Multimodal Interaction Framework for Collaborative Augmented Reality in Education

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Summary
One of the most important technologies today is augmented reality technology, it allows users to experience the real world using virtual objects that are combined with the real world. This technology is interesting and has become applied in many sectors such as the shopping and medicine, also it has been included in the sector of education. In the field of education, AR technology has become widely used due to its effectiveness. It has many benefits, such as arousing students' interest in learning imaginative concepts that are difficult to understand. On the other hand, studies have proven that collaborative between students increases learning opportunities by exchanging information, and this is known as Collaborative Learning. The use of multimodal creates a distinctive and interesting experience, especially for students, as it increases the interaction of users with the technologies. The research aims at developing collaborative framework for developing achievement of 6th graders through designing a framework that integrated a collaborative framework with a multimodal input "hand-gesture and touch", considering the development of an effective, fun and easy to use framework with a multimodal interaction in AR technology that was applied to reformulate the genetics and traits lesson from the science textbook for the 6th grade, the first semester, the second lesson, in an interactive manner by creating a video based on the science teachers' consultations and a puzzle game in which the game images were inserted. As well, the framework adopted the cooperative between students to solve the questions. The finding showed a significant difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of remembering, understanding, and applying. Which indicates the success of the framework, in addition to the fact that 43 students preferred to use the framework over traditional education.
Keywords:
Augmented reality, AR, multimodal, collaborative, framework.

1. Introduction

The merging between computer graphics and the real world is commonly called Augmented Reality (AR). It allows users to experience the real world with virtual objects composited with the real world. This technology is very interesting for the possibility of integrating the digital content with the real world and interacting to the point where it can be applied to a wider range of application domains such as in the field of medicine, manufacturing, architecture, education and many more. In this study, the researcher focused on using the AR in education and how it helped to improve the educational process by reviewing the related literature. In education, this technology plays a big role and achieves many benefits such as arousing the interest of students and children to learn concepts which are imaginary and difficult to understand. Particularly, in case learning is cooperative among students, AR will achieve remarkable successes as there is exchange of experiences. As well as one way to manage AR technology is to use multimodal (i.e. hand gestures, voice, pen, and touch) to create a distinct and interesting experience specifically in our field of research - collaborative education using AR technology. This study focused on three aspects, the aspect of augmented reality technology, the aspect of cooperative education, as well as the aspect of using multimodal input to produce a framework that includes the advantages of all the aspects and to achieve an effective framework in the field of science education for elementary level. AR is a 3Dimensional (3D) technology that merges sensory perception in the real-world with digital worlds in real-time [1], or it is merging real and virtual object with a few amounts of virtual data [2]. Several researchers have indicated that AR has prospect educational affordances which are useful in many fields, and it is used in several educational contexts (i.e. humanities and arts, engineering, manufacturing, construction, and science [1]). Furthermore, AR is a new technology for teaching which has the potential for pedagogical applications [2].

1.1. AR Advantages in Education Field

The following are some of the advantages of using AR in education are: 1) support for easy interaction between

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real and virtual environments. 2) the use of a tangible interface symbol for object manipulation. 3) the ability for a smooth transition between reality and virtuality [3]. However, experts are not exempted from shortcomings as they may be ignorant of the knowledge that will cause difficulty for trainers to learn from experts. Consequently, using AR is a favorable solution to support the training of trainers using expert performance data [4]. Capture features can be obtainable while using AR in education using mobile devices with features of developing AR-based applications. also, the admission of AR as one of the most promising technologies for education by New Media Consortium (www.NMC.org) and the Educause Learning Initiative (www.educause.edu). Furthermore, the learning outcomes will be efficient and better when using the characteristics of AR media such as: sensory immersion, navigation, and manipulation [1].

1.2. Collaborative Learning

Collaborative learning is social interactions among students or trainers or teachers as well. It is "a situation in which two or more people learn or attempt to learn something together" [5]. " Collaborative learning is a method applied to learners for performing common tasks in small groups in order to reach shared goals or learning results" [6]. Additionally, collaborative learning allows students or trainer to interact with other students and the educational content at the same time. This leads to deeper understanding and higher motivation [7]. Furthermore, it is possible to improve the collaboration using shared visual information [8].

1.3. Multimodal Interaction in AR

A Multimodal is a two or more user's input mods that are combined and processed such as: pen, speech and touch [9]. to create a more natural and intuitive style of interaction [8]. One of the obstacles of using the current AR systems is that it lacks for robustness and accuracy as users are restricted to hand's movements that previously defined; therefore, using two or more multimodal interfaces may increase the percentage of their robustness and improve the interaction between the physical and virtual worlds [10].

1.4. Statement of The Problem

There are many areas used for AR technology, including the field of education. The research problem stemmed from the results of many previous studies that indicated the importance of using visual effects as they contribute to achieving high results of success among students. In addition, they emphasized that the use of collaboration in education has impressive results because of the sharing of experiences and knowledge among users. However, most of the educational techniques are facing a problem; users can use only touch screens. Hence, more advancement in interaction is needed to improve users' experience in augmented environments. Also, science subject was chosen because, as witnessed, students lack basic interest in STEM "Science, technology, engineering, and mathematics" [11], which creates a barrier for students in researching and participating in STEM fields. The current challenge is summarized in two points:

- Providing an interactive collaborative framework among users to increase the efficiency of using AR technology in education field.
- Using multimodal interaction to increase interactivity between the environment and users.

