QuiLegAl application as a teaching resource from the perception of undergraduate Chemistry students

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ABSTRACT

The objective of this study was to identify and discuss contributions of QuiLegAl, a multi-platform application (app), to the teaching and learning processes, based on an evaluative approach carried out by a group of undergraduate *licenciatura* students in Chemistry. The app QuiLegAl is part of a master's thesis, which was dedicated to the development of digital learning objects as an alternative for teaching Science and Chemistry topics, such as chemical bonds and chemical equations and their representations. The research adopted a qualitative approach, with characteristics of a case study. For data production, evaluation questionnaires proposed by Oliveira (2017) and audio recordings and observation were used. The organization and analysis of the results were carried out based on the content analysis techniques (BARDIN, 2011), as well as on the triangulation of data from different sources. The results presented by the study indicate that QuiLegAl, object of evaluation by the undergraduate students, meets the requirements of the different aspects evaluated, namely the integration of visual, sound and interactive resources and the possibilities of building molecular structures, which can contribute to imparting user autonomy. These aspects demonstrate the potential of the app as a pedagogical resource for the teaching of Natural Sciences. The study suggests that QuiLegAl can motivate users to know, explore and plan new approaches to the topic of chemical bonds, using the app as an alternative to the teaching and learning processes.

KEYWORDS: Digital technologies. Applications. Science teaching. Graduation. Teaching Chemistry.

INTRODUCTION

Nowadays, the teaching of Natural Sciences, especially the teaching of Chemistry, has been challenging teachers, given the complexity of some topics, the abstract concepts involved and the resistance of many students to studying subjects in this area. They end up classifying it as difficult and abstract, a sort of "Hydra of Lerna", the Greek multi-headed monster (ZAPATEIRO *et al*., 2017).

However, innumerable researches have tried to come up with alternatives and methodological strategies to broaden the possibilities of Science teaching. These researches also try to demystify the idea, inculcated into many students, that learning Science and Chemistry is a sacrifice and, at the same time, try to present teachers with different possibilities for the teaching process, either based on experimentation, inquiry-based learning strategies, games and digital technologies (VIDRIK, 2016; AZEVEDO, 2004; SOARES, 2013; LEITE, 2015).

Brazilian official documents, such as the *Base Nacional Comum Curricular* (BNCC) (Brazil's National Common Curricular Base), highlight as a specific competence for the area of Natural Sciences the student's need to acquire different languages and to interact with digital technologies in order to communicate, access and produce diverse knowledge, while being capable of solving the different situations proposed by this field of study (BNCC, 2016). Such proposition is based on the general competence number 5 of the BNCC (Digital Culture), which refers the importance of "Understanding, using and creating digital technologies in a critical, meaningful and ethical way" (BNCC, 2016).

The applications (apps) for mobile devices, objects that are increasingly compact, have become popular among users, especially among younger people and students. The ease of production, dissemination and marketing for profit (or nonprofit) of these digital resources in app stores has increased significantly in recent years, including the ones geared towards the educational area (NICHELE; SCHLEMMER, 2014; ARANHA *et al*., 2017). This rapid growth in the production and dissemination of the apps with an educational focus lacks studies, especially regarding the quality of such digital resources and their possible contributions to the educational area.

This lacuna is reflected in the fact that the apps available in the main app stores (Google Play Store and Apple's App Store) are not scrutinized in a curatorial process, with an evaluation of the technical and pedagogical aspects involved, before being made available to users. Another issue that makes it difficult for teachers to analyze apps is the inefficient search engines used by the app stores, combined with these professionals' lack of time and criteria to select apps with potential for teaching in different areas of knowledge (OLIVEIRA; SOUTO; CARVALHO, 2016).

According to the specialized literature, the evaluation of different digital resources, such as learning objects, hypermedia and apps, is necessary and an important component for their development and/or possible use in the teaching process (FAGUNDES, 2014, NICHELE; SCHLEMMER, 2014, OLIVEIRA; SOUTO; CARVALHO, 2016, OLIVEIRA; CARVALHO; KAPITANGO-A-SAMBA, 2019). The evaluative attempts should consider the experiences of teachers and/or specialists as well as those of users, including students in general and also undergraduate students, as in the case of this study. Such attempts carried out by different groups

aim at assessing these resources in terms of their technical, pedagogical and specific aspects in order to provide an integrated review and to identify possibilities and limitations (FAGUNDES, 2014; OLIVEIRA; SOUTO; CARVALHO, 2016; OLIVEIRA; MILANI JÚNIOR; CARVALHO, 2020).

This article is a development of a master's thesis and aims to identify and discuss the contributions of QuiLegAl, a multiplatform app, to the teaching and learning processes, based on an evaluative approach carried out by a group of undergraduate Chemistry students. In the context of the *Plano Nacional de Formation de Professores da Educação Básica* (Parfor) (Brazil's National Plan for Teacher Education of Basic Education), these students were in their second *licenciatura* – a course that allows its holder to teach subjects in primary and/or secondary education in Brazil.

CHEMISTRY TEACHING AND CONTEMPORARY DIGITAL TECHNOLOGIES

Chemistry teaching can impart autonomy, once it contributes to the formation of worldviews, to the interpretation and understanding of nature and to the development of perceptions that explain the phenomena experienced in students' daily life. The autonomy allows students to take a stand on important issues that society has to face and on different problems related to the constant transformation of the contemporary world (SANTOS; SCHNETZLER, 1996; MACENO; GUIMARÃES, 2013).

