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RESEARCH ARTICLE

Learning the chemical elements through an augmented reality application for elementary school children

Eder Campos-Pajuelo[1] **Leonardo Vargas-Hernandez**[1] **Fernando Sierra-Liñan**[2] **Joselyn Zapata-Paulini**[3] **Michael Cabanillas-Carbonell**[4*]

[1] Universidad Autónoma del Perú, Lima, Perú
[2] Facultad de Ingeniería, Universidad Privada del Norte, Lima, Perú
[3] Universidad Continental, Lima, Perú
[4] Vicerrectorado de Investigación, Universidad Norbert Wiener, Lima, Perú

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Correspondence to: Michael Cabanillas-Carbonell, Vicerrectorado de Investigación, Universidad Norbert Wiener, Lima, Perú; Email: mcabanillas@ieee.org

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Abstract: Traditional learning in the chemistry course has often been seen as a boring course among students due to the use of static, non-dynamic, and interactive learning materials. The implementation of digital media in education has provided multiple advantages. Implementing technologies such as augmented reality promotes effective learning because it allows students to interact with virtual elements in our real environment. The present research was delimited in the development of an application with augmented reality for learning chemical elements in 5^{th}-grade elementary school students to provide a support tool for teachers and students to help achieve a better understanding of the chemical elements. The Mobile-D methodology was used to develop the augmented reality application called "Atomik-3D", which is focused on developing mobile applications. Once the application was developed, functional tests were carried out to analyze surface recognition characteristics and ease of use. Twenty tests were carried out, giving us positive results. Through the analysis of the results, it was possible to identify that, for the recognition of flat surfaces, the mobile application has a good performance on illuminated surfaces with more than 30 lux. Likewise, the Marker technology used in this project has a very efficient recognition time of a flat area, mostly no more than 1.5 seconds. Finally, 85% of the surveyed participants agreed that the application was easy and very easy to use.

Keywords: chemistry course, elementary school children, augmented reality, Mobile-D

1 Introduction

The study is an activity of utmost importance for personal development, being able to promote job opportunities to improve the quality of life of people in the academic field. According to the Banco Mundial (2018), an engine of development for societies is education, where effective instruments are obtained for a reduction of poverty and improvement in the quality of health services. In addition to avoiding the low performance in the learning of each human being, giving as a constant benefit the entry of great opportunities for long-term economic development (Papadakis & Kalogiannakis, 2019), thus favouring the institutions that make investments where everything turns out to be essential (Kikilias et al., 2009; Papadakis, 2022). Nowadays, education has undergone significant changes in the entire scope of a hierarchical student plan due to the situation experienced by COVID-19 (Poultsakis et al., 2021). This caused the government to impose virtual distance education (UNICEF, 2020) which was a great challenge for all students and teachers when raising a subject.

Searching for information on specific topics dictated by the teacher can be very complex for students (Skaraki & Kolokotronis, 2022). During this process, it is not straightforward to have the possibility of not finding accurate information of what is required, as well as to find the help of some content in a visual way that helps them to understand the information they review (Lobo et al., 2019). Calero (2009) expresses that, for a good study process, it is necessary to count on diverse resources that facilitate the student to have his subjects learned in a more accessible way. Having as main tools internet, books, sheets, library articles, and audio equipment, among other materials of educational character, entails to the student a reflection of enthusiasm with the most accessible factors that he can find within his reach. For such reason, the benefits that the study techniques contribute are fundamental, where the concepts of a mental image are granted more power than abstract knowledge because images in movement and in a dynamic way call more attention to the student (Restrepo et al., 2015).

At the primary level of educational institutions, traditional learning can be observed, which has led to students having a low level of understanding (Kapaniaris & Zampetoglou, 2021). This particular case in the chemistry course evidences the problems related to the teaching of this subject, such as the lack of didactic resources, laboratories and qualified teachers (Stojanovska et al., 2020). According to Hsiung (2018), chemistry, in its majority, is usually perceived by students as a boring subject. The traditional teaching, which is taught in this course, goes hand in hand with static books. In the case of subjects such as the study of Chemical Elements, the workbooks provided to Peruvian students include only text and images that are often not enough to facilitate the study of the subject. This is because the representation of enough graphic content is required.

