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Effectiveness and perception of augmented reality in the teaching of structured programming fundamentals in university students

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Abstract

INTRODUCTION: Even while studying programming languages is essential for science and technology education, some students, especially novices, may find it challenging. One reason might be that these pupils are unable to comprehend programming basics, notably the usage of selective and repeated structures (loops), which are too complex and abstract for them to comprehend.
OBJECTIVES: Programming structured applications requires understanding the relationship between variable-operators and declarations, so a more intuitive and practical visualization technique is needed. In view of this, this article presents an augmented reality (AR) learning system using a DF-RA mobile application that offers visual representation and interactivity to help college students in entry-level computer science-related majors learn to program structured applications using dynamic and interactive flowcharts.
METHODS: In order to examine the influences of said Augmented Reality-enhanced system on student learning, an experiment will be carried out within the group with 34 university students. All students used both an augmented reality-enhanced version and a conventional paper version (classic methodology with paper flowcharts).
RESULTS: The expected results is that the augmented reality version through the DF-RA mobile application made students have a better learning efficiency than the traditional paper system. In addition, the system enhanced with Augmented Reality also made students have improved perceptions in terms of system usability, flow experience, and usage perception.
CONCLUSION: Experimental findings were analyzed to demonstrate that the augmented reality learning system increases students' motivation to study structured programming fundamentals and their practical competence.

Keywords: programming fundamentals, augmented reality, usability, perception, augmented reality-based learning, flowcharts.

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1. Introduction

One of the newest abilities that are crucial for student learning in the 21st century is computational thinking. In this century, a generation of digital creators rather than consumers has emerged. As a result, a lot of nations have updated their educational systems by adding components of this skill to their curricula. Basically, the ability to understand how an event will unfold is a computational thinking skill. This capacity has been described using a variety of notions, each with its own special characteristics. According to Selby [1], the five elements of computational thinking are abstraction, algorithm, decomposition, evaluation, and generalization. It is acknowledged that in

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order to master computer science and IT, students must possess computational thinking abilities. [2] One of the foundational courses in computer science and information technology in higher education, computer programming requires students to learn and develop problem-solving, critical thinking, and writing codes in a specific programming language, making it a challenging subject to learn [3, 8]. It appears that most students frequently lack these abilities to enable them to learn computer science and IT courses efficiently. As information technology has grown, many tools have been created and used to improve student learning. Game-based learning, for instance, emphasizes the improvement of both interest and knowledge [4]. Additionally, several research look into how to improve students' understanding of programming by utilizing a 3D environment [5] or visual aids [6], and the conclusions of these studies show some promising results. Students should ideally have strong metacognitive skills as well as excellent cognitive capacities, from which knowledge and skills can be categorized [7]. Metacognitive information, in general, refers to the knowledge that aids students in keeping track of their learning. On the other hand, metacognitive skills cover activities like planning, keeping track of, and evaluating [9], [10]. As a result, developing metacognitive skills is necessary for teaching and studying computer programming [11]. Because it might provide a natural way to deliver information based on reality, augmented reality (AR)-based learning has recently drawn more study interest [12], [13], [14]. According to [15], augmented reality (AR) technology may present new chances to improve student learning in terms of contextual visualization and learning engagement. In terms of contextual visualization, augmented reality (AR) visualization combines the physical environment with synthetic sensory data produced by graphic computing and object identification technologies [16] [17]. Students might learn how to utilize programming codes to position items and grasp their relationships by using this visualizing approach. According to [18], augmented reality (AR) enables augmented information for the surrounding real world to become interactive and manipulable, which could encourage students to have positive attitudes toward exploration, inquiry, logical thinking, and reasoning. In essence, visualization and interactivity, two aspects of augmented reality, may be able to help beginners overcome their two biggest challenges when learning programming. Few research have examined how AR technology might be utilized to improve students' learning of the programming language and what the affects of such a system might be on student learning, despite the fact that AR technology's potential is valuable. This study intends to close this gap by creating an AR-based learning system and exploring how it affects student learning. The following research issues are more specifically covered in this study: (a) could a structured programming fundamentals learning system be created using augmented reality technology? (b) Does this AR-based education method aid in students' academic progress?

2. Design

Augmented Reality is an emerging technology, few studies have investigated how it can be used to help students learn structured programming fundamentals. To fill the gap, this study develops a learning system based on a DF-RA mobile application with Augmented Reality. Below are the two learning systems: the conventional paper version and the version of the DF-RA mobile application with augmented reality.