The development of scientific knowledge in different areas, combined with technological advances, the Internet and a quick access to information, has provided the development of a contemporary digital culture which has been capable of influencing the ways of producing, accessing and communicating new knowledge (KENSKI, 2012). In this sense, it can be observed that, in the educational area, a vast academic publishing has been consolidated regarding the teaching process, resources and pedagogical and methodological strategies that can provide teaching practice with a basis, especially in the teaching of Chemistry (POZO; CRESPO, 2009; CUNHA, 2012; CORRÊA, 2015; LEITE, 2015).

The visual nature involved in Chemistry teaching, given its microscopic, symbolic and conceptual aspects, has encouraged educators and researchers to investigate new forms of teaching, especially regarding topics involving the atomic nature of matter. Chemical bonds and chemical reactions and their representations are perceived as problematic themes, both from the point of view of teaching and of students' learning experience (GIORDAN; GÓIS, 2015; OLIVEIRA; MILANI JÚNIOR; CARVALHO, 2020).

Digital technologies (software, apps, simulators and games) have been referred by researchers such as Giordan (2015) and Machado (2016) as possibilities that can enrich and improve the teaching and learning processes of Natural Sciences. However, these authors emphasize that the use of such resources in the classroom has not advanced with the same speed as compared to the popularity achieved by digital technologies.

Nichele (2015) points out that, although the number of publications that discuss the use of digital technologies in the teaching of Chemistry has increased, studies that address mobile devices (tablets and smartphones), their apps and

their use in the teaching process are still scarce and recent in the specialized Brazilian literature. Nichele and Schlemmer (2014) and the Oliveira (2017) point out some important aspects that can encourage teachers to choose and evaluate an app for the educational area, especially for the Chemistry teaching, bearing in mind that the production and dissemination of these resources in the app stores do not submit to a curatorial process or even to an evaluation regarding the technical and pedagogical aspects involved.

The development of QuiLegAl was conceived as a pedagogical tool for the teaching of Natural Sciences, especially for topics involving chemical bonds and their representations. Nichele (2015, p. 33) points out that apps can "provide access to simulations, videos, images, exercises [and] more information combined with a certain 'personalization', built as the student interacts with these materials". Such tools result from a set of integrated media that these resources are equipped with, which can contribute to the teaching and learning of Chemistry.

Other studies indicate that digital technologies can contribute to the teaching and learning processes when the teacher addresses topics involving the three dimensions of chemical knowledge: macroscopic, symbolic and representational (GIORDAN; GOIS, 2005; LEITE, 2015, OLIVEIRA; MILANI JÚNIOR; CARVALHO, 2020). The discussions regarding the use of digital technologies and its possibilities for the educational area point out that the adoption of such resources involves planning and clear objectives of what is intended, so that it does not just become a mere distraction or a fun activity without a pedagogical goal. A careful consideration is always important when discussing the use of teaching resources, either traditional or digital ones (ZAPATEIRO *et al.*, 2017). Moreover, in-service training for teachers aimed at the use of digital technologies in the classroom is also important (DEMO, 2011; SILVA; SOUTO, 2019).

METHODOLOGICAL ASPECTS AND RESEARCH CONTEXT

This study employed a qualitative approach. As described by Bogdan and Biklen (1994), such approach is based on the direct contact with the natural environment – in this case, with a group of undergraduate students in their second *licenciatura*, a degree in Chemistry. The evaluation of the app QuiLegAl and the descriptive data produced from reports and dialogues with this group of students are also characteristics of a qualitative research, a type which can broaden the understanding of the object of investigation.

The instruments used in the production of the data were the questionnaire for the evaluation of the app, proposed by the Oliveira (2017), which included the assessment of technical and pedagogical aspects, and audio recordings (podcast), field notes and observations carried during the exploration of QuiLegAl. The treatment and analysis of the data were performed based on induction, from the reading and rereading of the data produced, according to the content analysis techniques proposed by Bardin (2011). These techniques encompass three stages of analysis: pre-analysis; exploration and treatment of the material; and categorization, which allows the interpretation of the data from the units of analysis. In this study, the triangulation of different data sources was one of the means to expand the understanding of the perceptions presented by the group when evaluating QuiLegAl on its different aspects.

The activities analyzed in this study were carried out in 2017 with a class of undergraduate students who were in their second *licenciatura*, a degree in Chemistry at the Federal University of Mato Grosso (UFMT), in Cuiabá, state of Mato Grosso, Brazil. The class was joined by 14 undergraduate students, from whom eight agreed to participate in the study. The evaluation activities of QuiLegAl took place during the classes of the course "Information and Communication Technologies for the teaching of Chemistry". The proposal of the evaluation developed as follows:

a) at first, after installing the app on a laptop and projecting its interface on a whiteboard, the main characteristics of QuiLegAl were presented, as well as some basic commands and the purpose for which it was developed – this presentation lasted about 20 minutes;

b) subsequently, the students participating in the research were divided into four pairs, forming groups that are referred to here as "G1", "G2", "G3" and "G4" – this division accounts for the fact that the app consists of four modules: 1 – chemical elements and chemical bonds; 2 – chemical compounds and their representations; 3 – equations and chemical reactions; and the 4 – "*Construtor livre*" (free constructor for structures such as molecules). After a draw, each pair became responsible for exploring and evaluating the app based on the exploration of a randomly attributed topic;

c) the pairs were able to explore the app installed on the laptop according to the attributed topic, starting with the module 1 – chemical elements and chemical bonds; before starting the activities proposed by QuiLegAl, each student received a questionnaire, designed by the Oliveira (2017), so that he/she could register their inferences, assessments and suggestions within the evaluation proposed;

d) while a pair interacted directly with the activities of the app in the laptop with a multimedia projector, their dialogues were recorded by an MP3 player; at the same time, the other pairs followed and discussed the activities proposed by the app projected on the whiteboard. When necessary, the whole class helped the pair to solve their attributed topic, so that everybody would interact and participate – they also discussed doubts and opinions on aspects to be improved, considering the resources offered by the app under evaluation;

e) after carrying out these activities, which lasted around 1 hour and 30 minutes, the groups met separately and, with the questionnaire in hand, and they carried out the evaluation of the app, considering the various aspects investigated, namely regarding the following dimensions: techniques, didactic and pedagogical aspects and Chemistry; they could also make suggestions of improvements. The results are shown in tables 1, 2 and 3 next (each member of the group answered the evaluation questionnaire – see the section "Results and discussions").