Consequently, the main goal of the study is to develop a collaborative framework with a multimodal interaction in AR technology that can be used in education.

1.5. Research Hypotheses

To answer the study questions, the following hypotheses were formulated:

1) There were no differences between the mean scores of the experimental group in the science course in the posttest at the level of remembering after the specified the effect of the pre-test.
2) There were no differences between the average scores of the experimental group in the science course in the post-test at the level of understanding after adjusting for the effect of the pre-test.
3) There were no differences between the mean scores of the experimental group in the science course in the posttest at the level of application after adjusting for the effect of the pre-test.
4) There were no differences between post-test and pretest of the experimental group on the mean scores of the science course at the level of (remembering, understanding, and applying).

1.6. Objectives

The aim of this research is to build a framework used for assistance collaborative learning using multimodal input in AR technology for early education. To achieve the mentioned goal, the objectives of the thesis can be elaborated as follow:

- Collecting different studies in different sectors related to AR, whether in education or in another sector, collecting studies related to collaboration education, and other studies related to multimodal.

- Developed a collaborative AR framework with multimodal interface.
- Evaluation and Validation the proposed framework.

1.7. Limitation of The Research

The current study was limited to the following limits:

1) Time limits: This study was applied in year 2021-2022.
2) Objectivity limit: This study was confined to the second lesson "Heredity and Traits", from the science textbook for 6th grade - first semester.
3) Human limit: A random sample of sixth grade students was chosen. The sample consisted of 48 students from sixth grade.

1.8. Research Background

The literature discusses: (1) the initiatives and related work in term of AR technology in education; for higher education and for early education, (2) the collaboration using AR in education for both higher and early education, (3) the multimodal using AR, and multimodal using AR in education field. First: the initiatives and related work in term of AR technology in education; for higher education and for early education The collaboration between students in higher education field as they designed and implemented a mobile game-based learning application for an academic semester by university students called Quiz Time! This application enhances personalized and collaborative learning [12]. Authors in the application employs, for testing the knowledge of learners, an assessing knowledge module, a victoria-based recommendation module for proposing personalized collaboration in group playing, a dynamic fuzzy logic-based advice generator for tailored assistance to learners' profile and misconceptions. A cognitive learner modeler supports the aforementioned modules. In conclusion, students in higher education can assist to promote knowledge level by incorporating personalization and collaboration in mobile game-based learning. Moreover, authors stated that one of limitation is social preferences which are not considered for collaboration. However, the authors did not clarify what kind of social preferences they meant. In [13], the researcher developed a mobile application MIT app inventor. They used AR for undergraduate students to teach the "Advanced Mobile Applications" course, and the application was distinguished by using a collaborative game to teach advanced mobile programming to a small group of students. The results were promising, and it could be useful, and an easy tool for teaching mobile programming. However, the researcher did not see how an application can motivate students and improve their performance in the course. I think we cannot depend on the results because they relied on a small sample. In [14] study, they did not involve a curriculum as a co-design process for a collaborative learning experience. They are involved children of primary school by using cooperative enquiry techniques to design and evaluation of an AR textbook and proposed features of a key design that can be integrated into collaborative AR textbook. The results showed that the children surprisingly interact in the co-design sessions. From other side, [15] emphasized in their study that collaborative learning can be a remote collaborative among learners as they have demonstrated in their study. They have conducted an experiment on a group of people in different locations but using the same network or same Bluetooth to solve the same puzzle board using their real hands in a virtual environment. However, the researchers faced two problems: Network stability and compatible of the devices. Nevertheless, they saw that it could be used for teaching, science and engineering. Second: The collaboration using AR in education for both higher and early education. In [16] study, the researchers aimed to monitor the interaction of 16 seventh graders in rural schools. They also aimed to report the interactions using the ScholAR application and its effect on their performance as the application depended on a collaborative environment. The application contained 6 Mathematics topics of introduction to three dimensional Solids targeted to enhance the spatial visualization skills. The researchers divided the students into two groups: The group that was taught by the conventional method and the experimental group. They conducted a comparative study between the two groups. The results showed that the application helped in developing spatial visualization skills realizing the existence of 3D shapes in the surrounding. By the help of the application, it enhanced students' performance; those who used the App. by post testing, the results of Bloom's taxonomy showed the success of the students who used the application. In [17] study, the researchers developed a collaborative learning framework based on AR integration with LMS, so that the tool based on Web3D and integrates with eLearning platforms as a plug-in resource. An inexperienced teacher can browse the web page of the LMS course to design and create activities easily. The framework can design augmented scenes based on the desired texture marker. It is operated by students in an interactive manner remotely on mobile devices in a multiplayer cooperative mode. The researcher believes that the framework still lacks geographical awareness. Third, the multimodal using AR, and multimodal using AR in education field. In [18], a multimodal interface was used. They specifically used speech and paddle gestures in the user's interaction with the system as it arranges virtual furniture in a virtual room. Unlike other applications that rely on multimodal AR applications, the researchers adopted multimodal fusion that is based on the combination of time-based and semantic techniques to disambiguate a user's speech and gesture input. The study results showed that the combination of gestures and speech improves interaction with virtual tools the speech was suitable for controlling the system and for spatial input, and the gestures helped in it. They see that the multimedia interfaces can be expanded to include different fields in augmented reality to determine its effectiveness. In [19] research, they aimed to discover multimedia interaction in augmented reality to enhance the user's experience in AR applications. They have designed a prototype design that contains two types of modalities: Speech and gesture interaction. The outcomes showed that speech is superior to nodding by number, but they have the same time. The researchers believe that the combination of speech and gesture is effective interaction methods to perform simple tasks. In the study of [9], they mentioned a multimodal as one of AR interface types. However, as there is a lack of work on a produced framework in adaptive interfaces field, they proposed a general framework to clarify the adaptive multimodal interface in mobile AR environment. On the other side, [20] developed an android application to help non-Hindi speaking tourists.