2.1. Conventional paper version

The content to be studied is problem solving through flowcharts, which allow students to solve problems of any kind; dividing it into a finite number of elementary steps and clearly indicating the order of execution by means of a set of graphic symbols. As illustrated in Figure 1, an ordinary version of the learning system contains two mechanisms to help students learn: the flowchart graph and the desktop testing of the variables (output) is done manually on a piece of paper.

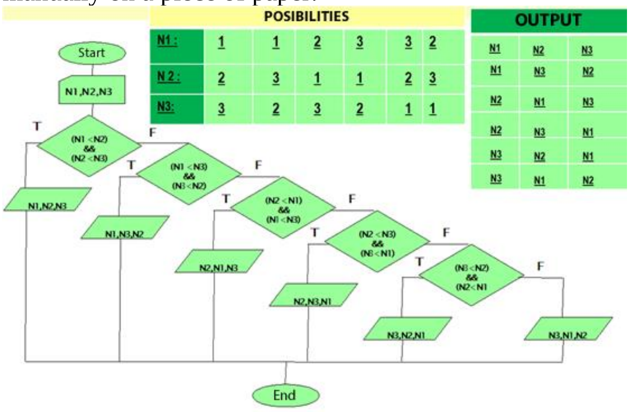

Figure 1. Conventional paper version of the learning system

The flowchart. It allows students to visually represent what operations are required and in what sequence they must be performed to solve a given problem. When students complete the flowchart correctly, the result is displayed in the display symbol on the screen. Students are required to remember the correct use of each symbol and its function in the diagram, the order and how they are used.

Desktop test of variables (Output). This element shows a view of the result of the value of the variables after the execution of the flowchart. The result illustrates from the user's perspective the different possibilities of values that the variables can take. In other words, when the student assigns different values to the variables and tests the flowchart, the result can be immediately observed. In this way, students can examine the output of the variables and further adjust the flowchart.

2.2. Mobile application DF-RA with Augmented Reality version

The DF-RA mobile application with Augmented Reality version offers students two mechanisms to help them learn: holistic environment and command cards, as shown in Figure 2. The flowchart in the version with augmented reality is different from the version on conventional paper. It is used to display the values of the equivalent variables for reference.

problems, especially the concept of simple and compound (nested) conditionals, loops for handling counters and accumulators of variable values.

This study used a within-subject experiment to assess the effects of the AR-based learning system. Participants were exposed to both the standard version (which is described in the section design of the traditional paper version) and the AR enhanced version (which is described in the section design of the mobile application DF-RA improved with Augmented Reality), and their responses to the two versions were then further compared. The participants were split into two groups (Group A and Group B) in order to reduce treatment order biases. Group A

