 1: The development phases

A special questionnaire instrument named Learning Style Inventory developed by Dawna Markova containing 12 questions has been distributed to 50 Computer Science students to determine the most preferred student learning styles. The purpose of this data collection is important to determine the overall concept of the prototype delivery in the next design phase, such as sensory multimedia elements (text, image, animation and video), as well as useful and creative techniques to help weak learners interact with the proposed application.

B Design

During the design phase, the developers created an entire storyboard (refer Figure 2) that illustrates the pre-visualization of the composition of the instructional content interfaces according to the three distinct difficulties (easy, moderate and difficult). The instructional contents include interactive tutorials and quizzes have been designed in accordance with the learning objectives and needs of the students.

Several gamification elements in learning are integrated to promote a self-learning experience among weak learners. According to [18], game-based learning creates attraction, participation in the learning activities to understand the concept, and allows students to engage with educational materials in a playful and dynamic ways. The features are concluded in **Table 1**.

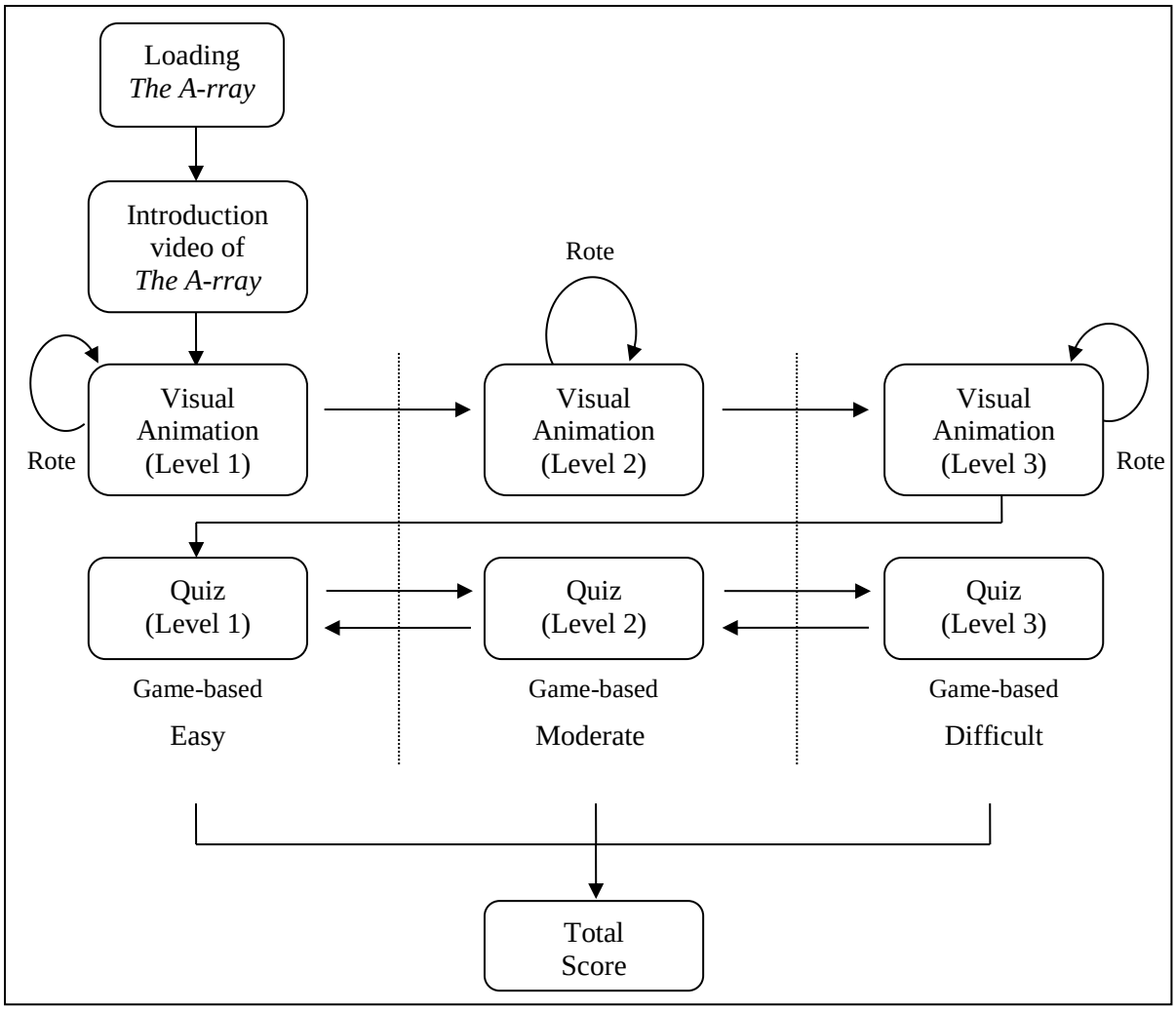

Figure 2: A Storyboard of the prototype

Table 1: Element of game-based learning

Game Features	Activities
Interaction	Students able to control and explore the instructional content display by clicking command buttons provided. It is either notification of prompt messages will be displayed for asking student's confirmation, or notification of alert message to avoid any abort process.
Simulation	Students can visually learn through the simulation of C++ programming codes that will be generated automatically according to the set of algorithms. A feature known as Pointer Animation with Color is applied to clearly reinforce the codes generated.