As the Indian language is translated into a language of their choice using text-to-speech interaction and visual aid based on AR technology, they have used many tools to implement the application. They have used OpenCV for real time overlay to show the translated text in AR. They used MT for the translation of the required language where the entered text is translated using translate and TTS to convert the text into an interactive language. To extract and convert the scanned text via the camera to textual data, a method the computer can understand, they used OCR. They also asserted that it could be used by students to learn the language. In [21] study, the researcher conducted an evaluation study of how the integrated multimodal representations in AR affect the experiences of museum visitors. They created a real fruit exhibition in an experimental enhanced reality exhibition based on marker-based AR and video see-through screens in which they provided tangible, visual, and audible interaction for the participants. The experiment was applied to 48 university students. The results indicated that the study of the experiment was more attractive to the participants, and it was more interactive than the static exhibition. The students appreciated the immediate comments provided by AR to confirm their actions. In the concept of gestures, there were two studies: [8] [22], where [8] suggested collaborative multimodal platform based on Gesture and Head Pointing (GHP), projector-based mixed reality (MR), remote system, which enable the remote user to easily help the local user by sharing gestures and pointing the head based on the MR, as well as verifying the role of GHP sharing in the MR for the tasks Typical factories. Authors confirmed that the results were encouraging and that GHP sharing may enhance performance and remote interaction. From the abovementioned review, the following conclusions were found: All the previous studies revealed promising results in using AR technology in education either for higher education or early education. On the other side, initiatives praised the use of the collaborative method to increase the effectiveness of augmented reality-based tools and applications in the education sector. The other studies confirmed the effectiveness of sensory immersion and increased interaction with virtual surroundings and reality using multimedia input methods. From this point, this study inspired collaboration learning using AR technology in terms of knowledge exchange among students using AR technology, so that it is interesting. To increase the sensory immersion and interaction with the real and virtual environment, I decided to use multi-modal input, specifically gesture, and touch. The contribution of this research is the creation of a framework based on collaborative AR technology, using multi-modal input, for 6th graders students in science education.

2. Methodology

This section represents a detailed study methodology and its experimental method, as well as an introduction to the study population and its sample. It includes a presentation of the procedures that were followed in this study, which consisted of two stages, including: First stage: The first step included the following: (1) Interviewing the science teachers of the sixth grade, (2) analyzing the content of the science textbook of the sixth grade - the first semester, the second lesson, specifically the topic of "Heredity and Traits", (3) doing the validity and stability of this analysis, (4) formulating the behavioral objectives, (5) designing and implementing the framework used in the experiment, and (6) designing the study tools; a cognitive achievement test that measures both the level of remembering, understanding and applying. Second stage: It included the following procedures for applying the experiment: (1) collecting a random sample of sixth grade students, (2) preparing the experimental group, (3) applying the pre-test to the group, (4) applying the post-test to the same group, and finally, (5) presenting the statistical methods used in the study. The experimental approach was adopted in this study. One of the designs of this approach is the design of unequal groups based on the group with two tests; a pre-test and a post-test, to know the effect of the independent variable (the multi-media interaction framework for collaborative augmented reality) on the dependent variable (achievement at the lowest cognitive levels of the Taxonomy of Bloom (remembering, understanding and applying). The researcher also relied on the observation on the experimental group and asked them about their impression of the presented framework.

2.1. Study Sample

Due to the world passing through the Corona pandemic, which disrupted for all life activities, that include in class teaching, the researcher faced difficulty in finding a primary school that might contribute to the completion of this study, as well as the difficulty of communicating with parents in collecting students or going to them.

2.2. Study Variables

The following are the study variables:

- The independent variable: The multimode interaction framework for collaborative augmented reality.
- Dependent variable: The cognitive achievement at the lowest cognitive levels of the Bloom's Taxonomy (remembering, understanding, and applying).

2.3. Data Collection

The data was collected as follows: Interview with Specialists:
An interview was conducted with four female teachers of science education and who are teaching the sixth graders. The topic of heredity and traits was chosen and agreed to be as a topic for the study as students have difficulty distinguishing between the terms 'heredity' and 'traits'. It was also agreed that the teachers would write the pre and post test questions. The teachers would also provide the necessary materials such as pictures and videos, as well as game questions to build the proposed framework. Preparing the Study Experience: Analyzing the content of the scientific education subject with the aim of determining as follows:

