A Case Study Using Augmented Reality for Teaching Organic Compound Reactions

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Abstract—This research-to-practice full paper is elaborated from the next problem, 'Augmented Reality's technology can assist in understanding the contents of Chemistry in a more concise way? The Case Study was conducted in a small-town school. The absence of structures, such as teaching laboratories, limited Internet access, or an insufficient number of computers is common in many small cities such as the one chosen. There is also a lack of teachers trained in pedagogical methods that make the student take an interest in learning. On the other hand, most young people and teachers have cell phones and enjoy recreational activities. So, we combine these various aspects to promote learning in a playful, cooperative way and based on a relevant learning theory. This paper is aimed at analyzing learning supported by Augmented Reality (AR) for Chemistry teaching. It was a quantitative study using Augmented Reality with the intent to check the benefits that AR brings to education. We focused on Organic Reactions because many students have difficulties with this topic and we evaluate that this topic is appropriate for using Augmented Reality. First, a pedagogical approach had been discussed with teachers of the proposed discipline and from that, an app for the Android system was developed, to assist in teaching Organic Compound Reactions, uniting Vygotsky concepts on the Proximal Development Zone. The proposal is integrated to the movement based on learning by design in basic schools, STEM, the system promotes students' abilities to work with technology to understand the teaching of Chemistry. Evaluations were carried out with 54 high school students during the semester, and the results obtained on the technology used identified that 84% of students considered the contents of chemistry relevant. A significant part suggested that the approach using Augmented Reality could be used in teaching other subjects. It was possible to observe the learning with cooperative characteristics highlighting the importance of working with this perspective, uniting attractive technologies that can collaborate effectively for the construction of knowledge in school disciplines.

Keywords—Augmented Reality, Chemistry, Teaching

I. Introduction

Basic education needs new practices to guarantee fluidity in learning. Therefore, teachers seek new methodologies to attract students to their subjects, especially the exact sciences. However, in many schools there is a greater emphasis on the transmission of content, the memorization of symbols and formulas, leaving aside the construction of scientific knowledge. The problem addressed in this article is based on the absence of an explanation for abstract concepts. Organic chemistry in elementary school is an example of this, since due to the complexity of the subject and the absence of attractive activities, it does not meet the student's needs.

For Ramírez & Bueno (2020), skills and knowledge are acquired by learning and doing in a fully immersive environment, as this favors knowledge construction. Augmented Reality (AR) according to Kirner, Reis & Kirner (2012) is the superimposition of virtual objects enriching the real world. AR in education has much to contribute, as we can explore its resources as a motivating element for teaching chemistry. AR technology enables students to have a new look at learning, and with this differentiated practice they can become familiar with the subject and its contents.

To detail and know about the effect of AR technology on Chemistry education, studies in this regard are essential. Nasharuddin & Umar (2021), point out that there are three currently expanding digital technologies in mobile device based education; they are augmented reality, virtual reality and mixed reality. Visualizing the mechanism of atoms and chemical bonds is one of the challenges faced by chemistry students, these digital technologies make learning more enjoyable. Thus, the research sought to answer the following question: Can Augmented Reality technology aid in the understanding of chemistry content in a more concise manner?

Chemistry carries in many of its theories and concepts in an abstract way worked in science becoming one of the main points that hinder the learning of high school students. However, according to Zhang et al. (2018) there is a distinction between virtual objects immersed in the real world, which are constantly merging, and it is in this segment that Chemistry fits. It is also observed that in the school

system there is little interactivity regarding the number of lessons and complex subjects of Chemistry topics. The research of Fu et al. (2021) shows that experiences with technological tools gives the student a deeper understanding and mastery of knowledge, and they can apply what they have learned to the teaching of chemistry. Thus, the present research is justified by understanding that there is a large space to be explored for the benefit of teaching and learning.