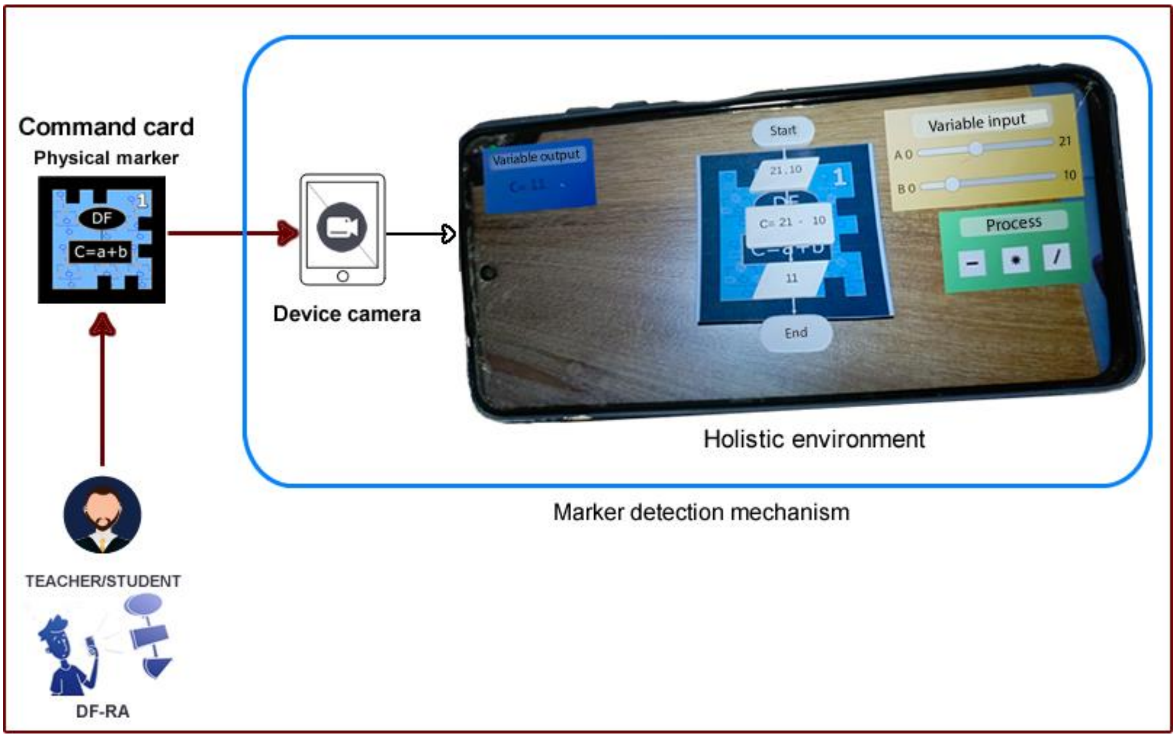

Figure 2. Mobile application DF-RA with Augmented Reality version of the learning system

3. Materials and Method

To answer the second research question (i.e. does this AR-based education method aid in students' academic progress?), an experimental design was conducted to evaluate the effect. dynamics of AR-based learning systems, in terms of four aspects: system usability, learning efficiency, experience flow and perception of use.

The participants were 34 first-year university students of careers related to computer science from the city of Guayaquil. Although all of them had passed the "fundamentals of programming" course (16 weeks) in the second semester, they have difficulty developing programming logic. In other words, there are gaps in background knowledge about programming logic to solve

students used mobile application DF-RA improved with Augmented Reality version first, followed by the traditional paper version, while Group B students used the traditional paper version first, followed by the mobile application DF-RA improved with Augmented Reality version. The treatment sequence could be balanced in this way. Particularly, the following methods were used.

1. Participants received a quick 10-minute tutorial on how to utilize the learning systems before utilizing them. Additionally, in order to make them focus on the learning tasks, they were required to complete 15 practical exercises in which they had to learn some of the fundamentals of programming, including input, processing calculations, and displaying the results of typed variables of primitive data. 2. During the system use session, the participants in

the two groups used different versions of the learning systems. Group A students first used the Augmented Reality version for 30 minutes and then the traditional paper version for 30 minutes, while Group B students first used the traditional paper version and then switched to the enhanced version. with Augmented Reality during the same period of time. 3. All of the participants were asked to complete three surveys about flow experience, usage perception, and system usability in order to gather data. After using both systems, the participants' responses for the two versions were gathered in this manner.

3.1. Measurements

Usability of a system. A scale for existing systems that aims to provide a comprehensive picture of usability assessment was used to gather data on the systems' usability [19]. Ten items made up the scale, five of which were favourably and five negatively worded (see Figure. 3). Respondents ranged from strongly disagree to strongly agree when rating each topic on a 5-point Likert scale. The scale eventually produced a value, ranging from 0 to 100, that served as an overall indicator of the system's usability. With a Cronbach's alpha of 0.93, the scale had a sufficient level of dependability [20].