- Identification of the scientific education subject: The science education subject was chosen for the sixth graders, the first semester. The topic of genetics and traits was chosen. Due to the similarity of its terms, this topic was chosen.
- Determining the goal of the analysis process: The content analysis process aimed at identifying educational experiences in each term of the genetics and traits lesson to be used in the interactive multimedia framework software for collaborative augmented reality.
- In the analysis process, the researcher carefully read all the terms in the traits and heredity lesson with the aim of deducing what the content of the scientific material includes from educational experiences for each term. After that, the results of the analysis are inserted in a table to showing the number of educational experiences in each term. The number of educational experiences resulting from the analysis process in its current form has reached ten educational experiences distributed in terms of heredity and traits.
- Calculating the validity of the content analysis of the terms: The researcher prepared a form containing the educational experiences resulting from the analysis process and presented it to the same science education teachers where they agree with the result of the analysis without modifying.14. Stability of The Research

[23] said that the stability and analysis of the content of the topics can be done by one of these two methods:

- The researcher analyzes the same material twice, separated by a period of time and without referring to the previous analysis.
- To analyze the scientific material, so that two researchers agree at the beginning of the determination on the basis of the analysis and its procedures.

In both cases, statistical methods are used to find the coefficient of agreement, which represents the reliability coefficient. The researcher relied on the temporal analysis, as she relied on a time interval between the two analyzes estimated at fifteen days between the two analyzes, as the re-analyzing of the terms of heredity and traits again after an interval of fifteen days. The researcher found a complete agreement between the results of the first and second analysis. Therefore, the coefficient of agreement is equal to (1) depending on Holsti's (1969) equation was used to test the reliability
$CR = \frac{2M}{N1+N2}$ which indicates coefficient reliability of the analysis [23]. In Table 1 below are the results of the Content Analysis.

2.4. Formulation of Measurable and Observable Behavioral Goals:

The educational goals, especially when they are formulated in a behavioral way, are a central element in the educational process. Accordingly, the researcher, after analyzing each major term of heredity and traits separately, she determined the behavioral goals for each term according to the educational experiences resulting from the process of analyzing the content of the genetics and traits lesson. In the process of setting these goals, the researcher considered the following important points:

Table 1. Content Analysis Result Using Temporal Analysis

	Content Analysis Results	***Stability Coefficient***

First Analysis	10	100%
Second Analysis	10	
Difference points	0	
Agreement points	10	

- Formulating the behavioral goals in a clear and simplified manner.
- The behavioral objectives fulfill the learner's needs and take into account his characteristics.
- The behavioral goals described in the statement are observable and measurable.
- Limiting the goal statement to one of the learning outcomes.
- Considering the clarity of their formulation and the extent to which they represent educational experiences.
- Commitment to Bloom and his colleagues' classification of levels of behavioral goals in the cognitive domain and contains six contents, starting with simple mental abilities and ending at more complex levels.
- Remembering: It is the ability to "recognizing or recalling knowledge from memory. Remembering is when memory is used to produce or retrieve definitions, facts, or lists or to recite previously learned information" [2].
- Understanding: It is the ability to "constructing meaning from different types of functions when they written or by graphic messages or activities such as: interpreting, exemplifying, classifying, summarizing, inferring, comparing, or explaining" [2].
- Applying: It is the ability to "carrying out or using a procedure through executing or implementing. Applying relates to or refers to situations where learned material is used through products" [2].

The reason why the researcher specifically chose these three levels of knowledge in the cognitive domain was because of the easiness of measuring them and their compatibility with the characteristics of the age of students from (6th graders). On the other hand; due to the students' age, they cannot deal with higher levels of Bloom classification which are: Analyzing, composition, and Evaluation. In light of the previous considerations, the researcher identified the goals, so the number in its initial form amounted to ten behavioral goals that were distributed in terms of heredity and traits. Then, the researcher presented the behavioral goals to the same group of teachers who are specialized in teaching science. The aim of consulting the teachers is to judge the suitability of the objective goals in terms of: (1) their relevance to the level, (2) the clarity of formulation and (3) the extent of their representation to the educational experiences. The arbitrators were satisfied with these analyzes.

3. The Proposed Framework

T he researcher followed the following stages to build the educational framework. Two main stages were followed to build this framework:

3.1. Theoretical Framework Planning:

1) Justifications underpinning the design of the framework:

- Through the educational reality in which we live and based on previous study [11] that confirm the low level of students in scientific education subjects, the science education subject was chosen, and when interviewing science teachers of the sixth graders. They confirmed this weakness among students. There is also confusion between the terms of heredity and traits. The studies also confirmed the need for the science curriculum to the interactive application aspect and the low level of the student in science education.
- Accelerated cognitive development, which led to the need of using the computerized learning style to help attract students' interest and then clarifying the terms of genetics and traits and explaining them in a smooth and fun way for children.

2) Analyzing the content of the genetics and traits lesson and extracting educational experiences:

The researcher analyzed the genetics and traits lesson and identified the following terms: Heredity, inherited trait, instinct, and acquired trait. The terms, educational experiences and behavioral objectives were extracted from the science education textbook of the sixth grade -first semester, second lesson. The terms, educational experiences and behavioral objectives were presented to two science teachers who expressed their satisfaction with them.

3) Framework objectives:

A number of general objectives have been identified for the framework, the most important of which are:

- Providing students with basic, simplified and integrated information about heredity and traits.
- Developing the capability of memory among students, so that they can know the terms of "inheritance, hereditary trait, instinct, and acquired traits".
- Training students to differentiate among the term's heredity and traits "heredity, hereditary trait, instinct, and acquired traits" by differentiating each example of each term.
- To develop the overall understanding among students to increase their ability to understand what the terms of heredity and traits (heredity, hereditary trait, instinct, and acquired traits) .

