LUMEN ET VIRTUS

Apps as a pedagogical resource for meaningful learning in the teaching of Chemistry – Brief review of the literature

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ABSTRACT

The teaching of chemistry is characterized as an experimental science, presenting complex contents that make it difficult for students to understand. In view of this reality, the use of technological resources, such as smartphones, through the manipulation of applications (Apps), has proven effective in promoting learning in an interactive and dynamic way in Brazilian elementary education. In order to demonstrate the effectiveness of Apps in the teaching-learning process in chemistry classes, this article presents a brief review of the use of cell phones and Apps in the teaching and learning process in Chemistry classes. The methodology used was a qualitative systematic review of the exploratory type, of publications from databases published in the period from 2017 to 2020. The discussion of the research demonstrated that cell phone Apps can be used as a resource for teaching chemistry subjects, considering that there are numerous applications related to the teaching of the subject, which enables teaching in a dynamic and meaningful way, thus formalizing the development of the student's interest in learning the subjects planned in the school menu. It is necessary to consider that the use of technologies is significant and specific in

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the teaching of chemistry, however, the traditional methodology of interpersonal contact still corresponds as an indisputable resource in the consolidation of learning.

Keywords: Teaching, Chemistry, Apps, Mobile.

INTRODUCTION

The teaching of chemistry is characterized as an experimental science, presenting complex contents that make it difficult for students to understand, who often have predominantly theoretical classes, resulting in boredom and disinterest. Given this reality, the use of technological resources, such as smartphones, through the manipulation of applications (Apps), has proven effective in promoting learning in an interactive and dynamic way in Brazilian elementary education (Guarda et al., 2023; da Silva & Amaral, 2016; Lopes and Pimenta, 2017). The resource is related to the concept of mobile learning, which is defined by the contemporary perception of the m-learning system in which it uses the internet network and mobile telecommunication resources and other personal technological devices to improve student learning, making access to learning in real time and with access anywhere outside the school environment more flexible (Cardoso et al., 2021).

From this perspective, the National Common Curriculum Base (BNCC), which covers from early childhood education to elementary school, guides the development of curricula in educational institutions throughout the country, with emphasis on ten general competencies, especially general skill No. 5, which emphasizes the importance of using digital information and communication technologies (DICTs) (Brazil, 2018).

In this sense, it is worth emphasizing that the use of DICTs in education is not a simple "means" or "support" to promote learning or arouse the interest of students. They should be used together with students so that they build a critical, meaningful, reflective and ethical perception, where the stimulus to the creative production of knowledge aims to solve everyday problems (Brasil, 2018).

In this way, it is observed that the follow-up of the theme addressed, leads to the verification that the cell phone, through the Apps, can be used as a resource for use inside and outside the classroom, since it is a material of easy access and locomotion, in addition to the factors that determine the teacher's strategic actions regarding the encouragement and exposure of a study method that can complement their learning after the use of the traditional study resources of indisputable relevance, such as didactic material and video classes (Conceição, 2018; Silva, et al., 2020).

Thus, motivated by the students' difficulty with the Chemistry discipline and the strategic view about the use of cell phones by students, and with the objective of demonstrating the effectiveness of Apps in the teaching-learning process in chemistry classes, this article presents a brief review of the use of cell phones and Apps in the teaching and learning process in Chemistry classes.

THEORETICAL FRAMEWORK

INFORMATION AND COMMUNICATION TECHNOLOGY (ICTS)

The term Information and Communication Technologies – ICT – is the most common to refer to electronic and technological devices, including computers, internet, tablets and smartphones. As the term ICT encompasses older technologies such as television, newspapers and mimeographs, researchers have used the term New Technologies to refer to digital technologies or Digital Information and Communication Technologies (DICT) (Bara-Nauskas and Valente, 2013; Kenski, 1998).

Applications are also considered a form of ICT. Given that ICTs are the focus of study and bibliographic development, the cell phone is widely used by today's contemporary society, as it allows multiple facets of communication between societies, peoples, ethnicities and countries, with this, its approach in the school environment has guaranteed taste and interest by a good part of the members of the school society, considering the alliance of practicality, efficiency and communication (Souza, 2017).