Participation Level	Participation points earned by each student is also linked to promotion in a level system that acts as "badges" for active learners of *The A-rray*. When a student earns a certain amount of points, (s)he is promoted up to the next level.
Scoring	At the end of the visual animation of the learning tutorial, three set of quiz questions are given to evaluate the level of students' understanding. Score for each set of quiz will be collected to get the overall score. Students are given a chance to improve their

	score before continuing to the next quiz assesment.

C Development

The development stage involved the implementation of the instructional strategies and appropriate multimedia elements that consistent with analysis of the learning styles and intended learners. A Visual Basic Programming Language was used to create this visual animation courseware. This type of programming language is chosen because its Graphical User Interface (GUI) will look and act like standard Windows programs, as it enables learners to control and explore the learning contents and activities in playful and interactive ways with the command button provided.

After choosing the method and concept of instructional content delivery in the previous designing phase, the development stages begin with the creating of interface according to the distinct difficulty modules (namely; easy, moderate and difficult). The appropriate functionalities and creative features (such as rote learning, and game-based learning) for each module were accordingly created to come out with the prototype as shown in **Figure 3** until **Figure 6**.

A prototype in **Figure 3** above depicts the first visual tutorial with user's control and self-exploring. The topic of this module is about on how to declare an array variable that can store many values with the approapriate data types (either integer, float or double). In this module, students can define their own array by setting array's name, size and particular data type. An error message will appear if the array's size inserted is non-integer number. Afterwards, the C++ programming codes will automatically generated as soon as the 'ENTER' button is clicked.

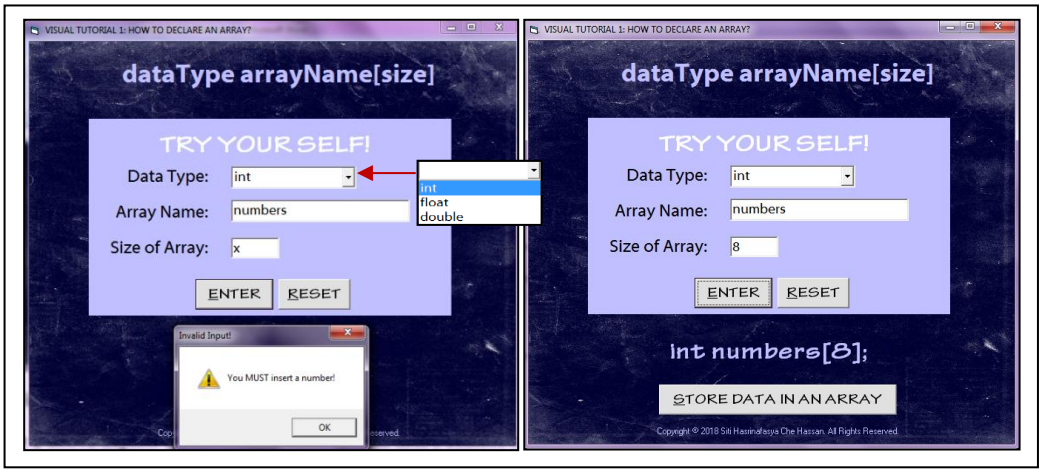

Figure 3: Visual animation level 1 (Easy)