Technology has provided multiple advantages and opportunities for students, making the development of digital educational activities possible, which have become powerful tools that facilitate and promote effective learning (Kallou & Kikilia, 2021; Papadakis et al., 2021). According to Gil et al. (2014), of the technologies that offer a novel way of teaching is Augmented Reality (AR), where students can interact with virtual elements in an authentic environment and thus can facilitate and improve the understanding of the subjects (Tzagkaraki et al., 2021; Verawati et al., 2022). This is how AR comes into play, thanks to the possibility of displaying 3D content while allowing us to add information in text or audio mode and providing users with a high degree of interactivity (Cabanillas et al., 2020; Gamboa et al., 2021). AR has great potential to be a tool to support the learning of chemical elements.

For this reason, the present research is carried out on designing and implementing a mobile application with AR to learn the chemical elements and analyze aspects such as the operation of QR codes. QR codes are reflected in the 3D form of patterns required as position, alignment, and synchronization for ease of use of the mobile application for the student. The development and implementation of the application do not seek to replace the traditional methodology. It is a support tool for teachers and students to help achieve higher learning performance of the chemical elements. Furthermore, it contributes to new chances of success in subsequent evaluations conducted by institutions and organizations of cooperation and development, generating an increase in educational level within the educational institution.

This work is structured as follows: section 2 describes the methodology, detailing the phases of the Mobile-D methodology applied for the project's development. Section 3 describes the Results and Discussions of the tests performed on the AR application. Finally, section 4 details the Conclusions obtained from the results.

2 Methodology

The complexity of the chemical elements seen within the field of chemistry is because, for the most part, the structures, characteristics, and the inability to visualize what they study, are confusing for students. Furthermore, causing a somewhat poor understanding of the subject at the time of studying since they do not have the visual support to reinforce what they read (Maier & Klinker, 2013). Traditional learning in chemistry (the chemical elements) is not always efficient enough, complicating learning by students. Therefore, new technologies are required to promote interactive learning and thus improve students' academic achievements (Dwi Wiwik et al., 2019; Papadakis et al., 2021).

The great potential that AR has to improve the quality and fluency of teaching-learning is what makes it stand out (Sendari et al., 2020). Learning chemistry with this technology allows students to complement the study of various topics, favouring the understanding of chemical elements and the formation of chemical compounds (Iyamuremye et al., 2022). Chemistry is supported by the periodic table, which is a fundamental instrument for systematically studying chemical elements (Torrens, 2021). It provides an in-depth knowledge of the chemical elements surrounding us, helping to classify them according to their behaviour and atomic structure and providing a specific location according to their particularities.

The research developed is descriptive because it seeks to describe the characteristics of an augmented reality application used for learning chemical elements. It also used the Mobile-D methodology, which has five phases: exploration, initialization, production, stabilization, and system testing. This methodology has been implemented in other research-oriented fields of education to achieve designs and developments of interactive applications with an agile approach (Alnanih et al., 2019; Gomez & Hernandez, 2016; Papadakis & Orfanakis, 2018).

2.1 Exploration

In this phase, the Stakeholders were defined. Furthermore, the scopes and the functional and non-functional requirements were identified, and the project was established. The stakeholders are the companies belonging to the Education sector, and the users of the application were the students of the Educational Institution "7234 Las Palmeras".

(1) Scope definition: An AR application was developed and implemented for the learning of the chemical elements in students of the 5th grade of primary school "7234 Las Palmeras" called "Atomik-3D", using a Smartphone or a Tablet, thus visualizing the contents that serve as study support.

(2) Definition of the modules according to the requirements. In Table 1, the modules were defined in addition to their main functional requirements.