The objective of this article is to describe the Learning supported by Augmented Reality as an aid in the Teaching of Chemistry from an approach in Reactions of Organic Compounds. The article aims to describe the experiences of learning in Chemistry teaching with the use of Augmented Reality, validate the students' learning with a technological approach in Chemistry teaching using Augmented Reality and propose the use of Augmented Reality technology in Chemistry teaching.

Augmented Reality applied to chemistry stands out in certain content knowledge that usually occurs in a mediated way and most know the teacher as the mediator of knowledge. Vygotsky [1978] understands that the mediator of knowledge is any instrument that promotes learning, such as: blackboards, books, maps, software and applications, therefore, the application used in the case study of this article is an instrument that mediates knowledge. To report on this research, this article is organized as follows: Section 2 presents related work, Section 3 presents the methodology, Section 4 presents the Edarch App, Section 5 presents Results and Discussions, and finally Section 6 Concluding Remarks and Future Work.

II. RELATED WORK

This section presents some relevant research developed using AR to support Chemistry teaching. The research proposed by Abbasi et al. (2017) presents a methodological approach that has as its theme the hybridization of methane with practices in AR. The application created on the Android platform had in its development software such as Autodesk Maya. The operation took place with 56 students in three major phases and had a success rate of 80.7%. For this reason, the researchers affirm that the experiments using AR is a new method capable of complementing the student's understanding of chemical processes.

Ashida & Makino (2018) developed a method for operating AR smart devices. In the application methodology, AR was added with Information and Communication Technology (ICT) on mobile devices such as cell phones and tablets. Three tests were performed with 13 previously selected formulas, and it was concluded that the system is quite effective and that AR together with mobile devices is a new way of learning in Chemistry. An approach to aid knowledge in Organic Chemistry is presented in Gonçalves et al. (2017).

The research presents the development of an application using AR technology, making the visualization of organic compounds simple and practical for both students and teachers, through Unity, Vuforia, markers, computers or mobile devices. The research of "Specific heat experiment" is presented by Wirjadi et al. (2021). The work aimed to provide students with a chemistry lab experience to better display the concepts. The research promises to facilitate online chemistry teaching in high schools to verify the contributions. In this same vein, Scotta et al. (2014), present the creation of a prototype that serves as an augmented and autonomous instruction guide for chemical experiments. The research proves that it is possible to sequence experiments and guide students to perform them.

The proposal characterized that students were encouraged and more effective in the classroom. The cited works are highlighted for promoting teaching and learning directed at many areas of chemistry such as: hybridization, organic compounds, chemical reactions, periodic table, and chemistry laboratory. What differentiates this work from those cited above are: the content of addition reactions of organic compounds, the presentation to the student of a detailed way to understand the mechanism of the 5 types of reactions within the subject and by promoting Vygotsky's concepts of ZPD, Zone of Proximal Development and Mediation.

III. METHODOLOGY

This research is classified as a Case Study. This method contributes to a better understanding of individual phenomena, organizational and political processes in society. For Yin (2015), it is a tool used to understand the way and the reasons that led to a certain decision. The application depends on the approach with the AR system to make use of data collection instruments The research also presents a qualitative approach, seeking to evaluate and analyze the results through qualitative techniques and procedure with interviews and questionnaires. The interpretation occurs from the analysis of the data collected that contextualize the research.

The data collection instruments were made by means of interviews and questionnaires. The interviews were unstructured with open and closed questions, which allowed for a better understanding of the study. In data collection, 4 (four) questionnaires were applied before the implementation of the AR system and 4 (four) after the experience. The questionnaires used in the research were closed and open for the students, which allowed after the data collection to verify the motivation of the Chemistry content. A semi-open questionnaire was applied to the teacher, with the objective of verifying the affinity regarding the use of technology and the type of learning.