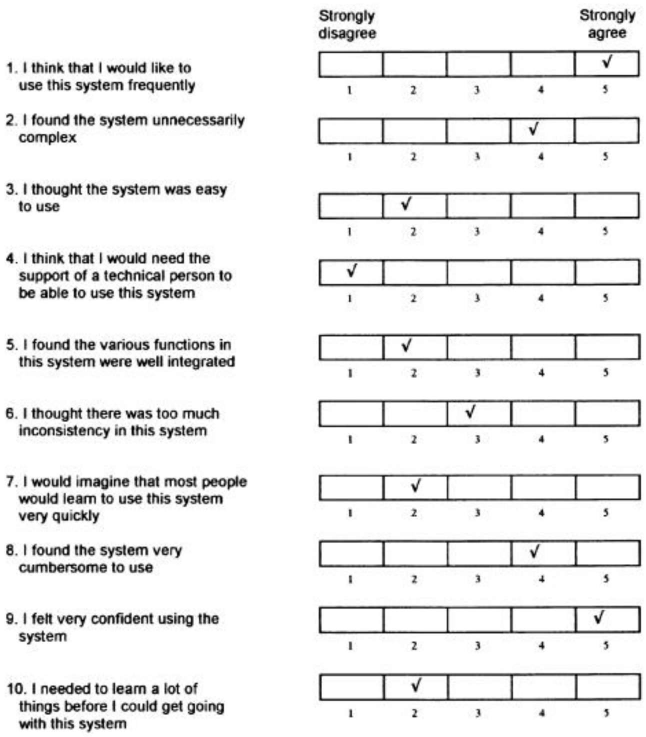

Figure 3. Usability scale evaluation

Learning efficiency. The rate at which novices pick up knowledge or skills and become proficient like experts can be referred to as learning efficiency [21]. In other words, learning effectiveness focuses on the degrees of competence that students might successfully complete their jobs over the course of a given period of time. Thus, the number of successfully completed tasks during the system usage session (i.e., 30 minutes) was employed in this study's calculation to calculate learning efficiency. During the session, the numbers of exercises completed were recorded in the records of an Excel sheet for later analysis.

Flow experience. Utilizing a scale that has already been developed for measuring flow experience in video games [22], flow experience was quantified. Four specific aspects of the original scale, namely concentration (six items, e.g., no distraction from the task is highlighted; I can remain focused in the system), goal clarity (four items, e.g., overall system goals were presented in the beginning of the game; overall system goals were presented clearly), autonomy (three items, e.g., I know the next step in the game; I feel a sense of control over the game), and immersion (seven items, e.g., I forget about time passing while using the system; I feel emotionally involved in the system) were appropriate for the purposes of this study. Each of the four facets' items was rated on a 5-point Likert scale, with 1 being the strongest disagreement and 5 being the strongest agreement. The four questionnaire aspects' reliability coefficients (Cronbach's alpha) were, respectively, 0.55, 0.66, 0.46, and 0.51.

Usage perception. The authors of this article created a perception questionnaire that was used to gauge student perception of system utilization. Five questions were asked in the questionnaire: (a) Helpfulness: Which system aids in your understanding of a flowchart's instructions? (b) Ease of use: Which system is simpler to understand and operate? (c) Enjoyment: Which learning system do you enjoy using the most? (d) Efficiency: Which system enables you to finish the exercises more successfully? e) Preference: Which system do you favor using to study the principles of programming and flowcharts? The participants were required to select one of the two options for each item.

3.2. Data Analysis

The independent variable of the experiment was the system instrument with two versions: the traditional paper version and the mobile application DF-RA improved with Augmented Reality version. The dependent variables were the participants' reactions in terms of the four dimensions: system usability, learning efficiency, flow experience, and usage perception.

Paired-sample t tests were conducted to examine the different reactions between the two systems for each dimension. All of the analyses were conducted using the Python programming language with the sciPy and statsmodels libraries.

4. Results and Discussion

4.1 Usability of a system

The means and standard deviation-SD of the scores for the system usability scale are displayed in Table 1. The findings show that the mean for the augmented reality version of the DF-RA mobile application was higher than for the conventional paper version. A further paired-sample t test demonstrated that a statistically significant difference ($t = 8.56$, $p < .01$) existed. The results imply that, in general, the AR-enhanced version enhanced system usability. The mobile application DF-RA with Augmented Reality version's capacity to display virtual information with AR-annotated objects in the context of a real world, which further improved perceived usability, may be one explanation for this finding. Additionally, the command cards might allow students more chances to manipulate these items and influence the codes, which might improve involvement and the way in which people perceive the usability of the system.

Table 1. The Results of System Usability.

	Mobile application DF-RA with Augmented Reality version		Conventional paper version		
	Mean	SD	Mean	SD	t
Usability	71.06	12.55	58.18	11.76	8,56**

**p <.01.

4.2 Learning Efficiency

The number of tasks that were finished and those that were not is shown in Table 2 for the two groups. Students in Group A completed more exercises using the mobile application DF-RA with Augmented Reality (14 units) than they did using the traditional paper version (11 units).
Similar results were reported for Group B, where students completed more tasks using the mobile application DF-RA with Augmented Reality (15 units) than they did using the traditional paper version (9 units). Students who used the augmented reality version of the DF-RA mobile application finished 29 (14+15) units in total, as opposed to 20 (11+9) units for students who used the traditional paper version. These findings imply that the mobile application DF-RA with Augmented Reality version performed exercises more successfully and within the allotted time than the traditional paper version.

Table 2. The number of tasks finished with the two versions.