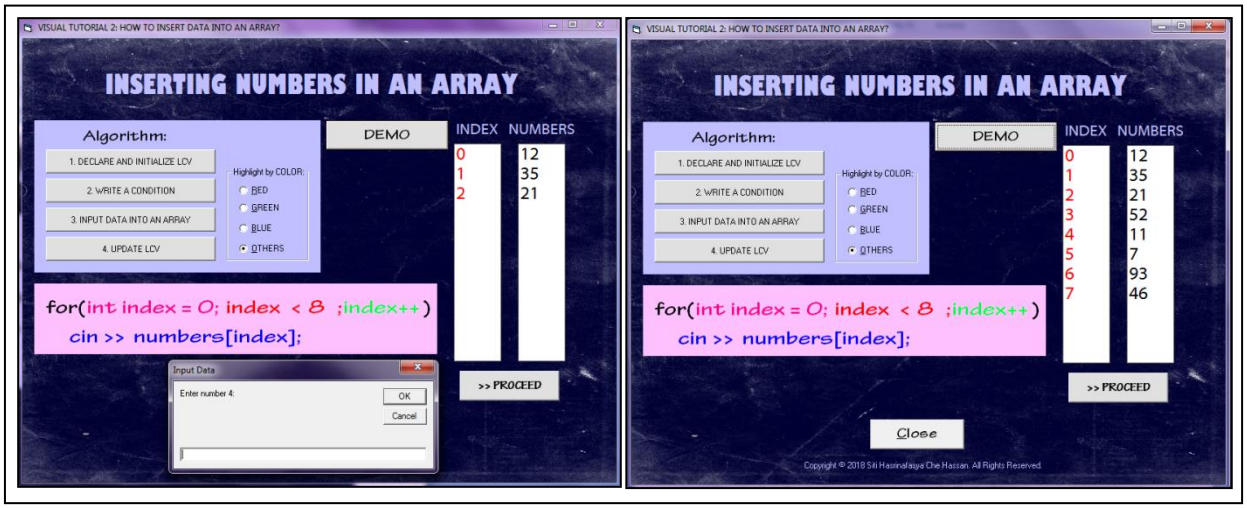

Figure 4: Visual animation level 2 (Moderate)

The second visual tutorial in **Figure 4** above demonstrates the process of inserting data into an array, where the number of data that can be entered is limited to the size of the array that has been defined by a learner in the first tutorial as in **Figure 3**. As the data is entered using the input box, it will be stored according to the corresponding index location in a memory. Subsequently, students can explore C++ programming code for all five basic operations in array manipulation such as summation, average, highest, lowest and count as shown in **Figure 5**.

In addition, colour is believed to be the most important visual experience and powerful information channel that can influences and improves human memory performance [19]. In all these three visual tutorials, colour can play a role in motivating learners to perceive, pay attention, remember, think and understand the syntax of the C++ programming codes that will be generated automatically according to the sequance of an algorithm.