QuiLegAl, object of evaluation by the undergraduate students, is an app built with the use of markup language HTML 5 and different frameworks, based on the JavaScript programming language, one of the most used in the world. This app was developed by the Oliveira (2017) alongside a team composed of different

professionals (linked to the educational area and applied computing). It resulted in the design of versatile resource, that is also free, being an open-source software, with possibilities for improvement by other researchers in the area.

RESULTS AND DISCUSSIONS

The results and analyses presented in this section correspond to the perceptions presented by the students when exploring QuiLegAl in a classroom environment, where they played the roles of evaluators of the app, as well as of future Chemistry teachers. The results obtained with the questionnaire will be presented, according to three dimensions: technical, didactic and pedagogical aspects and aspects directly related to Chemistry.

Evaluation of the Quilegal app from the proposed questionnaire

As previously mentioned, the results of the technical aspects evaluated by the students are presented in Table 1.

Table 1 – Evaluation of the app QuiLegAl: results regarding the technical aspects

Consider the following scale and check only one box for each aspect evaluated:					
Great: indicates that the evaluated aspect has been fully met.					
Good: indicates that the evaluated aspect was met, but you have minor caveats.					
Regular: indicates that the evaluated aspect was only partially met (50%) in some situations.					
Bad: indicates that the evaluated aspect was not met most of the times; it must be reconsidered.					
Really bad: indicates that the evaluated aspect was not met or identified, which indicates the need for change and/or adjustment.					
ASPECTS OF THE TECHNICAL DIMENSION According to your assessment, check the box that best describes the aspects of the app QuiLegAl listed below.	Great	Good	Regular	Bad	Really bad
How do you evaluate the content, level of education and target audience of the app?*	3	5			
How do you evaluate instructions for the use of the app from a technical and educational point of view?***	5	3			
How do you evaluate the compatibility with operating systems for mobile devices and computers?**	4	4			
How do you evaluate the fact that the app does not require an Internet connection to run?	7	1			
How do you evaluate the possibility of accessing the app through the web?	6	2			
Navigability					
How do you evaluate the autonomy to access the content and use the app?	5	3			
How do you evaluate the student's possibilities to interrupt, resume and restart an activity at any time during the exploration of the app?***	5	3			

Interface					
How do you evaluate the organization of the themes in the menu proposed by the app?	6	2			
Regarding the use of images, animations and simulations, are they relevant to the content covered?***	4	4			
How do you evaluate the harmony among colors, fonts, texts, animations, sounds and other resources used in the app?*	1	3	4		
How do you evaluate the distribution of hypertexts and their use in the context of teaching explored by the app?**	4	4			

Source: Own Oliveira (2017), including some questions adapted from Campos, Martins and Nunes (2008)*, Silva (2012)** and Ribeiro (2015)***.

Regarding the technical dimension, the tabulation of the data presented in Table 1 shows students' assessment of every aspect they were asked to consider. The results are presented based on the number of "checks" for each box of the scale. As it can be seen, the general aspects and the navigability were evaluated positively, with the predominance of the adjectives "great" and "good". This shows the approval of these aspects by the students and emphasizes the importance of the technical issues when developing an app, as well as of the consideration of the reality of teaching. Dialogues that took place during the evaluation process demonstrate that some aspects, such as the fact that this is an offline app, seemed to please the undergraduate students, who – it is important to emphasize – are also going to be Chemistry teachers in the future.

> [...] It works offline, without an Internet connection, you know, so there are lots of possibilities. (G2)
>
> [...] This app on the mobile phone will be excellent! I think it will be better on the phone than on the computer. On the computer, it would be better for the teacher to use. (G8)
>
> [...] With the app in a USB flash drive, you can take it to the classroom and use the projector. So, you can mount it and you can work with the whole classroom. (G7)

In the context of evaluation, the first excerpt emphasizes the fact that QuiLegAl does not require an Internet connection to run its different functionalities. This may facilitate the use in the context in which these soon-to-be teachers will be placed, since access to the Internet for teaching activities with students of public schools of state level is still scarce and/or considered deficient in Brazil. In the third excerpt, the versatility and compatibility of QuiLegAl is associated with different operating systems, as the participant suggests possibilities of use in the classroom with resources that students and schools already have, such as the cellphone and the multimedia projector. Regarding the interface of the app, the data from the questionnaire suggest a positive evaluation, although an aspect has been evaluated as "regular" – harmony of colors, fonts, texts, animations and sounds. This may indicate an aspect worthy of attention, something to be observed and/or improved in QuiLegAl. Apropos, some statements are presented next.

[...] The screen for the animation response could have a lighter tone with a darker background. (G1)

[...] Light colors, you know, sometimes combining colors would be a good idea. (G8)

[...] Change for more striking colors. (G5)

The perceptions of the undergraduates at different times of the evaluation of QuiLegAl indicates that the combination of colors can be improved and that the colors could be brighter. The last excerpt, for example, refers to an animation of a chemical reaction present in the module 3 of the app, which uses gray and black against a white background. The suggestions indicate that the use and combination of colors, fonts and text are important elements in the construction of an app – when this is not more carefully considered the visual aspect of the resource may be impaired.