4) Determining the components of the framework:

The researcher was interested in reformulating the genetics and traits lesson from the science book for the sixth grade, the first semester, the second lesson, in an interactive manner by:

- Adding video, which was determined by the science education teachers in this link https://youtu.be/NmXEQHNww7U, which includes educational video about heredity and traits. The video was chosen by the teachers according to their experience.
- The puzzle game in which the game images were also set by the teacher where were consisted of 3 pictures, a picture of a bird building its nest, a dolphin playing with a ball, and a spider weaving its web.
- In the educational aspect there is specified questions appear after successfully solving the game, these questions are also written by the teacher.

5) Main process for the framework:

When teaching the framework, the program relies mainly on cooperative teaching using augmented reality technology and improving it using multimodal input through the proposed framework that contains a video clip, a game. To interact with the game, a hand movement and questions should be used. The researcher has followed several steps in applying the framework as follows:

- After the students studied heredity and traits in the traditional way by their teachers, the researcher gave the students a general idea about the topic of study.
- Cooperative work and play between two students in one session.
- Students using Android device to start using the suggested framework.
- Reteach the experimental group using the proposed framework.

6) Methods for evaluating the impact of the program

The impact of the proposed framework has been evaluated in two ways:

- The proposed framework was presented to teachers of the primary stage. They confirmed the validity of the information received, with the addition of some modifications suggested by teachers after filling a form of software arbitration on a multimodal interaction framework for collaborative augmented reality in education. These suggestions were taken into consideration including increasing the time in the game, as well as making levels in the game (easy, medium, and hard).
- The implementation of the pre-and post-test through the application of the proposed framework to know its impact on the identification of the term of heredity and traits. The pre and post-test were written by the teachers and these tests. With the help of the teachers, the preand post-test questions were distributed on the cognitive levels of the objectives in the achievement test.

3.2. Framework Architecture

In this framework there are basic three tools were adopted to create the proposed framework as follows:

1) Unity

Was used to build and design the basics of the framework, and [24] defines Unity as an industry-level game engine used for multi-platform video game development. It is appropriate for professional game creation, as well as beginner game developers.

2) ARCore

It is a platform created by Google to develop and create augmented reality applications for Android devices as the phone can sense and understand the environment and interact with information. It also works as extensions to application development programs such as Android Studio, which works on developing and programming Android applications [24] [25] [26].

3) AR Foundation

Was used because the frame is an AR environment, and it is the responsible for creating an augmented reality environment, and it is also supported by the Manomotion SDK. [24] mentioned that the AR foundation allows the development and work of an augmented reality application once, and then publish it across many device platforms including iOS devices that use ARKit and Android devices that use ARCore. It also provides the basic features of each platform. It is a multiplatform application programming interface that allows work for multiple platforms such as ios and Android and has been developed by Unity. [27] [25] explain that AR Foundation aims to create AR applications easily as these applications can be run on iOS and Android systems. The researcher also explained that AR Foundation has a common API (Application Programming Interface) that covers the basic functions of both Android ARCore and iOS ARKit, and which make it possible to create AR apps for both platforms from a single code base.

4) ManoMotion

In the framework it was used for hand-gesture recognition purposes. As defined by [27]: It is a company that released their SDK that supports the hand gesture input with AR Foundation, which in turn contributes to the development of the application by doing 3D gestural analysis in real time and allows realistic gesture control of augmented reality applications simply by using the 2D-camera available in any smart device. ManoMotion's SDK requires a standard RGB image to work properly [28]. In the figure 1 shown the Architecture of the Framework.

3.3. Implementation

In following lines are the description of the Framework:

In this study, the QR Code related to the genetics and traits lesson was used as shown in the below figure. It was enlarged and the code was revised to be of sufficient size to be captured via the mobile camera without being greatly affected by the passage of the students' hand in front of the code.

- When start playing the frame, the camera must detect the QR Code of the lesson, then the main menu starts, which contains two options: video and game. Figure 2 shown the main menu.