In addition, it should be noted that children and young people increasingly adopt telecommunication tools in order to sustain their personal and interpersonal interactions in real time, either for the purpose of expanding relationships, as well as for the expansion of sources of studies, allowing for the adequacy of study, through a means of communication that is easily accessible and manipulated (Leite, 2021).

Therefore, the concept of ICTs is defined in the midst of the importance that such resources focus on the development of teaching and learning in the school environment, since they explore in a diversified way, the transmission of knowledge in a playful way, giving a broad view of a certain object of study to students, in addition to facilitating the teacher's teaching (Machado, 2020).

ICTS IN THE SCHOOL ENVIRONMENT TO PROMOTE MEANINGFUL LEARNING

ICTs bring varied teaching perspectives and enable different modes of learning, enriching educational tools, student understanding and meaningful learning in Chemistry, acting as a partner in the improvement and academic performance of students (Perfeito, 2020). In this context, when analyzing the contributions of Machado and Nunes (2021), the importance of introducing innovations and integrating the use of technologies to promote teaching methodologies that facilitate understanding and arouse students' interest in the integrability of content is evident. It is important to note that these resources can be incorporated into the teaching of any subject in the school curriculum, regardless of academic or school level. (Santana, 2019).

Therefore, the purpose of the use of apps in the teaching of chemistry emphasizes the expansion of teaching in a safe way, given that the use of Apps points to cognitive development, in order to stand out as an accessible resource of general interest by the school society, also allowing the development of learning through the resolution of questions in real time and concomitant with the analysis of the results obtained by the App (Beckman, Lima and Almeida, 2020).

In this context, this inclusion has become not only a necessity, but a way to innovate teaching through an active methodology (Lemos, Dutra and Neves, 2021). It can be seen that the innovation of methodologies from the insertion of Apps inspires their use in other areas of compulsory education in school education, as well as inclusive teaching, as elucidated by the teachings of Valério et al. (2021, p.1) in the following way:

> Teaching and learning are a joint process [...] As in all other areas, in the teaching of organic chemistry, it is necessary to create methodologies that can be used in the classroom, making people with hearing impairment understand what is taught in the classroom.

In this sense, its use in the intermediation of the relationship between student and teacher, combined with extensive knowledge about its technological manipulation, access to remote classes did not inspire major difficulties in the 2020 and 2021 school year, whether through applications or classes transmitted in real time or recorded, in addition to online questionnaires, research tools, social networks and groups of people focused on sharing files and didactic material (Leite, 2019).

As exposed, it is important to highlight the teachings of Silva (2021, p.17) in which they point out the relevance of digital literacy, as a way to establish the student's preparation for new technologies and teaching methodologies in Brazil:

> The inclusion of information and communication technologies in public schools in Brazil only manifested government investments in 1996-2002, in which they boosted the inclusion of ICTs in several schools around the world [...] digital literacy can be used for new types of teaching methodologies, in addition to promoting government public actions (Silva, 2021, p.17).

Cyberculture in the school environment is a trend that has been highlighted since the time of teletransmitted courses on demarcated days and times, a fact that has gradually been molded and improved in order to concretely emphasize the teaching of diverse subjects (Souza, 2017).

In addition to the use of ICTs in the intermediation of the teaching and learning process, it is important to emphasize that the teacher must play a fundamental role in the mediation of teaching, since certain subjects are predisposed to inspire difficulties in understanding and interest in the student, thus, according to the teachings collated by Leite

(2020, p.14) highlights the peculiarities of learning chemistry, As the following excerpt highlights:

> The school space hides the existing knowledge and experience of the students, showing "a teaching that does not interest them or does not make sense for their existences, and in this context it is very likely that the refusal to learn will arise". When we are faced with a problem like this, it is possible to see one of the reasons for the great demotivation of students: not understanding why they study chemistry. [...] It is possible to observe and reflect on where change is necessary, with a transformation in the reality experienced and forming students capable of being subjects of their own learning process. We can easily see that in recent years the world has undergone many changes that directly influence coexistence. Technological advances, paradigm shifts, among others, have transformed the way individuals relate to each other and this has consequences for the way of teaching. The teaching of the discipline of Chemistry is sometimes conducted mechanically, with repetitions of mathematical calculations, frequency of use of expository classes, which causes the student's lack of affinity with the content, generating his or her disinterest.