Table 1 Application modules

Module	Description
Home Screen	This module is presented when starting the application, showing the application logo and letting us learn the option.
We learn menu	In the let us learn module, several options show a brief description and the different 3D models.
Augmented Reality	The application can show the 3D models in a real environment, with the information of each model shown.
Questions	This module contains the questions to evaluate for each option presented.

3) Project Setup: The necessary tools to be used to develop the application were Unity version 2019. 1.4f1 Unity is the graphics engine that allows the interaction of 3D models for the creation of games (Unity, 2016, 2019). C# programming language, this object-oriented scripting language, is used for programming in Unity (Zapata et al., 2020). Vuforia 8.3.8, JDK, SDK, is a library that allows the detection of objects by markers set to display 3D objects (Sendari et al., 2020; Unity, 2018). Mobile-D methodology; Sublime text editor for programming and the indispensable use of a computer with 8GB RAM, 250GB Solid Disk, and Windows 10 Operating System for optimal application execution. Regarding the necessary tools on the part of the user, was necessary a Smartphone that has Android 9, 64GB Hard Disk, 4GB RAM, or a Tablet that has Android 8, 32GB Hard Disk, 3GB RAM.

2.2 Initialization

In this stage, the development environment was prepared, and the team's training was defined. For the first stage, the primary resources were established. Additionally, the installation and configuration of the software are to be used for the project's development, as detailed in Section A.3. In addition, the project architecture was developed, and the navigability flow was established.

(1) Project Architecture: Figure 1 shows the architecture of the application, in which the device, by using the camera to capture the real world, then selects the object a user wants to see; the QR Code API SDK then loads the 3D object, and then be grouped with the rest of the application and can be displayed on the screen.

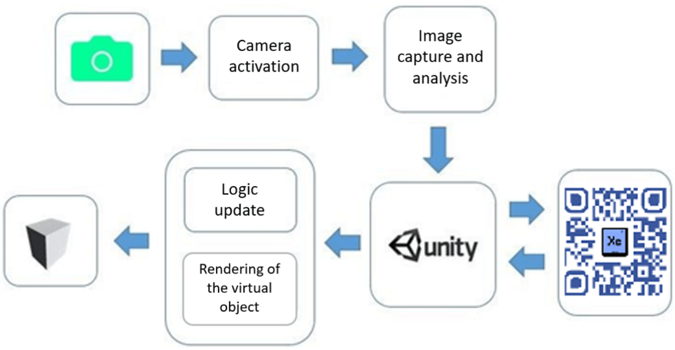

Figure 1 Application architecture

(2) Navigability: As a start of the navigability flow, first, the home screen of the application is presented with the option to learn, which, when selected, shows the buttons of the different categories such as Metals, Non-Metals, States, Groups and Periods. Pressing any category will activate the mobile device's camera, and the 3D model will be generated.

2.3 Production

In this phase, the design of the interfaces was developed, and the functionalities of the modules were implemented. Finally, the respective revisions were generated.

(1) Interface Design: At startup, the application home screen is presented (Figure 2) with the let us learn option; pressing the button displays the following content interface where the different categories are shown.

Figure 2 Start menu of the "Atomik - 3D" application

Figure 3 shows the categories such as Metals, Non-Metals, States, Groups, and Periods and the credit, question, and exit options.

Figure 3 Menu contents

The augmented reality interface, shown in Figure 4, allows the visualization of the 3D models of the selected option 3D models and navigating between models. This interface also has the option of questions.

Figure 4 Augmented reality interface

Figure 5 shows the list of practices according to the selected category and an option to navigate between screens.

Figure 5 Practice interface

The following interface consists of questions and alternatives, where the answers are validated through a green colour if correct and red colour if wrong (Figure 6).