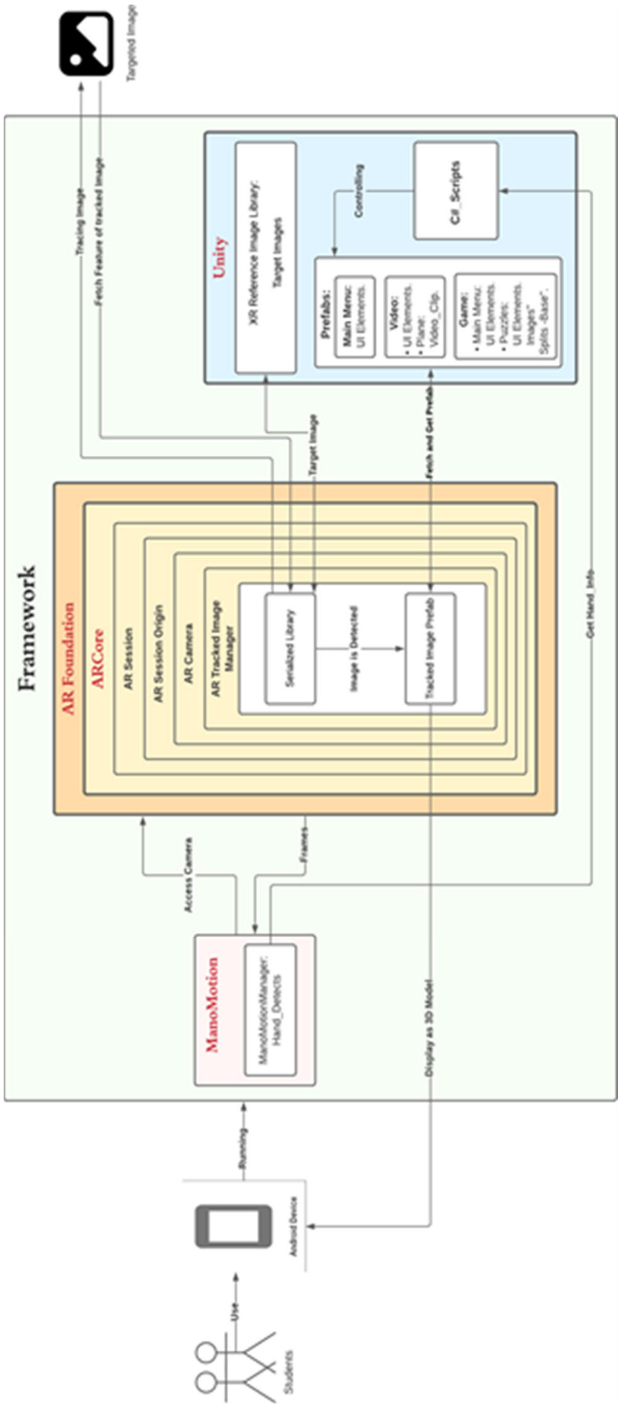

Figure 1. Architecture of the Framework.

- When choosing the video, the framework moves to the video section, which contains the educational video specified by the parameters, as well as it contains a back button to the main menu.
- The video contains play, pause, pause, forward, 15 seconds, and loop buttons, as well as the video's timer.

- When pressing the back button, it will return to the main menu.
- In the main menu, when choosing the game, it will go to the virtual puzzle game section.
- A screen appears to choose the appropriate level to play, whether easy, medium or difficult. It also contains a back button to the main menu. Figure 3 shows the levels in the framework.
- When choosing an easy level - a picture of a puzzle about a bird building its nest will appear, and for intermediate level, a picture of a puzzle of dolphin playing with a ball will appear and when choosing a difficult level, a picture of a puzzle of a spider weaving its web will appear (picture were specified by the parameters) and the student must move the puzzle pieces using hand gestures, so that the piece is in the right place, if the student place the piece in the wrong place, the piece will move back to the previous place till they can find its correct place, taking into account the time, and there is also a button to return to the main menu. Figure 4 shown moving the puzzle pieces using hand gestures.
- When the time finishes, a message appears that the game is over, try again, and when try again, the game returns from the beginning.
- When solving the puzzle correctly, the question appears (for easy level: the bird builds its nest, it is an adjective) (for intermediate level: the dolphin playing with the ball is an adjective) and (for difficult level: the spider weaving its web is an adjective) and the student must choose the correct answer from the two options (hereditary or acquired).
- When choosing the correct answer, the color of choice will be green. Figure 5
- When choosing the wrong answer, a red color appears with the answer, and the student can modify his choice by choosing again. Figure 6
- The student can replay the game via the 'Replay button' or return to the Play Levels screen via the Back button.
- When pressing the back button, it will return to the Play Levels screen.

1) Study on an Experimental Sample

The meeting was applied to a group of 48 students from the sixth grade - primary school. The researcher started talking to them about the experience. She started with a simplified explanation of the framework and the tests that they will be given (the pre- and post-test which were written by the science teacher). The researcher started sending the pre-test on the students' mobile phones and then they started solving it electronically. The results were also delivered electronically. Then, the researcher presented the framework to the students, and explained how to use it. The experiment was carried out in the presence of two students with each other to achieve the principle of cooperation. The experiment was carried out under precautionary measures against the Corona virus. After the students used the framework and cooperated with each other, the researcher submitted, electronically on the students' mobile phones, the post-test (which was the same as the pre-test). Following that, the students began solving and sending them electronically. Figure 7 shows students using the framework and solving the question.

Figure 2.Main Menu After Detect the QR Code.

Figure 3.Levels of the Game.

Figure 4.Moving puzzle Pieces Using Hand Gestures.

Figure 5.Correct Answer.

Figure 6.Wrong Answer.

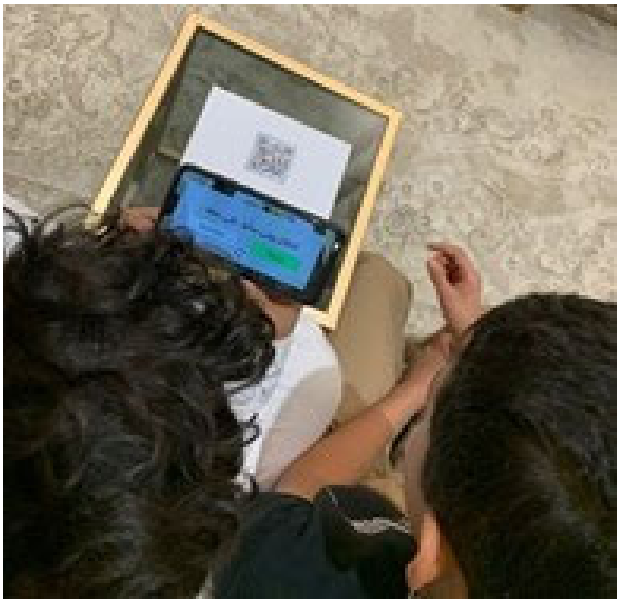

Figure 7.Students are Answering the Question.