As observed, the process of dynamization of classes should be inserted through ICTs, especially through the use of the telephone resource, since it is an instrument that the vast majority of students have an affinity with, as well as generates greater proximity between students and teachers, thus creating a fluent friendship circuit in the discussion of themes, suggestions and creation of study strategies and optimization of teaching and learning processes.

MOBILE LEARNING AS A COMPLEMENTARY DIGITAL TEACHING RESOURCE IN CHEMISTRY CLASSES

Mobile learning emerges as the possibility of accessible and complementary learning that the vast majority of students have access to (Moraes, 2020). With this, the perspectives of teaching through experimentation allow the use of applications to be obtained safely, eliminating any risk of accidents, as well as safety and dynamism in the results.

This proposal stands out in the process of teaching Chemistry, due to the use of games and media applications for use on cell phones, this system had already been consolidated in the Brazilian and international educational process a long time ago by language schools, in which they offered their students telecommunication and mobile communication devices, in which they allowed students to exercise language learning in a flexible way (Santos and Leite, 2019).

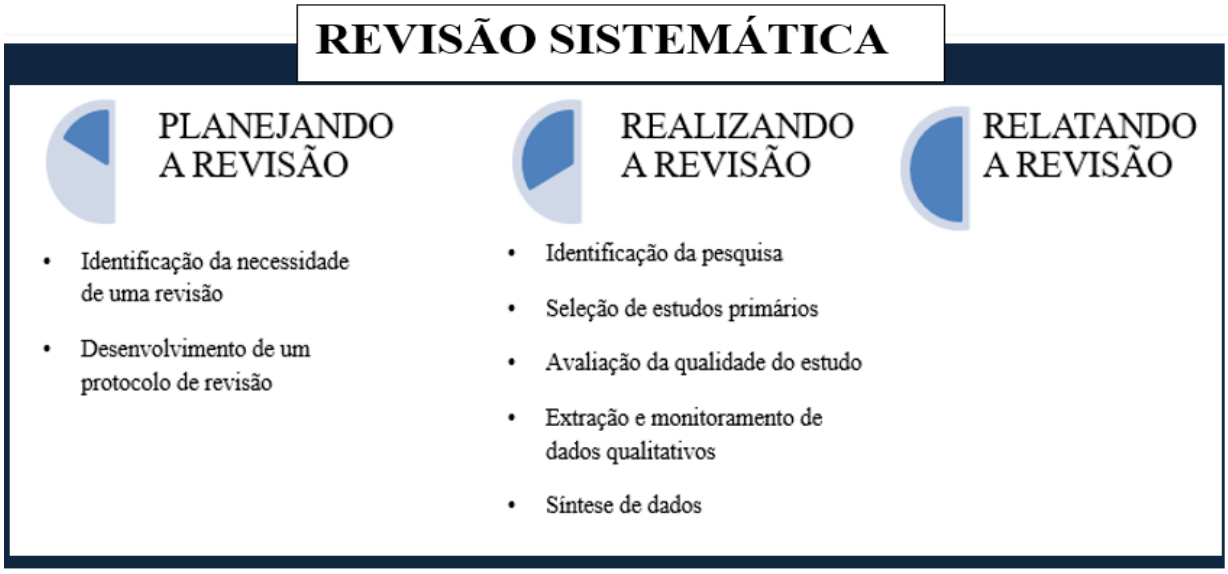
In this sense, Chemistry classes can become more attractive to students, when through the m-learning system, games and applications can produce knowledge at the time of classes, as well as after them, complementing knowledge in a differentiated and playful way (Silva and Rufino, 2021). In addition, the convenience that the m-learning system

determines, generates savings in time, motivation and a multitude of other precepts related to the optimization of learning in chemistry classes (Lima et al., 2018).