For the identification of each student, in his group was

given a password with the group number, example:(1), call number of the journal example:(2) sex of the student example, female:(F), first letter of the name example: (A), putting the information together we will have the following identification: 12FA. The experiment was applied in a State School, located in the city of [ommited for revision], with 62 high school students. The choice of the institution occurred because the school is the institution with the largest number of students in the city and it was informed that the school lacked resources and teaching materials.

IV. APP EDARCH

The construction of the Edarch App went through three phases illustrated in Figure 1: the molecule creation process, marker definition, and compilations in the Unity 5 platform. The definition of the markers was done to systematize the object capture, using figures of varying dimensions to encode and reflect them. In the encoding and recognition of the markers Vuforia was used, a free subscription website with a platform that optimizes the objects handled for the Unity 5 system.

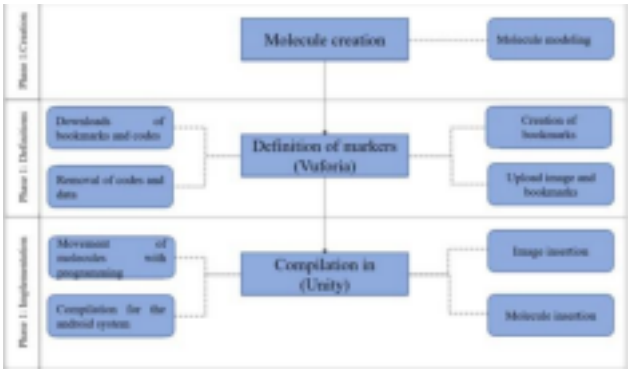


Fig. 1. Edarch Application Creation Process

The methodological steps are directed to the teacher and the students according to their roles within the learning system and use of the application, Table I demonstrates the activities.

TABLE I. DESCRIPTION OF LEARNING ACTIVITIES

Description of Activities		
Administrator	*Teacher*	*Student*
Develops the AR Application (App)	Use the (App)	Learn the method
Introducing the (App) to the teacher	Explain the Subject	Use the (App)
Expose the method to the teacher	Introducing the method to the student	Learn Chemical Reactions
		Do the Activities

Source: The author

The AR system and the Chemistry content depend on factors for use such as the student's responsibilities which are "elaborate the activity, Chemistry content, do the activities" and the teacher's descriptions "explain the subject, elaborate the activities, present app" and the administrator's roles "develop the app, expose the method, present the app to students and teachers" these descriptions indicated in Fig 2 below.

Fig. 2 - Use Case Diagram of the Proposed System.

V. RESULTS AND DISCUSSIONS

To use the Edarch application, it is necessary to install the APK on cell phones compatible with the Android platform.

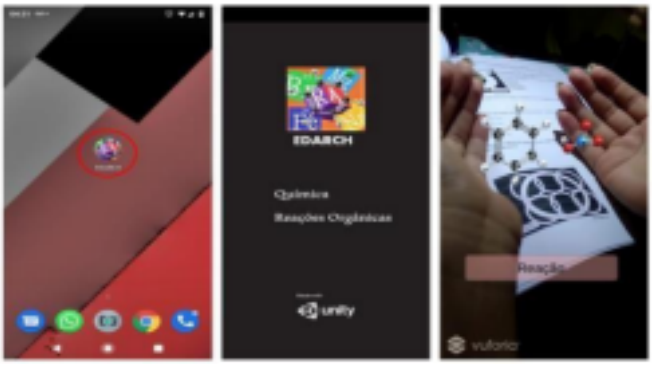


Fig. 3. Edarch Application Interface and its Functionality.

The application and use of the approach with the students, occurred during the Chemical Reactions class, and was divided into three phases:

Phase 1: Exploration. Where the teacher is responsible for: • Evaluating the molecules in the app;
• Suggesting subjects to be worked on;
• Evaluating the suggested approach.

Phase 2: Exploration. Where the student is responsible for: • Evaluating the molecules of the app;
• Evaluating the app's structure;
• Evaluating the classroom approach.