The results regarding the second dimension of the evaluation, i.e., the didactic and pedagogical dimension, are shown in Table 2. This dimension was divided into four aspects, highlighted in bold in the table, that were composed of different items evaluated individually by the students when exploring the app and making their comments, suggestions and criticisms.

Table 2 – Didactic and pedagogical dimension and its results

Consider the following scale and check only one box for each aspect evaluated:					
Great: indicates that the evaluated aspect has been fully met.					
Good: indicates that the evaluated aspect was met, but you have minor caveats.					
Regular: indicates that the evaluated aspect was only partially met (50%) in some situations.					
Bad: indicates that the evaluated aspect was not met most of the times; it must be reconsidered.					
Really bad: indicates that the evaluated aspect was not met or identified, which indicates the need for change and/or adjustment.					
ASPECTS OF THE DIDACTIC AND PEDAGOGICAL DIMENSION According to your assessment, check the box that best describes the aspects of the app QuiLegAl listed below.	Great	Good	Regular	Bad	Really bad
Interactivity and feedback					
How do you evaluate the possibility created by the app that allows the user/student to insert data and get feedback?***	5	3			
How do you evaluate the presence of interactive assessment activities involving solving problem situations proposed by the app?	3	5			
How do you evaluate the possibilities offered by the app regarding interactive activities to be developed in groups or individually?***	6	2			
How do you evaluate the presence and use of interactive tools, such as buttons, icons, options and building of molecules in the app?	5	3			
How do you evaluate the level of interaction (student participation) required by the app?*	5	3			
How do you evaluate the feedback given during the activities proposed by the app?***	4	3	1		

Motivational resources					
How do you evaluate the presence of motivational resources used in the app?	2	6			
How do you evaluate the sound resources and sound effects used in the activities proposed by the app?*	1	5	2		
How do you evaluate the temporary record of students' answers in some activities of the app?	4	2	1		
How do you evaluate the harmony between the recreational and educational elements involved in the design of the app?**	4	4			
How do you evaluate the mechanisms that allow you to avoid or reduce errors, that is, the tips offered by the app regarding error management?	2	6			
Fundamentals and pedagogical content					
How do you evaluate the user guide for teachers (tutorial)?***	2	6			
How do you evaluate the presence of educational objectives?	4	4			
How do you evaluate the contextualization of the content?*	5	3			
How do you evaluate the level of complexity required in the approach to the content?*	5	3			
How do you evaluate the possibility of an interdisciplinary approach using the app?*	4	3	1		
Attention to special needs					
How do you evaluate the presence of tools that allow the access and exploration of the content by the deaf students?***	3		5		

Source: Own Oliveira (2017), including some questions adapted from Campos, Martins and Nunes (2008)*, Silva (2012)** and Ribeiro (2015)***.

Regarding interactivity and feedback, the results of the different aspects indicate positive evaluations – namely, the possibility of entering data in the app, the presence of interactive assessment activities, whether carried out individually or in pairs, and the possibility of building molecular structures. In this regard, when exploring and evaluating the topic 2 of QuiLegAl, "Construtor Livre", a student reported to his colleague the step by step of the building of the hydrofluoric acid (HF) structure:

> [...] [For the] H [hydrogen] clicked there. I will need an electron because it only has one electron in the valence shell. Click on "Fluorine", then they make a single bond. Top-notch! (G6)

When observing the construction carried out in QuiLegAl by this pair of students and the explanation of how the representation of the covalent bond occurs, it could be noted that one of them was surprised with the possibilities of interaction and representation created by the app. He seems to be motivated and happy to finish the chemical representation and to receive feedback from the software. The presence of interactive assessment activities also called students' attention. The following excerpt can help us to understand the evaluation of this aspect.

> [...] In this part of the game, you have to call someone. There is that thing of the two people interacting to learn at least, isn't it? That's very different, very cool. (G6)

The possibility of students interacting in pairs when using QuiLegAl, in an activity that simulates a sort of game, is welcome by the participants. They seem to recognize how important the different kinds of interactions are (student-to-student, student-to-QuiLegAl and/or even student-to-teacher). These interactions can be applied in the development of different activities and are perceived as something that can contribute to the teaching and learning of the subject.

The feedback given in activities was evaluated as "regular" by one student. This did not interfere significantly in the evaluation of the aspect, because the other undergraduate students checked the boxes "great" and "good". Therefore, according to the results, the feedbacks given in QuiLegAl were sufficient.

The evaluations regarding motivational resources indicate the importance of aspects that can catch students' attention, mechanisms that help users reduce errors (tips) and strategies for combining recreational and pedagogical aspects in the design of the activities proposed in QuiLegAl. The interaction of undergraduate students with the app also revealed some possibilities of use related to this aspect.

> [...] [The app can help] assimilate the content, build learning. The student can learn in a playful way, isn't it? (G3)

When presenting his perception, the undergraduate student seems to recognize the pedagogical objective involving the activity proposed by the "Construtor livre". He also points out the recreational aspect involved in the activity as an important tool for learning. Playfulness should not be isolated from the pedagogical objectives proposed by the teacher when exploring the resource – otherwise, as Zapateiro *et al*. (2017) warn us, the class will be exposed to mere "just for fun" activities.

Still considering the motivational aspects, two items were evaluated as "regular" – the sound effects, sounds and temporary records of answers and representations built by users. Regarding the sound, some observations registered during the exploration of QuiLegAl by the participants allow us to understand what may have led the students to such evaluation:

> [...] The background music could have a slightly lower volume, when the speaker is explaining the content. (G3)

> [...] It is observed that the sound emitted by the laptop used in the classroom is low. So, the other students, when following the activity, may not have heard some sounds from the explanation of some tutorials and animations. (Observation by the researcher)

The students' and the researcher's observations registered during the evaluation of the app provide some hints as to what may have led to the "Regular" rating previously mentioned. This can be considered as an aspect to be adjusted or improved in QuiLegAl.