METHODOLOGICAL PROCEDURES

The present study was carried out using a methodology adapted from the Systematic Review (SR), figure 1, due to its reliability and standardization, thus allowing its replication. The literature review was qualitative in nature associated with the theme chemistry, Apps and education. According to Kitchenham (2004), "a systematic review of the literature is a means of identifying, evaluating, and interpreting all available research relevant to a specific research question, area topic, or phenomenon of interest."

Figure 1. Methodology applied to the work



Source: Authors, 2024

The procedures for carrying out this SR, set out in the figure above, are organized into 03 phases: Planning the review, performing the review and reporting the review. The methodological protocol was adapted based on the definitions listed by Kitchenham (2004), with some adaptations inherent to the needs perceived in this research. The activities developed are described below in Chart 1.

Table 1. Protocol of qualitative systematic review associated with the theme of chemistry, Apps and education.

STATE-OF-THE-ART RESEARCH PROTOCOL		SEARCH RESULT 19/03/2021
Database consulted (bibliometric tool)	Google Scholar Metrics(google scholar)	
Quest	Review Articles	
Searches made by	year of publication; Keywords	
Keywords	Chemistry teaching; app	
Boolean operator used	"and" ; "and"	
Year	Since 2017	

Searched language	Pages in Portuguese	100 Items(0.06s)
Searched language	in any language	126 items(0.05s)
Classification	by relevance	32

Source: Authors, 2024

This study adopted the following terms in its search strategy: "teaching Chemistry" and "app" (which should be present in the title or abstract). These terms were also searched in English and Spanish. However, for the scope of the work, only works in Portuguese were considered. The following data source was chosen for the research: Google Scholar Metrics (google scholar). The analysis period was limited to studies published from 2017 to 2021 so that it was possible to identify a greater number of studies and any changes in profile that occurred over time. The types of documents accepted in this SR were journal or conference articles, theses and dissertations.

After the evaluation of the articles, a total of 100 documents were returned, 29 of which were duplicates, thus leaving 71 files that were submitted to a preliminary analysis, which consisted of reading their abstracts as well as their methodology. After this initial process, 48 documents remained that were analyzed.

DISCUSSION

IDENTIFICATION AND REVIEW PROTOCOL

The literature reports that every day the increasing number of applications with potential for the area of Chemistry Education are developed and launched, which hinders a more effective monitoring. The use of education applications for smartphones available in the virtual stores "Play Store", "Google Store" and "App Store", can be grouped into two categories according to the focus of each one: Apps by subjects (or themes) and by target groups. Chart 2 shows a random sample of some free Apps available for smartphones by subject. The apps listed are the ones that have been found to have the highest user ratings, at least between 3 and 5 stars, and all apps are free or have to pay some amount for a full version (Nichele and Do Canto, 2018; Da Silva and Rufino, 2021; De Lima et al., 2018)

Table 2. Free Chemistry apps available for smartphones by discipline (or themes).

DISCIPLINA	SISTEMA ANDROID	CARACTERÍSTICAS	DOWNLOAD
Química orgânica	Química	reações química; tabela periodica; esquemas químicos	5.000.000
	Funções orgânicas em química - o teste	Funções orgânicas e bioquímica	5.000.000
	Substâncias química: química orgânica; inorgânica	Funções orgânicas e bioquímica	5.000.000
	Hidrocarbonetos: as estruturas e fórmulas químicas	Funções orgânicas	100.000
Química Inorgânica	Substâncias química: química orgânica; inorgânica	Funções orgânicas e bioquímica	5.000.000
	resolver formulacion química inorgânica quimify	Funções orgânicas e bioquímica	50.000
Química analítica	Calculadora química	concentrações;massas,volumes, preparo de soluções	100.000
Química Geral	Química	reações química; tabela periodica; esquemas químicos	5.000.000
	química master-química básica	reações química; tabela periodica; esquemas químicos	100.000
	tabela periódica 2021-química	reações química; tabela periodica; esquemas químicos	5.000.000
	Resumão de química	reações química; tabela periodica; esquemas químicos	100.000
	Calculadora química	concentrações;massas,volumes, preparo de soluções	100.000
	Kingdraw chemical structure editor	desenhar struturas químicas	100.000
	Lab4chemistry	experiências químicas	5.000
Química Ambiental	Desafio Ambiental	noticias sobre meio ambiente;poluição água	50.000
	cuidado ambiental	informações acerca da contaminação ambiental	5.000
Bioquímica	Funções orgânicas em química - o teste	Funções orgânicas e bioquímica	5.000.000