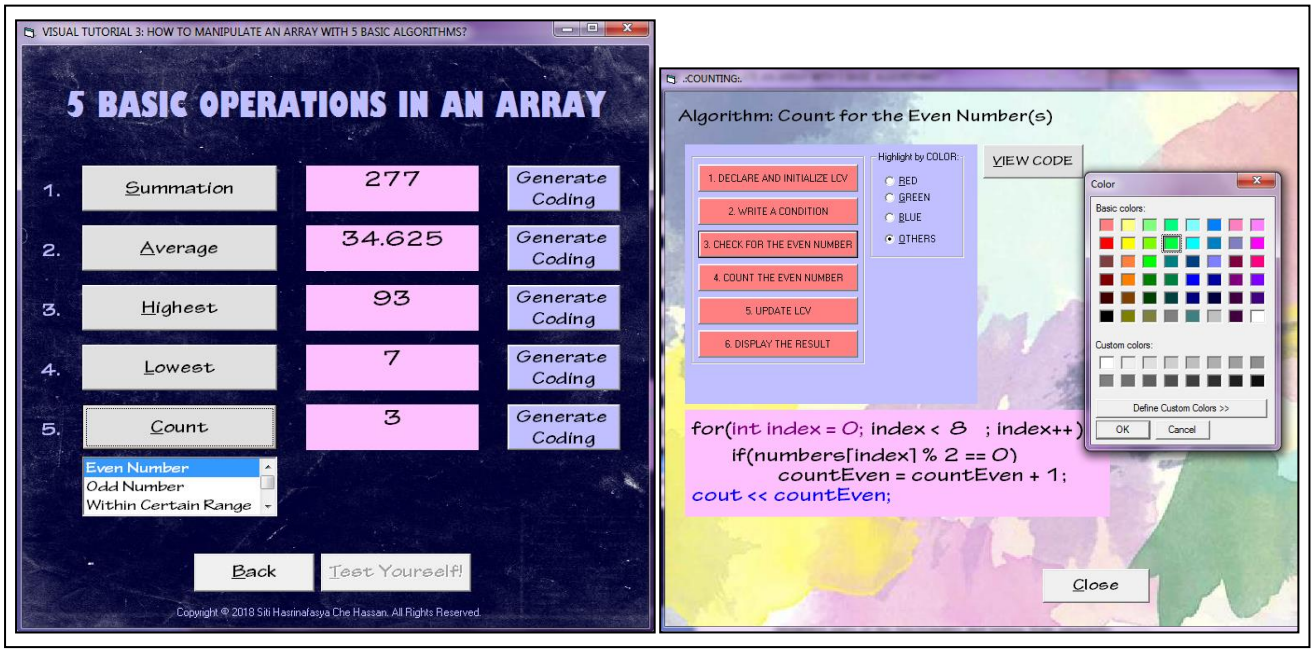

Figure 5: Visual animation level 3 (Difficult)

Three set of quiz questions are provided to evaluate the understanding level of students. Students are not allowed to continue to the next quiz level, if the number of questions correctly answered is less than 40%. Thus, student has a chance to improve his score obtained in each level of quiz. Lastly, the total of scores for each level of quiz will be accumulated to produce final mark.

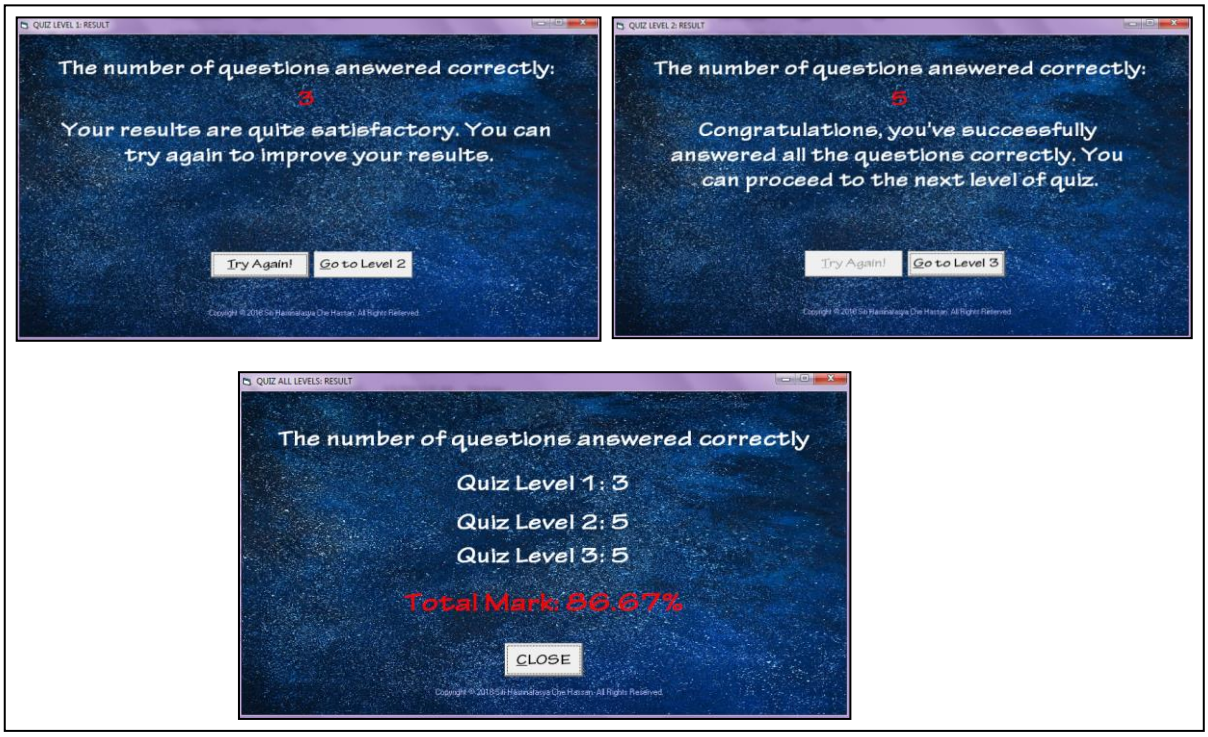

Figure 6: Quiz assessment

D Implementation

After careful analysis, design, and development, the proposed prototype will then be implemented and delivered to ensure that the application operates as needed. During this phase, all the Graphical User Interfaces were tested individually. Where, it is not only to verifies a code per the design specificitions, but also to uncover application's vulnerabilities. After that, every GUI unit has been integrated to test their continuity and functionality. Here, a few instructors were randomly asked to provide some feedbacks regarding to the design techniques such as user navigational control, exception handling and etc.