Regarding the fundamentals and the pedagogical content, the results show that the students approved the presence of the tutorial, as well as of other aspects related to the pedagogical objectives, to the level of complexity and to the

contextualization of the contents covered. Only one "regular" was found and it was attributed to the possibility of an interdisciplinary approach, suggesting that one of the undergraduate students did not find in QuiLegAl resources or activities capable of developing a coordinated approach to the various subjects of the school curriculum or even of enabling possibilities for an integrated teaching in the area of Natural Sciences.

Lastly, the results regarding the attention paid to students with special needs indicate that "regular" was the most common evaluation. Students agree that QuiLegAl needs adjustments, so that it can attend to students with special needs.

[...] Adjust for the visually impaired. (G1)

This student emphasizes the need to make adjustments so that QuiLegAl can attend to the needs of users with full or partial decrease of their hearing ability. According to the participants, the visual focus of the interfaces could only partially assist deaf students, as the guidelines and some screen functionalities are presented only in audio. Therefore, these guidelines should be presented in a written text.

The last dimension of the questionnaire relates to Chemistry and groups visual aspects as well as those related to representations, language, autonomy and the external use of the app. The results are presented in Table 3.

Table 3 – Chemical dimension and its results

Consider the following scale and check only one box for each aspect evaluated:					
Great: indicates that the evaluated aspect has been fully met.					
Good: indicates that the evaluated aspect was met, but you have minor caveats.					
Regular: indicates that the evaluated aspect was only partially met (50%) in some situations.					
Bad: indicates that the evaluated aspect was not met most of the times; it must be reconsidered.					
Really bad: indicates that the evaluated aspect was not met or identified, which indicates the need for change and/or adjustment.					
ASPECTS OF THE CHEMICAL DIMENSION According to your assessment, check the box that best describes the aspects of the app QuiLegAl listed below.	Great	Good	Regular	Bad	Really bad
Representations and language					
How do you evaluate the approach to Science/Chemistry (language used, symbolic and representational aspects) presented in the app?	4	4			
How do you evaluate the possibility of the app favoring the consolidation of basic concepts of Science and Chemistry?	6	2			
How do you evaluate the presence of interactive and recreational elements in the approach to the content?	5	3			
How do you evaluate ability of the app to assist the student in representing diverse molecular structures?	4	4			
How do you evaluate the conceptual aspects presented in the app?	5	3			

Visual aspects					
How do you evaluate the use of images, animations and simulations in teaching Science/or Chemistry used in the app?*	3	5			
How do you evaluate the integration of texts, images, animations and interactive activities for teaching the content covered?	3	5			
Autonomy and applications					
How do you evaluate the possibility of using the "Construtor livre" (for structures such as molecules) presented in the app in Science and Chemistry teaching?	4	4			
How do you evaluate the possibility of using this application in Science and Chemistry teaching?	5	3			
External use aspects					
How do you evaluate the app regarding the possibilities of using it outside the confines of the school (as a complementary resource)?	6	2			
How do you evaluate the requirements of school resources and conditions to the use of this app in a teaching situation?	6	2			
Use this space for criticisms or suggestions.					

Source: Own Oliveira (2017), including questions adapted from Campos, Martins and Nunes (2008)*.

The results related to the representations and the language used in the app show that all aspects investigated were evaluated positively. By confronting these results with other sources of data, we can better understand what led to such evaluation, from the points of view of the participant undergraduates.

> [...] It contains languages that facilitate the learning. (G5)

> [...] It's a simple language that they [students] can explore on their own, suddenly they don't need the help of the teacher. (G4)

Both conceptions show students' opinions when exploring QuiLegAl. They suggest that the language used is suitable for students and that they envisage possibilities for using the app that can go beyond the classroom confines, such as activities that require a practical approach to the knowledge of Chemistry. Talking about the conceptual aspects, one of the undergraduate students highlights:

> [...] This facilitates the learning of Chemistry, of chemical concepts. This [promotes] chemical literacy, also because it brings up this question of the cake. 'What is the name of this one here? But what about in the language of Chemistry?' That's good! (G3)

Checking his notes, the student remembered one of the topics of QuiLegAl, which explores playful and interactive elements in a dialogue between the atom and the cake, in which basic knowledge of the related Chemistry content is dynamically discussed, allowing the learner to apply some concepts. According to participant's point of view, this is positive aspect that could help the teaching and learning processes and could also account for the ratings of the aspects previously mentioned (Table 3).

The visual aspects were also evaluated positively. Some perceptions of the students are indicative of the related characteristics presented by QuiLegAl.

> [...] This is cool, because I put question in a test – for example: 'six moles of water form how many moles of oxygen and hydrogen if these atoms split?'. They [students] know that the molecule is H2O, but no one could understand [...]. Here they see, and having separated [the atoms], for them to count is much easier. (G1)

The arguments presented by the student when carrying out the analysis emphasize the importance of the visualization in the teaching processes when dealing with a theoretical question. The app enables the simulation of a chemical reaction. Exploring the activity, the student concluded that the form of presentation of such reaction, based on the representations of its visual elements, the ones that caused the product of the reaction, can facilitate the process of learning the topic. With this same perspective, other students said:

> [...] Most of our students are too lazy when it comes to reading, so it's a dynamic way [to teach], isn't it? We have the drawings, the visual, the auditory aspect. So, this is what catches their attention. (G7)

> It's true! In other [apps], there aren't. (G6)

The dialogues highlight the favorable opinion regarding the integration of the different resources, as a possibility to attract the students' attention and, at the same time, facilitate the approach to the topics in a dynamic and interactive way, that does not only require reading, but rather the active participation of the learner. This leads us is to student's autonomy in the learning process, aspect referred by this undergraduate student:

> [...] You can assign some activities that at home the student can do like this and like that. He goes there and does it, he can bring doubts to the class. (G3)

After carrying out the activity with the "Construtor livre", an undergraduate from G3 envisioned possibilities of applying the resource and, at the same time, enabling students to learn other ways that go beyond the confines of the classroom. This indicates the perception that extra-class activities to be carried out with QuiLegAl could expand students' understanding of the topic studied.