Source: Play Store

More important than identifying the number of Apps for smartphones and tablets that are available, is to identify their characteristics. For this, Apps can also be classified into categories that define their nature: Instructional/ molecular review/ study guides (Chemistry summary); structure and drawing visualization (Kingdraw chemical structure editor); utilities/database (periodic table; Hydrocarbons: chemical structures and formulas); simulators (Lab4chemistry) and research (promega) (Nichele and Do Canto, 2018; Da Silva and Rufino, 2021; De Lima et al., 2018):

- Instructional: Apps to teach or review organic chemistry topics (ebooks, study guide, flashcards);
- Structure visualization: Apps based on 3D modeling, containing representations of chemical compound structures;
- Simulation: Apps with animations or simulations of lab experiments;
- Database: Apps that make data available for querying.

It should be noted that games and applications provide the understanding of their interfaces, according to the age group of each student, thus aiming to complement the teaching processes, taught by teachers from other sources (Alana, Faria and Brondani, 2019).

PERFORMING THE REVIEW

The implementation of teaching by apps should be instigated by the entire school society, linking practicality and modernity in the midst of teaching processes (Nascimento, 2021). Thus, it is necessary for the chemistry teacher to apply and indicate the types of games and applications that will best meet the needs, as well as arouse the interest of students in the issues of teaching the aforementioned science, ensuring the complementation of teaching in a playful and accessible way (Paulozzi, 2016).

Santos and Cirino (2019), collate that the use of molecular geometry teaching allows students to visualize in an interactive way in a much more dynamic way, reflecting in an increasingly significant learning, allowing real-time simulation of results.

In this context, it is observed that the evaluation of an activity related to chemistry can be used with the use of applications, as was often used safely, in the period of pandemic and social isolation (Brito, 2021).

REPORTING THE REVIEW

Importance of the use of new technologies in the teaching of chemistry

Some students classify the study of the chemical discipline as complex and exhausting, since its precepts do not allude to a form of dynamic learning, considering learning based only on memorization and repetition (Alana, Farias, and Brondani, 2020).

Considering this point, it should be noted that according to the teachings collected by Palú, Schutz and Mayer (2020), the applicability of new technologies aimed at teaching chemistry became a trend when technological advancement demonstrated its influence on the effectiveness of results, especially in situations peculiar to students.

In this sense, the use of technologies in the mediation of chemistry contents in the school menu optimized not only student learning, but also facilitated the way the teacher presented and explored the subject in the school environment, thus allowing the consolidation of the extension of teaching from school to the residences of each component of the school society, how the use of the cell phone inspires such a statement (Leite, 2020).

The teachings of Araújo et al (2019) show that the use of technology in chemistry classes is formalized as didactic resources that make learning more meaningful to the student, as it explores an appeal field that the student is interested in, easy and practical and manipulates to study and understand the subjects.

By way of clarification, the use of cell phones and other technologies in the mediation of chemistry classes provide a better understanding of issues related to formula simulations, as well as their effects, scientific representations, and manipulation safety

(Scherer, 2019). In addition, the use of cell phones and applications indicate that public schools can determine different ways to supplement their teaching, given the absence and scarcity of resources (Pereira and Leite, 2021).

Considering all the advantages highlighted in the use of technologies, it is important to highlight a fundamental point in the acquisition of good results on the use of such sources, which are determined by the teacher's deepening of the knowledge of the technological resource and all the tools that he can use in the satisfactory exploration of the subject, as well as in directing the student on the use of such resources, for didactic purposes, since it is common for the view of many technologies to be linked only to the entertainment and idleness of students (Moura and Brandão 2018).