4. Statistical Methods

To verify the hypotheses of the study, the following statistical methods were used:

- Test of Item Difficulty.
- Test of Discriminant Items
- T-test to compare the average scores of the study sample in the pre-and post-test of the experimental group for the cognitive achievement test.
- observation

5. Findings

5.1. Test of Item Difficulty

Item difficulty (p) is defined as the proportion of examinees who answer an item correctly [29], and also the item difficulty for a single test item is defined as the proportion of examinees in a large tryout sample who answered the item correct [30]. The item difficulty for a single test item is defined as the proportion of examinees in a large tryout sample who get that item correct. For any individual item *i* , the index of item difficulty is *Pi*, which varies from 0.0 to 1.0 . item is difficult if the *Pi* approach 0.0, and its less difficult if *Pi* approach to 1.0. table 2 illustrated the Item – Difficulty Index. Table 3 shows that the items (Q2, Q4, Q5, Q6) are very easy, Q7 is easy, and Q3 is moderate.

5.2. Test f Discriminant Items

The proportion value – item discrimination can be expressed in several different ways. Most commonly, the degree of discrimination is represented by D (for difference or discrimination) or by r (the correlation between performance on the item and on the external criterion or total test score) [?]. D is usually defined as the simple difference in percent right in the " high" and " low" groups. And table 4 shows Discrimination index as follows:

Table 5 shows that the items (Q2, Q3, Q4, Q7) are marginal and needs revision, and (Q5 and Q6) should be eliminated or completely revised.

5.3. Hypothesis Test

To answer the study questions, the following hypotheses were formulated:

1- There are no differences between post-test and pre-test of the experimental group on the mean scores of the science course at the level of remembering at significant level $\alpha \leq 0.05$.

- T test: To test the hypothesis we used paired sample T test [31] to test the difference between post-test and pretest of the experimental group on the mean scores of the science course at the level of remembering at significant level $\alpha \leq 0.05$, and the results in table 6 showed that the absolute value of calculated test (t-test =2.92) which is more the critical value (t-critical

= 2.26) and the (pvalue = 0.005 < 0.05) . Thus, we succeed in rejecting the null hypothesis; Consequently, the results indicated that there was a significant difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of remembering at significant level $\alpha \leq 0.05$.

2- There are no differences between post-test and pre-test of the experimental group on the mean scores of the science course at the level of understanding at significant level $\alpha \leq 0.05$.

- T test: To test the hypothesis, we used paired sample Ttest to test the difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of understanding at significant level $\alpha \leq 0.05$, and the results in table 7 showed that the absolute value of calculated t-test (t-test = 7.93) which is more the critical value (t-critical = 2.26) and the (pvalue = 0.00 < 0.05). Thus, we succeed in rejecting the null hypothesis; Consequently, the results indicated that there was a significant difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of understanding at significant level $\alpha \leq 0.05$.

3- There are no differences between post-test and pre-test of the experimental group on the mean scores of the science course at the level of application at significant level $\alpha \leq 0.05$.

- T test: To test the hypothesis we used paired sample T test to test the difference between post-test and pretest of the experimental group on the mean scores of the science course at the level of application at significant level $\alpha \leq 0.05$, and the results in table 8 showed that the absolute value of calculated t-test (t-test =6.2) which is More the critical value (t-critical = 2.26) and the (pvalue = 0.000 < 0.05) . Thus, we succeed in rejecting the null hypothesis; Consequently, The results indicated that there was a significant difference between posttest and pre-test of the experimental group on the mean scores of the science course at the level of application at significant level $\alpha \leq 0.05$.

4- There are no differences between post-test and pretest of the experimental group on the mean scores of the science course at the level of (remembering, understanding, and applying) at significant level $\alpha \leq 0.05$.

- T test: To test the hypothesis we used paired sample T test to test the difference between post-test and pretest of the experimental group on the mean scores of the science course at the level of (remembering, understanding, and applying) at significant level $\alpha \leq 0.05$, and the results in table 9 showed that the absolute value of calculated t-test (test=8.88) which is more than the critical value (t-critical = 2.26) and the (p-value = 0.000 < 0.05) . The results indicated that there is a significant between post-test and pre-test of the experimental group on the mean scores of the science course at the level of (remembering, understanding, and applying) at significant level $\alpha \leq 0.05$.

5.4. Observation

During the conduct of the study, the researcher noticed the students' interest in the framework used in the study, and that 43 students out of 48 expressed their approval and interaction with the framework and preferred it over traditional education and said they wished that education using technology would be better than traditional education, as it reached them with information through the framework . While 5 students showed their preference for traditional education, but with technology education as an additional aid to traditional education.