E Evaluation

Usability testing is the process that must be considered after completing the application implementation. In general, the goal of software evaluation is to ensure that the proposed application is practically executable and pleasing to the learners. Thus, the usability evaluation is specifically designed to assess the consistency of the Graphical User Interfaces (GUIs) and interaction of a system with the users. In practically, the usability evaluation is done through subjective user experiences with a self-evaluation questionnaire. Five question items from the System Usability Scale (SUS), as shown in **Table 2** was selected as an

evaluation tool in term of effectiveness, efficiency and users' satisfaction. The result of software usability testing was discussed further in the next section.

4 Result and Discussion

In this section, there two stages of evaluation will be discussed. The first analysis was conducted during the initial stage of development processes, to determine the students' learning style. The second **Table 2** below concludes an analysis based on the learning style of 50 Computer Science students who are currently taking on the subject of C ++ Structured Programming. The students' learning style can be categorized into six groups namely; Auditory Kinesthetic Visual (AKV), Auditory Visual Kinesthetic (AVK), Kinesthetic Auditory Visual (KAV), Kinesthetic Visual Auditory (KVA), Visual Kinesthetic Auditory (VKA), and Visual Auditory Kinesthetic (VAK). According to the analysis in table below, it was found that Visual learning styles that comprises of VKA and VAK dominates the overall learning styles. Where, the number of students who are categorized as visual thinkers is 27 students from 50 students, which is 54%. Thus, the researchers concluded that the use of visual animation as an aid learning tool can promise an increase in the interest and understanding of the students on the programming concepts.

Table 2: The analysis on Students Learning Style

	Auditory		**Kinesthetic**		**Visual**	
Learning styles / Group	**AKV**	**AVK**	**KAV**	**KVA**	**VKA**	**VAK**
Group 1	0	1	1	11	10	3
Group 2	0	3	1	6	12	2
Total	0	4	2	17	22	5

After the application was completely developed, the usability testing was done as the second analysis stage, in order to measure the effectiveness, efficiency and users' satisfaction towards system. A self-evaluation questionnaire towards software usability was distributed among 50 Computer Science students. From the survey, 55% of respondents agreed that they would like to use the application frequently, 66% of respondents agreed that the application is easy to use, 59% of respondents agreed that the various functions in the application were well integrated, 59% of respondents agreed that most people would learn to use this application very quickly, and 55% of respondents agreed that they felt very confident when using the application. Therefore, the researchers concluded that the majority of students are satisfied with visual animation software as an alternative learning tool in understanding programming subjects.

Table 3: The analysis of the SUS

No	**Questions**	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1	I think that I would like to use this product frequently.	0	8	27	55	10
2	I thought the product was easy to use.	0	4	22	66	8
3	I found the various functions in the product were well integrated.	1	3	26	59	11
4	I imagine that most people would learn to use this product very quickly.	0	7	26	59	8
5	I felt very confident using the product.	1	4	30	55	10

5 Conclusion

The visual animation with an interactive user controlled has been developed with gamification concept to accomodate the weak learners in learning Structured Programming. Many studies have shown that most of the logical reasoning of weak learners in computer problem solving usually results in high failure rates. In computer problem solving, there are at least five basic algorithms such as summation, average, counting, find the lowest value and find the highest value have been strengthened for the weak learners to refine their schematic knowledge in structured programming. Therefore, researchers feel that the use of the visual animation as a medium to learn the C++ programming language has proven to be effective in attracting students' interest in learning programming as well as enhancing students' understanding. With the interest and deep understanding of the concepts taught, the students would naturally excel in their tests and exams.

In this paper, the method of learning C++ programming through visual animation application integrated with gamification was considered as an alternative teaching and learning methods to the the current method as its effectiveness has been proven. The prototype of the application has been developed by adopting the ADDIE model as the main guideline for the entire developement process. Besides, the SUS survey was implemented to evaluate the effectiveness and usability of the multimedia courseware. The result of usability testing on the multimedia courseware indicates positive acceptance from the students. However, there are still rooms for improvement before gaining maximum acceptance from the students. The proposed prototype is considered has fulfilled the minimum characteristic as effective multimedia learning and suitable for visual thinker learning style. Thus, its effectiveness, efficiency and users' satisfaction toward learning results are still required to be tested furthermore at the next research. The paper concludes that a multimedia courseware integrated with visual animation and gamification concepts is an effective and usable learning tool for teaching and learning C++ Structured Programming language because it can positively contribute towards students understanding of the topic, thus, improving their performance and motivation in programming learning.

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