Phase 3: Evaluating learning with the AR method. • Evaluate the teacher's methods;
• Evaluate the learning with the approach; • Evaluate the interaction between teacher and student.

A. Teachers' Analysis of the Proposed Approach

Questionnaires were applied to 16 public school chemistry teachers in the municipality of [ommited for revision]. These teachers work in high school and college. The analyses are related to the use of technological supports and the evaluation of the application.. All teachers stated that they use technological resources in the classroom, and indicated that they use computers and projectors, cell phones, or tablets.

Most teachers were not familiar with AR technology

before using the Edarch application. By using the proposed approach, the teacher was able to observe the Chemical Reactions and Molecular Geometry of the compounds present in the application. The teachers considered the application to be user-friendly, and had no difficulty using it. Figure 4 presents the graph with the teachers' prior knowledge about the AR technology, and evaluation of the chemical molecules.

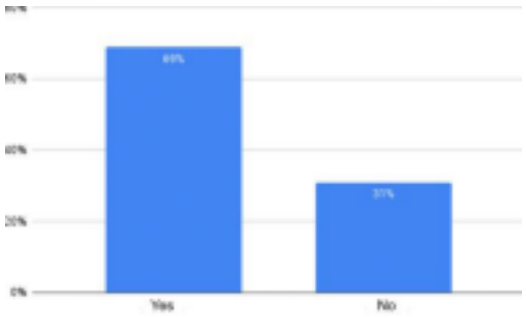


Fig. 4(A). AR knowledge

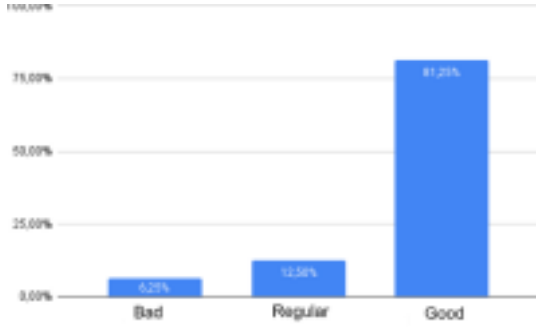


Fig. 4(B). Visualization of Chemical Molecules

Regarding the evaluation of the teaching method, and the way that teachers can use this technological resource, the question was asked about the teachers' interest in using this approach as a teaching support in chemistry classes. The teachers showed interest, because according to the report of one teacher, "The application allows the three-dimensional visualization of molecules and allows better visualization of the phenomena (reaction). This is in addition to the mental process of "Abstraction" required by Chemistry". Another teacher also emphasized that the proposed approach can be used as a didactic support "Considering that most students use smartphones, the tool would be usual". In addition, another teacher reported that "The three-dimensional visualization facilitates the understanding of the reaction mechanism".

When asked about the recommendation of the application to other teachers and students, all evaluated positively, and justified: "To facilitate learning", "Just seeing it already facilitated, because to develop this content I always look for content and games as support", "Because it would help to draw students' attention and maybe facilitate learning". Thus, the speeches of teachers support the importance of tools that serve as an aid to classes, and that is an attractive resource for students, since augmented reality is associated with education standing out as a method for combining images in the learning process Yaman & Karakose [2016].

B. Analysis on Augmented Reality technology and use in Learning

Considering the teaching methods adopted by teachers in Brazilian schools, the influential reflection on the evaluation results stands out. The methods applied in the Exact Sciences subjects should also be observed. The methodology conditions adopted in most cases are unfavorable to the performance of most students, and are factors that influence the student's low performance. When questioning the students about their knowledge of the Augmented Reality technology, we noticed that 61% did not know about it.

When analyzing the technological tools used by the teacher, it is observed that most of them are able to use these tools in a didactic way. However, it is notable that this use is moderated by student observation. By highlighting the methods, we discuss the tools that can help in the methodological dynamism of teaching. With that, one of the first corresponding tools are the technologies that attract a large part of the students "Software and Applications". However, systematic knowledge about the knowledge mediating tool is needed.