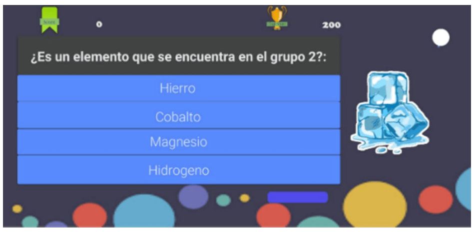

Figure 6 Question interface

Finally, Figure 7 shows the result; the score and a Congratulations message are displayed at the end of the practice.

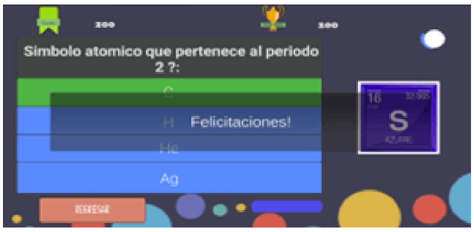

Figure 7 Result

(2) User stories and task cards: User stories and task cards were developed based on the functional requirements, using the templates provided in the methodology documentation. The user stories measured the type, difficulty, effort, and priority; within the task cards, the type, difficulty, confidence, effort, and status. After evaluating these measures, it was possible to provide an agile approach contributing to collaboration, creativity, and continuous product improvement.

2.4 Stabilization

At this stage, adjustments and integration of all the application modules were made, stabilizing the correct operation.

Figure 8 shows the home screen's coding, allowing you to travel to the category menu scene.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class CambiodeEscena : MonoBehaviour
{
    // Start is called before the first frame update
    void Start()
    {

    }

    // Update is called once per frame
    void Update()
    {

    }

    public void Cambiar(string cambioEscena)
    {
        SceneManager.LoadScene(cambioEscena);
    }
}
```

Figure 8 Home screen coding

Figure 9 shows the code of the Questions interface, where the question data() method allows us to travel to the questions menu, and the exit() menu allows us to exit the application.

```
chivos varios                                    Questionw
using UnityEngine;
using System.Collections.Generic;
using System.Xml;
using System.Xml.Serialization;
using System.IO;
using System;

//dont mess this file unless you know what you are doing, if you want to change the

public struct Questionw {
    public string questionText;
    public string answerA;
    public string answerB;
    public string answerC;
    public string answerD;
    public int correctAnswerID;
}

[XmlRoot]
public class QuestionData {
    [XmlArray("Questions")]
    [XmlArrayItem("Question")]
    public List<Questionw>
    questions = new List<Questionw>();