Table 2.Item- Difficulty Index

Range	***Difficulty index***
Below and 20	Very difficult
21-40	difficult
41-60	Average
61-80	Easy
81 and above	Very easy

Table 3.Test of Item Difficulty

Number of item	***Difficulty Pi***
Q2	90%
Q3	50%
Q4	90%
Q5	100%
Q6	100%
Q7	70%

Table 4.Discrimination Index

Range	***Discrimination index***
D ≥ 0.40	The item is functioning quite satisfactorily
0.30 ≤ D ≤ 0.39	Little or no revision is required
0.20 ≤ D ≤ 0.29	The item is marginal and needs revision
D < 0.19	The item should be eliminated or completely revised.

Table 5.Test of Discriminant Items

Number of item	***High group***	***Low group***	***Discrimination Pi***
Q2	5	4	0.2
Q3	3	2	0.2
Q4	5	4	0.2
Q5	5	5	0
Q6	5	5	0
Q7	4	3	0.2

Table 6. Paired sample t-test for testing the difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of remembering at significant level α≤ 0.05

Bloom Scale	***Type of test***	***No.***	***Mean***	***S.D***	***T test***	***P-value***
Level of remembering	Pre test	48	1.79	0.41	-2.92	0.005
	Post test	48	1.98	0.14		

Table 7. Paired sample t-test for testing the difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of understanding at significant level α≤ 0.05

Bloom Scale	***Type of test***	***No.***	***Mean***	***S.D***	***T test***	***P-value***
Level of understanding	Pre test	48	1.33	0.56	-7.93	0.000
	Post test	48	1.98	0.14		

Table 8.Paired sample t-test for testing the difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of application at significant level α≤ 0.05

Bloom Scale	***Type of test***	***No.***	***Mean***	***S.D***	***T test***	***P-value***
Level of application	Pre test	48	1.15	0.68	-6.20	0.000
	Post test	48	1.90	0.37		

Table 9.Paired sample t-test for testing the difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of (remembering, understanding, and applying) at significant level α≤ 0.05

Bloom Scale	***Type of test***	***No.***	***Mean***	***S.D***	***T test***	***P-value***
(Remembering, understanding, and applying) level	Pre test	48	4.27	1.09	-8.88	0.000
	Post test	48	5.85	0.41		

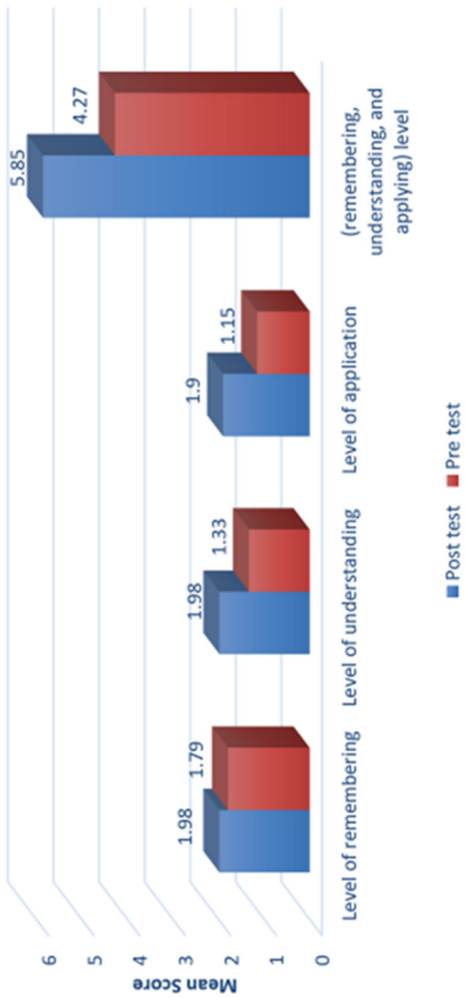

Figure 8.Means of pre and post-test.

6. Conclusion

The research aims at developing collaborative framework for developing achievement of 6th graders through designing a framework that integrated a collaborative framework with a multimodal input "hand-gesture and touch", considering the development of an effective, fun and easy to use framework with a multimodal interaction in AR technology that was applied to reformulate the genetics and traits lesson from the science textbook for the 6th grade, the first semester, the second lesson, in an interactive manner by creating a video based on the science teachers' consultations and a puzzle game in which the game images were inserted. As well, the framework adopted the cooperative between students to solve the questions. The finding showed there is a significant difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of remembering, level of understanding, and applying. Which indicates the success of the framework, in addition to the fact that 43 students preferred to use the framework over traditional education. The researcher wrote her conclusion of the research based on the findings of the study questions as follows:

- There is a significant difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of remembering.
- There is a significant difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of understanding.
- There is a significant difference between post-test and pre-test of the experimental group on the mean scores of the science course at the level of application.
- There is a significant between post-test and pre-test of the experimental group on the mean scores of the science course at the level of (remembering, understanding, and applying).
-

On the basis of the results of the analysis, we can answer the research questions:
How effective is the framework on the levels of Bloom's taxonomy; Remembering, understanding, and application?
According to findings that it positively affects on the three levels of Bloom taxonomy; Remembering, understanding, and application.
How effective is the system on academic achievement?
Since it positively affects on the three levels of Bloom's taxonomy; Remembering, understanding, and application, we can say that it may positively affect the academic achievement of students.

7. Future Research

- The researcher recommends developing a framework to allow online play.
- The researcher recommends using other platforms such as the iOS platform to use the application on it.
- researcher recommends using the customer solution to enable multi-use feature and hand tracking at the same time.

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