When considering the use of technology in education, they assume the positive results that these devices or software can contribute, but attention and methodological practices are needed for good use. Some students responded that they would like to participate in a classroom with the types of technology described in Table II.

TABLE II. USE OF TECHNOLOGIES TO BE USED IN THE CLASSROOM

Students	
221MT	A digital whiteboard would make the teacher's job much easier.
38FS	A technology that helps students to have something much better, something more enjoyable for a good class of amazing experiences.
59MD	Only computer for video lessons.
219FG	The cell phone, because then they could go on youtube to research how certain elements react or even applications..

The factors that can contribute to the teaching of chemistry depend on the methods and forms that teachers use, and the effectiveness of these methods is configured in results within the classroom. Each teacher's proposal is structured within the school profile. This requires a solid knowledge about the profile patterns of a school that is characterized, the teacher and his or her experiences can map this profile and adopt an approach appropriate to the class.

The subject of chemistry for some students is considered difficult to understand. Lack of interest may result from poorly designed methods, and a lack of solid grounding in the subject implies negative results. Thus, making chemistry attractive to students is a challenge that

the teacher must consider both academic and professional life.

The relationships that students have with learning are quite diverse, but many report the lack of structure common to school learning. Many consider it important that the teacher makes them learn through laboratory experiences. In addition, they emphasize the importance of the professor teaching with laboratory experiences, as reported in Table III.

TABLE III. EQUIPMENT YOU WOULD LIKE TO USE

Student	
221MT	Chemical glassware, atomic microscopes, VR, solar panels that interconnect the school and seek to develop the study of chemistry, these would make a great improvement in learning.
38FS	Chemical equipment in general, as we do not have an experiment room and equipment is in short supply.
59MD	Chemical equipment, since if we had this on hand, it would be much easier to learn.

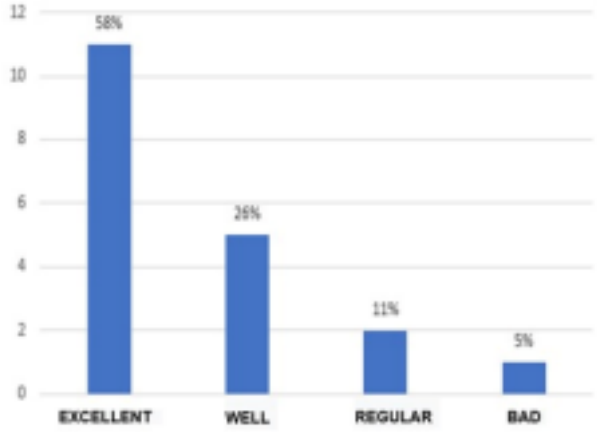
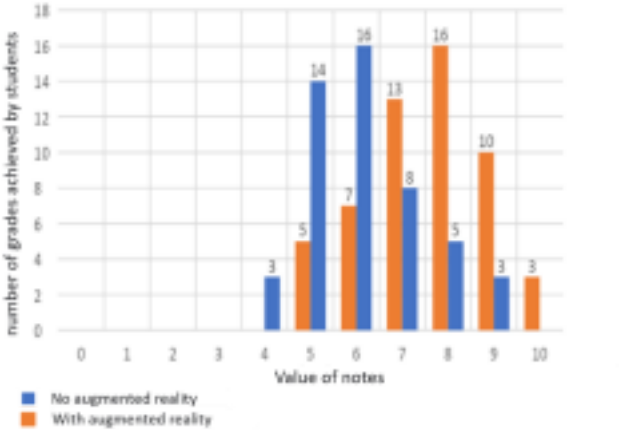


Fig. 5. Student Evaluation Before and After the Approach with AR

Figure 6 demonstrates the comparative data, the distance between these two levels the Zone of Real Development and Zone of Potential Development is the region that Vygotsky (1999) calls Zone of Proximal Development, the place where the teacher will be able to work the potentialities of a student, with the evolution of the departure of students who were in a Zone of Real development, below the expected observed in Figure 4, reaching the Zone of Potential Development with 22.2% compared to 31.4% before. Regarding the comparisons between the two spaces of the two zones, we can therefore consider that the experience with App Edarch has a significant highlight in the Proximal Development Zone. In this way, a relevant performance of the students is evident after the use in the learning with AR in the school environment.