Lastly, the evaluation of the external aspects associated with the use of the app seems to be perceived as a viable option. That are comments in that direction, when participants mention the possibility of having students use mobile devices.

> [...] Because, on the cellphone, it is much more practical to use, building things is faster. (G6)

It can be noted that the undergraduate students from G6, attentive to the technological context and to the reality of the students, sees advantages in using the app when carrying out activities such as building molecules on mobile devices. At the same time, the student seems to envision the possibility of exploring these resources in the teaching and learning processes.

The evaluation carried out through the questionnaire proposed by Oliveira (2017) shows that, in general, QuiLegAl met the expectations for most of the items

evaluated, according to the perception of the undergraduate students. They went further by pointing out aspects related to the app that were not included by the questionnaire, therefore suggesting possibilities for complementing and expanding the analysis of the data produced during this investigation.

Next, a set of data, related to categories that emerged from the treatment and organization of the results, will be presented. This will allows us to reflect and discuss the meaning of the undergraduate students' perceptions when evaluating the app, considering the different sources of data production. From the triangulation and analysis of these data, we are still interested in understanding important aspects that, from the point of view of the participants, may indicate the potentialities and limitations of the resource for the teaching and learning processes.

The emergence of the main categories, as well as the focus of analysis and the units of meaning can be seen in Table 4.

Table 4 – Perceptions of the students when exploring the QuiLegAl

Focus of analysis	Categories	Units of meaning
Conceptions about the app and its implications for the teaching and learning of Chemistry	A potential resource, recreational aspects and the learning of concepts from new approaches	G1, G2, G3, G4, G5, G6, G7 and G8
	Autonomy and assimilating knowledge using visual and interactive resources	G1, G2, G4, G6 and G8

Source: Own authorship (2018).

Category 1 – A potential resource, recreational aspects and the learning of concepts from new approaches

This first category aims at portraying, in an integrated, way aspects that were complementary during the analysis and, therefore, have proved to be recurrent in the perceptions presented by the undergraduate students. QuiLegAl presents characteristics that resemble a game, as well as playful aspects, as shown in the excerpts below:

> [...] There is fun in it, students can also have fun. (G7)

> [...] The competition too, which helps. It's great! (G5)

> [...] How cool, you can play in pairs or individually and on computers. I loved it, I believe students will love it! (G8)

The perceptions presented by the undergraduates demonstrate their enthusiasm when exploring an interactive activity that was considered by most of them as "fun". They identified characteristics that can motivate students, the target audience of the resource, and they even make it clear that QuiLegAl presents features that resemble games. This aspect was evaluated as a positive and motivational aspect, able to relate to the reality of learners, who are used to technological innovations, mobile devices and digital games.

The interactive activities that originated the excerpts transcribes above are included in topics 1 and 2 of QuiLegAl. These activities simulate an environment in

which the user needs to select elementary substances and compounds and apply some related concepts. This environment contains a series of sound effects and scores for correct answers and errors, that reminds us the idea of didactics game proposed by Cunha (2012, p. 95): "those that are directly related to the teaching of concepts and/or content, organized with determined rules and activities and that maintain a balance between the recreational function and the educational function".

It is worth mentioning that QuiLegAl surpasses the concept of a didactic game, as its design includes a set of integrated media, that are intended to establish a harmony between recreational and pedagogical aspects in the proposition of interactive activities involving basic concepts of Chemistry. At the same time, it takes into account the autonomy of both the student and the teacher in enabling the construction/representation of molecular structures associated with the theme, functioning as a constructor of molecular objects (GIORDAN; GÓIS, 2005).

Other notes indicate that the app presents a set of interactive activities that can be explored and contributes to the teaching of Chemistry.

> [...] Cool, the part of the bonds, substances, you can work with the content, you can explore it first and then apply it. (G2)

> [...] As a resource for the classroom, because the teacher may be teaching and as he is already interactive… He asks questions about the cake, so you can show him [the student] the questions about cake to introduce the topic of chemical reactions and then go to the explanation. (G6)

> [...] As a revision [tool] and even as an aid for learning, and not just reviewing.

> [...] Our students have learning difficulties. Sometimes we think they can master it so that it can be done as a review, they take it home and end up using it. (G3)

> [...] Outside school too, at home he [the student] can access and play, because it is easy and he learns too. (G4)

These students express that they have envisioned possibilities to approach the themes from QuiLegAl. This perception is amplified by other students (from G3 and G4), when they consider that the evaluated resource can help the teaching and learning processes and exceeds the confines of the classroom. Therefore, it can become a complementary tool for the teaching process. At the same time, students recognize other ways of learning and teaching based on the use of digital technologies.

The practical activity of exploring the app is perceived as an indispensable stage before choosing any resource, either digital or not (SILVA; CAMARGO; SILVA, 2018). During the course of this evaluation, the future teachers talked about the possibilities for using QuiLegAl. One of the participants reflected about the teaching practice and the possibilities to effectively apply this digital resource in the classroom.