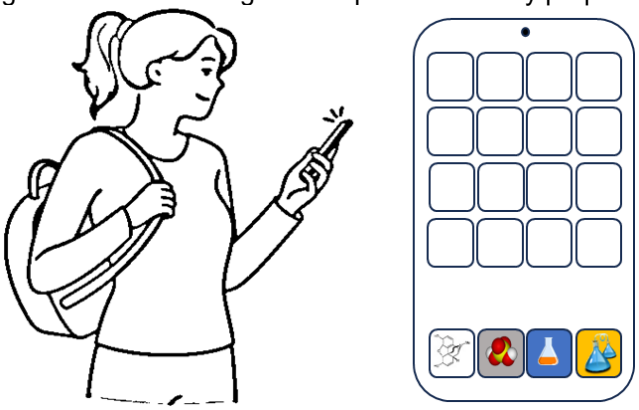
It is necessary to highlight the multiple functions that each technology employs in the daily lives of students, without highlighting the replacement that they must acquire for purposes other than their usual use. Thus, it is necessary to expose that the use of technological resources from leisure can also help in better didactics (Scherer, 2019).

Impacts of the use of ICTs in Chemistry classes

The constant insertion of technologies in Chemistry classes enables the greater interest of students, thus formalizing the awakening of curiosity in mixtures of components, as well as the analysis of studies of formulas, chains and other chemical components (Neto, 2020).

It is perceived that the use of cell phone applications points to a way of teaching chemistry, which can have positive effects on the development of the student's interest in learning the subject, since it will use a resource of great interest and aptitude by the vast majority of young people, in addition to referring to the intermediation of the use of applications and games, in which there is intimacy in their daily lives about manipulation, and/or great ease in understanding their development (Figure 2) (Santos and Leite, 2019).

Figure 2. Student using the cell phone for study purposes



Source: Authors, 2024

The monitoring of the chemistry teacher in the use of the cell phone for chemistry teaching applications expresses the possibility of solving doubts in addition to the possibility of discussing the observed results. The multiple applicability of the cell phone collates as the exposure of the various uses that the resource can have, considering that children and young people add, in their vast majority, the use of the device only for entertainment that escapes the didactic perceptions of learning chemistry (Ramos, 2018).

In addition, it is observed that the use of images in the midst of the results established in chemical experiments, it is emphasized that its propositions are safe and innovative (Hoppe, 2021). With this, cooperative learning points to the possibility of raising the level of understanding of chemistry teaching through Apps, since it enables the integration of students' teaching in the school environment, without distinguishing forms and competencies (Coelho, 2020).

Still on the definitions of augmented reality in relation to cooperative learning, it is observed that it demonstrates great perspicacity in the virtual sphere, defining the applicability even of assessment in virtual form, within the scope of high school (Rodrigues, 2021). It should be noted, in a complementary way, that the development of applications for the mediation of chemistry teaching, in the period of great environmental devastation, experienced in Brazil and in the world, encourages the preservation on a larger scale in the production of traditional resources such as books, as well as reserves the integrity of the environment, given that there are no ways of pollution based on waste and chemical formulas (Franco, 2021).

Mobile phone applications in chemistry teaching

The use of information resources in chemistry classes enables learning through games, Apps or even playful approaches that arouse interest, curiosity and the search for understanding about the subjects covered in the midst of dynamic processes (Becerra, 2023; Moraes, 2020).

Considering the presentation of the list of games existing on download platforms for android and IOS operating system telephone devices, as can be seen from the teachings collected by Simomukay and Oliveira (2020, p.4) in which they present the relevance of the application of games and applications in the teaching of chemistry, exposing the development of the software created by them, In order to optimize the teaching of chemistry:

> The generation of "digital natives", those who were born immersed in a digital world in which they can interact with the most diverse media available. It grows every day and will increasingly require teachers to seek innovative teaching approaches that

> provide a more interactive and pleasurable teaching and learning experience. [...] In this scenario, digital educational games are didactic-pedagogical learning resources that have playfulness and repeatability in their execution as characteristics and also have positive effects on students such as involvement, motivation and class enrichment. Educational games have the potential to motivate, facilitate learning, cognitive development, create new opportunities for knowledge and socialization, in addition to allowing exploration and experimentation. The digital educational game was called Aliens vs Students: Vol.1 - Organic Functions on the Farm; was created with the objective of being a didactic-pedagogical support resource for the learning process of organic functions in the teaching of Chemistry (Simomukay and Oliveira, 2020, p.4).