	Group A		Group B	
	Mobile application DF-RA with Augmented Reality version	Conventional paper version	Mobile application DF-RA with Augmented Reality version	Conventional paper version
Finished tasks	14	11	15	9
Unfinished tasks	3	6	2	8

This outcome might be explained by the fact that students had a global understanding of what they did and the results of their actions thanks to the real-time alteration of the value of the input variables through the visual controls of the DF-RA mobile application with Augmented Reality version. To put it another way, they might be more aware of what was happening in the virtual world while still being able to quickly alter their actions depending on the output data from the variables. As a result, they would take less time to complete the exercises, which would increase the number of exercises finished.

4.3 Flow Experience

The means and standard deviations of the scores on the flow scale in terms of the four facets are shown in Table 3. Further paired-sample t tests revealed that there was no significant difference in the goal facet, demonstrating that each of the two versions had clear goals to ensure that students' impressions of this facet were comparable. The results, however, showed a statistically significant difference in the features of immersion ($t=3.20$, $p<.01$), autonomy ($t=3.61$, $p<.01$), and concentration ($t=2.77$, $p<.01$). The findings suggested that students who used the augmented reality version of the DF-RA mobile application had a better experience with flow than those who used the traditional paper version. In other words, the augmented reality version of the DF-RA mobile application increased their level of interest in the learning exercises.

Table 3. The Results of the Flow Experience.

	Mobile application DF-RA with Augmented Reality version		Conventional paper version		
	Mean	SD	Mean	SD	t
Concentration	4.35	0.48	4.14	0.44	2.77**
Goal clarity	4.39	0.52	4.23	0.53	1.59
Autonomy	4.29	0.68	3.84	0.65	3.61**
Immersion	4.10	0.51	3.87	0.54	3.20**

The ability to alter the value of the input variables in real time using the graphical controls of the DF-RA mobile application with Augmented Reality version, providing students with a simple and manipulable method to create flowcharts, may be one explanation for this finding. This would give students better control, which would increase their sense of autonomy. They would also pay more attention and dive deeper due to the quick and immediate feedback to see the results of the variables. This could be the reason why all three characteristics of the flow experience increased.

4.4 Usage Perception

The outcome of table 4 suggests that the students preferred the augmented reality version of the DF-RA mobile application, finding it to be more practical, user-friendly, and effective. In the meantime, the majority of students agreed that using the DF-RA smartphone app with augmented reality made learning more engaging and fun. Using virtual 3D flowcharts, the DF-RA mobile application with Augmented Reality version provided students with an engaging, practical, and simple way to learn programming. As a result, the majority of respondents had a favorable attitude toward these elements.

Table 4. The quantity of students selecting the system

	Mobile application DF-RA with Augmented Reality version	Conventional paper version
Helpfulness	30	4
Ease-of-use	31	3
Enjoyment	33	1
Efficiency	31	3
Preference	32	2

More research will be needed in the future to produce Augmented Reality-enhanced learning systems that integrate usability and enjoyment. The results recommended adopting a framework made up of four characteristics (cognitive, motivational, usability, and affective aspects) as a place to start in order to discover the right amount of usability and enjoyment so that students may learn in a way that is both efficient and fun.

Conclusions

In this article, two research questions were answered. In response to the first question (i.e., could a structured programming fundamentals learning system be created using augmented reality technology?), this study proposed a mobile application DF-RA with an Augmented Reality version, where students can manipulate directly an AR-based marker as information to learn the concepts of simple and compound (nested) conditionals, loops to handle counters and accumulators of variable values, and immediately observe the results through visual representations. In response to the second research question, "Does this AR-based education method aid in students' academic progress?" the results revealed that (a) the mobile application DF-RA with Augmented Reality version enhanced students' perception of system usability; (b) the students who used the mobile application DF-RA with Augmented Reality version system completed more learning tasks within the allotted time; and (c) the mobile application DF-RA with Augmented Reality version system completed more learning tasks; (d) The students said the mobile application DF-RA with Augmented Reality version system was more practical, user-friendly, and effective, making the experience more pleasant.
The development and assessment components are covered by the study's contributions. This study provides experience for development on how to integrate Augmented Reality technology with a teaching system to aid students in learning the fundamentals of programming. Such an encounter might improve the real-world uses of technologically aided language learning. A framework is provided to explore the implications of the mobile application DF-RA with Augmented Reality learning system in terms of cognitive, motivational, usability, and affective aspects. The framework could be useful for creating learning systems that are enhanced by augmented reality in the future.

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