    public static QuestionData LoadFromText(string text) {
        try {
            XmlSerializer serializer = new XmlSerializer(typeof(QuestionData));
            return serializer.Deserialize(new StringReader(text)) as QuestionData;
        } catch (Exception e) {
            UnityEngine.Debug.LogError("Exception loading question data: " + e);
            return null;
        }
    }
}
```

Figure 9 Interface code Questions

2.5 Tests

The necessary tests were performed in this last phase, and the results were analyzed. The objective of the tests was to ensure compliance with the functional requirements to achieve user satisfaction with the correct operation of the developed mobile application. Therefore, test cases were used to ensure compliance with the functional requirements.

3 Results and discussions

The results were obtained by establishing the environments in which the tests were to be performed, and the number of tests for each objective was determined, being around 15 to 20 tests. The instruments to be used (smartphone, light meter, stopwatch) were then prepared, and the tests were performed for each objective, and the results could be interpreted at the end.

3.1 The QR Code API requires little light to recognize a flat surface

It was estimated that the tests performed should operate with a minimum of 30 lux to demonstrate the objective's success. In this test, we sought to recognize the mobile application in front of an area depending on the illumination level. These tests shown in Figure 10 were performed using the mobile application 15 times along with a mobile application to measure the surface illumination level (Lux) to identify if the QR Code API technology is suitable.

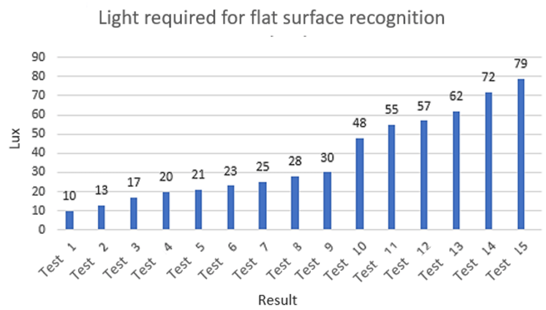

Figure 10 Luminosity test results

From all the tests performed on the application, it was obtained that when the amount of light is less than 30 lux, the recognition of flat surfaces works erroneously, unable to perform its function. When it is greater than or equal to 30 lux, the operation of the recognition of flat surfaces is correct. Finally, the test was acceptable after the tests and obtaining that the mobile application works with a minimum of 30 lux, which complies with the specifications.

3.2 The use of Marker technology requires little time for the recognition of a flat area

It was estimated that the tests should have an average of fewer than 2 seconds to demonstrate the objective's success. In the following test, we sought to obtain the times taken by the Marker technology to recognize a flat area. These tests shown in Figure 11 were performed using the mobile application 15 times, recording the smartphone screen while using the area recognition function. Later the recording was cut with Camtasia Studio to know how long the application takes to recognize a flat area.

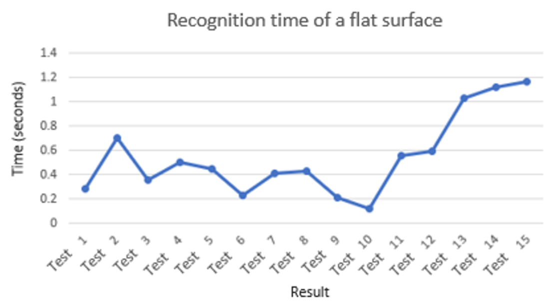

Figure 11 Recognition time test results

Figure 11 shows the test results in which the average recognition time of the flat surface obtained was 0.54 seconds, which complies with the specifications and, therefore, the test was acceptable.

3.3 The ease of use of the mobile application with augmented reality for learning the chemical elements is high

It was estimated that the tests should pass 70% of straightforward use to demonstrate the objective's success. The following test seeks to see how easy users can use a mobile application with augmented reality. The test shown in Figure 12 was performed on 20 people who were asked to use the mobile application. When they finished using it, they evaluated whether they found it easy, very easy, complicated, or complex.

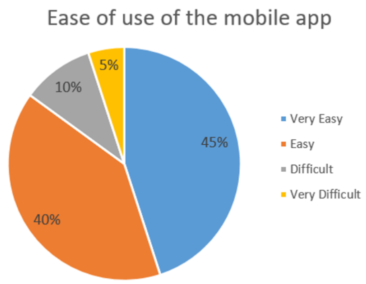

Figure 12 Ease-of-use test results

45% of the results obtained in the tests showed that usability is very easy, 40% of the tests found it easy, 10% found it difficult, and 5% found it Very difficult. Finally, after having carried out the tests and obtaining that 85% affirms that the usability is easy and very easy, it complies with what was specified, and consequently, the test was acceptable.

4 Conclusions

At the end of this project, it was possible to develop an augmented reality application that helps the learning of chemical elements using the QR Code API with Marker technology. Students can use the application to expand their knowledge of the chemical elements, complementing the traditional learning provided by the educational institution with technological learning through the application, helping them achieve higher learning performance and increase their chances of success in subsequent assessments.

After the results were obtained, it was possible to identify that, for the recognition of flat surfaces, the mobile application has a good performance on illuminated surfaces with more than 30 lux. Likewise, the Marker technology used in this project has a very efficient recognition time of a flat area, mostly no more than 1.5 seconds. Finally, it was found that most of the participants surveyed agreed that the application was very easy to use.

It is recommended for future work to test the Marker technology on iOS devices to evaluate its performance. To improve the user experience, adding more 3D models while adding more information about the objects or redirecting to web pages is recommended. Also, it should be noted that the QR Code API used in this research may represent a drawback if a user wants to work with not-so-modern cell phones due to incompatibility issues.

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