Figure 5 illustrates the results of the second evaluation where it was possible to observe a significant improvement in the students' performance. By highlighting the two highest grades, it can be seen that 16 students achieved grade 8. The second highest percentage in this scenario is accounted for by 13 students with a grade of 7. The difference between the two scenarios exposes that the AR approach presented a great alternative to work in a dynamic way. In addition, it contributed to the motivation of learning, because students showed greater confidence in answering the questions.



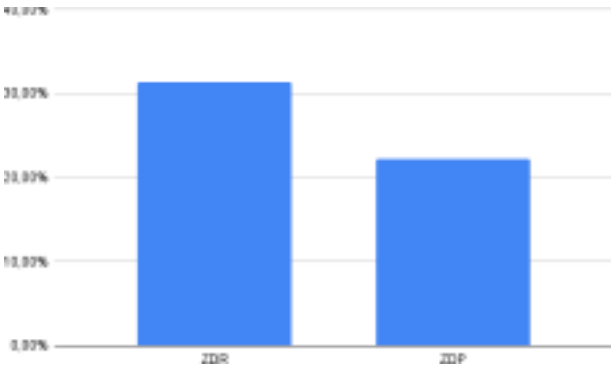


Fig. 6. Comparison between Actual and Potential Development Zone.

When asking students about using the Augmented Reality application as a Game, they evaluated the application presented. It is observed that most students liked the new method, some felt satisfied to be able to use Chemical molecules and to see them interact in the virtual field. Taking into account that most students did not know the technology used, 58% of students considered it Great and 26% rated the application as GOOD, this demonstrates that the application was well accepted by students.

Fig. 7. Students' evaluation of the proposal addressed with the Edarch application.

The students considered that the application had a great performance in the educational scope, 84% found it easy

to use on their cell phones. The students were also asked about the possibility of using the application during the school year, 85% of them considered it a great alternative to understand the school subjects. Figure. 8" shows the students using the proposed approach in the classroom.

Fig. 8. Students Performing Activities with the Proposed Approach

VI. RESULTS AND DISCUSSIONS

The results of this research were achieved, as we can describe this application as objective, as everyone in the group worked with a single purpose; contextual, because it is within the technological context of the students; motivating, as it promotes motivation so that students feel engaged in learning more. The approach is motivating, because through the AR support method it allows the visualization of molecules in 3D, which facilitates the understanding of the subject. The approach is also interactionist, as interactions between student-student and student-teacher are observed.

In highlighting the results achieved, it is also evident the objectives that guided this research, from the standpoint of evaluating Learning and the combination of an Augmented Reality application. Therefore, it is considered that the contributions of a structured approach give results not only in the quantitative aspects of a good school performance, but also the gains in the social learning structures that trigger cooperative relationships, which benefit the student and human protagonism within a Society.

The number of participants is a limitation in the experiment. The conditions of the city and the school made it impossible for a larger number to participate in the experiment. It is intended to carry out more experiments with a greater number of participants.

For future work on the Edarch application, we intend to compile for the IOS platform: nomenclature about the reactions, expansion in numbers of reactions, tutorials directed to teachers and students so that they can build their molecules on the Android system. The didactic approach used in Edarch, besides the development of chemical contents, can also be used in Biology, Physics, Mathematics, Engineering and other disciplines. Edarch can be inserted in playful activities in science teaching with emphasis on games with the application's markers.

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