> [...] I thought, like, the whole room, because then everyone interacts. Because, like, the group was wrong? Look, everyone sees it. (G5)

> [...] I'm thinking about a way to teach better, everyone learning together. Do what I said: split in groups, work in the classroom instead of individually, everyone participating. I would recommend them [students] to download the app on their cell phone. (G2)

These different points of view agree that one of the teaching strategies to use QuiLegAl may consist of exploring this app so that all students can interact at the same time. This can expand the possibilities of teaching and learning, either with mobile devices and/or laptops and multimedia projectors. The excerpts and arguments presented corroborate the possibilities of using QuiLegAl in the classroom and outside it. The perceptions go beyond that by signaling its potential as a didactic resource for teaching Chemistry and Natural Sciences, since the contents proposed by the app are initially seen in the final years of Basic Education.

Category 2 – Autonomy and assimilating knowledge using visual and interactive resources

The second category intends to show the different perceptions of the students about the design of the app. In this sense, the data from the questionnaire and other sources analyzed indicate that one of the unique characteristics of QuiLegAl is the combination of different media in a single virtual environment, that is, its interfaces (screens). The following excerpts bring other elements that allow us to expand our understanding on the topic.

> [...] I liked it because other apps I looked for are just one single thing. I found it interesting to mix these three, you know, because this is what we go through in the classroom and whether or not we want to play a game or [use] an app that is just one thing, it is meaningless. And so I liked the voices saying things, it's not just that reading thing. I found it interesting! (G6)

> [...] If you use only the book, it's not much. (G8)

The data indicate that the combination of visual, sound and interactive elements (text, sounds, images, animations and constructor) in the screens, especially regarding chemical bonds, caught the attention of the undergraduate student from G6. The students also agreed that the use of only one type of media – the written text, for example – can be tiresome, lead to little interaction and often become meaningless to the learner. The participants seem to agree that the use of several resources is more likely to hold one's attention, so they point out that the approach should not be limited to just one strategy or resource, such as the textbook, for example. As stated by the student from G6, this resource is not enough. This participant implies that other resources are important, including visual and interactive ones, because the book explores textual aspects and/or static objects and it is not interactive, i.e., does not have animations and practical activities in a virtual environment.

The "I found it interesting" (G6) indicates that the student saw the potential for integrating different media and interactive resources as an important factor, that can stimulate the teaching process. A similar idea is advocated by another student.

> [...] Animations, students today are very visual. [...] Those bonds, I found them really cool. I had never found a connection scheme explaining a covalent bond. Very nice! You can enter a classroom and show the animation, it makes it easier to work on the concepts. (G8)

This undergraduate student makes a statement about students of the 21st century which is also advocated by Kenski (2012). The author states that nowadays students are willing to interact (actively participate, learn from doing); they are used to media languages and are much more visual and interactive. These characteristics of this new generation are connected to the most diverse technological resources. Chemistry, in its turn, is also considered a visual science (ANDRADE NETO; RAUPP; MOREIRA, 2009, OLIVEIRA; MILANI JÚNIOR; CARVALHO, 2020) and has been using different technological resources capable of expanding the visual possibilities to better understand the atomic nature of matter and its implications in different areas of knowledge.

When referring to the app's interfaces, the students from G8 state that the integration of visual, sound and textual resources present on the screen that presents chemical bonds is something new. This highlights the potential of the animations that integrate these three types of resources when working with concepts that involve covalent bonds. The perceptions corroborate the ideas advocated by Giordan (2015. p. 3), when the author states that the audiovisual resources have gained prominence in the educational field due to the "ability to summarize in short excerpts a great number of concepts, ideas and knowledge", in a way which is "superior to other forms of communication". Braga (2014, p. 23) goes further by stating that animations can "become valuable didactic tools in helping students with any difficulty in understanding abstract concepts".

This perception is extended to the possibilities created by the animations, the interactive activities associated with the application of concepts through QuiLegAl and its constructor (found in the app). A student from G4 analyzes this aspect:

> [...] The part that will be open for the person to build, for them to work with the teacher. You can say: 'this part here, I will do it'. (G4)

Here the student recognizes the possibilities of interaction: student-teacher-app and/or student-app-teacher (among other possibilities). This conception highlights autonomy as being an important aspect. When providing these features that allow free constructions, a range of alternatives blossoms and the teacher and students can explore them. The user moves from a passive attitude to an active one that requires the activation of knowledge, necessary for the construction/representation of structures the learner wants to explore. This can be considered a unique characteristic observed by the undergraduate student when presenting his perceptions.

The following dialogue indicates the activation of some knowledge in the representation of a chemical structure using the free constructor.

> We are going to build two isomers with the chemical formula C5H12. (G1)

> C_5H_{12} in a straight line? (G8)

> But two structural formulas in the case ... (G1)

I put the carbons, H12; now the hydrogens are still missing. (G8)

You have to put them close in order to bond. (G1)

Can we build a chain of five… What's the name? (G8)

Five is 'pent', right? So it is 'pentane'. (G1)

Yes, it is true, let's see if it worked, check the bonds. (G8)

This is good to use in Chemistry in the 3rd year. (G1)

The dialogue initially presented by students from G1 and G8 demonstrates the mastery of some chemical concepts, especially the concept of "isomerism". After that, they plan the representation of the structure (C_5H_{12}) in QuiLegAl, by inserting the symbol of the carbon atom (C) and then stabilizing the molecule by adding hydrogens (H). This construction follows the octet theory. After distributing the hydrogens, the molecule needs to be named. The interaction of the pair demonstrates that G8 did not remember or did not know how to name the molecule, but, from the interaction with the classmates and with the app, a member of the group remembered the rule for the nomenclature and they came to an agreement on what the name is.