It is observed that the teacher must be multidynamic, thus applying resources that are familiar to the students, aiming to receive their interest in deepening learning about the context of chemistry. Almeida (2021), explores in the midst of his teachings, that the determinations of the use of the smartphone, also adds the sustainable way of preserving not only the environment, but the teacher's own health, in which he is exposed to chemical processes, in addition to the routine of countless students, classrooms, among other daily skills of the school environment.

In this sense, it is worth highlighting the dimension of relative importance in the teaching of chemistry through new communication and information technologies, aiming to integrate technology more and more in the process of teaching chemistry, a subject that for some students is classified as complex.

The approach to the theme demonstrates that the adoption of cell phone applications in the teaching of chemistry makes a dynamic mold that results in the greater interest of chemistry students, considering that the subject, from the traditionalist perspective, follows a teaching and learning script that makes little use of dynamic resources to offer content (Ramos, 2012).

In addition, it is verified in the midst of the teachings of Grando and Cleophas (2020), that the greatest difficulty is not punctuated by the applicability of the dynamics of the uses of chemistry by mobile learning, but to compensate for its manipulation also to teachers, considering that these professionals should guide its manipulation by students, considering that many teachers encounter resistance in the adequacy of their teaching, by technological and modern means.

In addition, the chemistry teaching method based on memorization and repetition is outdated in the pedagogical environment, so the use of ICTs such as cell phones contributes significantly to student learning (Silva, Prates and Ribeiro, 2016).

Technological advances and the need for social isolation have combined affinities in the midst of the current pandemic moment, given that the need for continuity of teaching and learning have been optimized and sustained by the use of teaching applications

(Souza, 2021). Among the vast technological collection, some applications demonstrate great acceptability of chemistry teaching students, as they promote the contextualization of play with the real learning of chemistry teaching (Vieira et al., 2019).

Emphasizing the use of cell phones, it should be noted that in the period of isolation caused by the Covid 19 pandemic, the use of the device can help in the remote teaching of classes, in which they can be complemented in the interim between one subject and another, on the use of chemistry teaching applications and games (Leite, 2020).

Considering the meanings of learning in the midst of the pandemic, it is verified that there are several ways to make the applicability of teaching more dynamic, as it defines the safety of the use of the chemistry laboratory, pointing out the need for the proper preparation of the chemistry teacher, to manipulate and answer questions in the midst of the use of pedagogical mediation in the midst of the need for social isolation (Barin et al., 2021).

FINAL CONSIDERATIONS

The discussion of the research demonstrated that cell phone Apps can be used as a resource for teaching chemistry subjects, considering that there are numerous applications related to the teaching of the subject, which enables teaching in a dynamic and meaningful way, thus formalizing the development of the student's interest in learning the subjects planned in the school menu.

Consequently, the topic addressed highlights the importance of technology in the integration of chemistry teaching, in an easy and accessible way to students, considering that the vast majority of students currently use and have ease in articulating cell phones, thus, when approaching the cell phone in the form of the use of Apps, as a teaching resource and easy engagement and interest of the student, Success in understanding and elaborating positive results can be achieved in an easy way.

In addition, it is important to note that the teacher and students must use the applications in order to evaluate whether there are real proposals for teaching chemistry, and the possibility of real learning. It is necessary to consider that the use of technologies is significant and specific in the teaching of chemistry, however, the traditional methodology of interpersonal contact still corresponds as an indisputable resource in the consolidation of learning.

With this, it is pointed out that the analysis of the technological tools for teaching chemistry should be repeatedly discussed and analyzed as to their real effectiveness in addition to the ways in which their approach can proceed in the elaboration of good results,

as consolidated by the present perception, in which it establishes the understanding in a pacified way as to the importance and effectiveness of the use of games and applications in the teaching of chemistry.

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