With the use of visual and interactive elements from the student-student-app interaction, undergraduates quickly finished the construction, which became the object of analysis by the pair when checking if the different elements met the rules for the chemical bonds and whether the constructed representation actually corresponded to the formula C_5H_{12}. The construction reveals that a single molecule can activate different knowledge/concepts in its representation. At the same time, when finishing the molecule, students could see the possibilities of using this resource in the construction of knowledge related to Organic Chemistry, usually explored at the end of the secondary education in Brazil.

Another student, overhearing the dialogue and the construction projected on the blackboard, complements:

[...] It even serves as a material for the teacher to study. (G2)

This claim indicates a new perspective – QuiLegAl ("Construtor Livre") helps the knowledge construction by the teacher in a process of continuing education, considering that, when talking about teaching and learning processes, teachers can be considered perennial learners (DEMO, 2011). The perception of the students demonstrates that this app can help both students and teachers to assimilate and apply chemical knowledge related to chemical bonds and associated topics.

FINAL CONSIDERATIONS

In this section, we turn our attention to the objectives that were established at the beginning of this study – i.e., to identify possible contributions from QuiLegAl, based on an evaluative approach carried out by a group of undergraduate Chemistry students. It is possible to assess some of the findings regarding the potential of this resource for the teaching of Natural Sciences, especially for the teaching of chemical bonds and their representations.

The results of this study suggest that aspects related to interactivity, to the possibilities of interaction created by QuiLegAl, whether carried out individually or in pairs, are important, as they may stimulate the development of new approaches in the teaching process, according to the undergraduate students. The presence of recreational and motivational aspects, which simulate games, was pointed out as important in the design of the app, as they can facilitate the approach and teaching of chemical bonds, catching learners' attention and motivating them to study the theme. These aspects are, in fact, important; however, they should not overshadow the pedagogical aspects and objectives that guide the use of any resource in the teaching process. If this principle is not carefully observed, teacher can undermine any attempt to innovate in the teaching process.

The combination of visual, sound, textual and interactive aspects was considered essential. Such aspects were perceived by the undergraduate students as distinct features of QuiLegAl. Other similar apps do not include such combination. The different visual resources (images, videos, animations) were pointed out by the participants as potential resources, capable of helping approach and teach the topics. These conceptions presented by the undergraduate students are supported by the specialized literature, which points out what audiovisual resources can contribute to the teaching and learning processes (RAUPP; SERANO; MOREIRA, 2009; CORREA; 2015; MACHADO, 2016; OLIVEIRA; CARVALHO; KAPITANGO-A-SAMBA,2019, OLIVEIRA; MILANI JÚNIOR;CARVALHO, 2020).

Another important aspect is imparting autonomy, enable by one of the functionalities present in the app – the "Construtor Livre". It was pointed out as a potential resource that allows the enlargement of the teaching and learning possibilities for students and teachers, considering the opportunities for teachers' continuous professional development and for the improvement of the teaching the chemical bonds.

Lastly, the limitations evidenced during the evaluation were mostly linked to the technical dimension, especially aspects related to the harmony of colors, texts and fonts. Participants have also added to this list of possible adjustments the background sound of the screens, as an aspect that requires attention and/or correction. Regarding the aspects related to attending to students with special needs, the app was perceived as limited, since it only partially assists deaf students. The functionalities targeting at visually impaired students, according to the participants, require specific adaptations in a new version of QuiLegAl, so that they could fully attend to this part of the public.

The results presented in this study lead us to the assertion that QuiLegAl, object of evaluation by the undergraduate students, med the different aspects covered by the questionnaire. This demonstrates the potential of the app as a didactic resource for teaching Natural Sciences. The discussions and results of this

study can motivate teachers in the area to learn about, explore and plan new approaches to the topic of chemical bonds, using QuiLegAl as an alternative to the teaching and learning processes.

Aplicativo QuiLegAl como recurso de ensino na percepção de graduandos de licenciatura em química

RESUMO

O objetivo deste estudo consistiu em identificar e discutir contribuições do aplicativo multiplataforma QuiLegAl para os processos de ensino e aprendizagem, a partir de uma abordagem avaliativa, realizada por um grupo de graduandos do curso de Licenciatura em Química. O aplicativo QuiLegAl é parte de uma Dissertação de Mestrado que aborda o desenvolvimento de objetos digitais de aprendizagem como uma alternativa para o ensino de determinados conteúdos de Ciências e Química, tais como ligações e equações químicas e suas representações. A presente pesquisa adotou uma abordagem qualitativa, com características de estudo de caso. Para a produção de dados, foram utilizados questionários avaliativos propostos por Oliveira (2017), registros de áudio e observação. A organização e análise dos resultados foram realizadas com base na análise de conteúdo (BARDIN, 2011), bem como na triangulação de dados oriundos de diferentes fontes. Os resultados apresentados pelo estudo revelam que o QuiLegAl, objeto de avaliação por parte dos graduandos, atende aos diferentes aspectos avaliados, destacando-se a integração entre recursos visuais, sonoros e interativos que estão associados a possibilidades de construção de estruturas moleculares. Tais características podem contribuir para desenvolver a autonomia do usuário, demonstrando o potencial do app enquanto recurso didático para o ensino de Ciências Naturais. Este estudo sugere que o uso do QuiLegAl pode motivar os usuários a conhecer, explorar e planejar novas abordagens para o tema das ligações químicas e a utilizar o aplicativo enquanto alternativa para os processos de ensino e aprendizagem.

PALAVRAS-CHAVE: Tecnologias digitais. Aplicativos. Ensino de Ciências. Licenciatura. Ensino de Química

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