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Using Technology to Support Chemistry Teaching and Learning in the Context of Brazilian Distance Education

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Abstract Distance education in Brazil exhibits a powerful impetus for education for all. This study examines the use of educational technologies to teach and learn Chemistry as part of an effort to contribute to teachers' professional development in the context of Brazilian education. Criteria for selection and analysis of different technologies were identified based on teachers' input and in the context of high school settings. They are: cost, ease of use, applicability in the classroom. The results if this analysis showed that after overcoming initial resistance, teachers used different technologies to increase engagement in the online classroom.

Keywords: *teaching and learning of chemistry, computational technologies, chemistry educational applications*

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1. Introduction

A recent survey study conducted identified more than 5 million of students taking fully distance or blended courses in Brazil [1]. As a result, the use of educational technologies has become more prevalent. This article discusses a range of teaching methodologies supported and enhanced by technology to inform teachers and other practitioners in Chemistry education. The educational technologies were selected according to some of their main features, such as, increase student motivation, produce greater student engagement, and offer teachers a greater support in monitoring learning activities.

The current context of the teaching of Chemistry in Brazil is permeated by challenges that begin even during initial teacher training, when many pre-service teachers are faced with pedagogical practices embedded in traditional sequences of content and techniques that are not very much in dialogue with the Brazilian reality [2]. Added to this scenario is the low teachers' remuneration, crowded classrooms and the devaluation of the profession, which ends up impacting negatively the number of teachers using technology in learning and teaching. In fact, in 2015, only 53.8% of teachers had higher education compatible with the area of knowledge they teach, and about 7% of these teachers did not even have any higher education [3]. Among the 1,670,823 graduate teachers working in high schools in Brazil, about 90% are graduates of undergraduate courses, not necessarily in their area of professional activity [3]. In the area of Chemistry, only 59.7% teachers have adequate training, according to data from the Teachers Report of Brazil, published by the Movement for Education in 2016. One of the strategies to improve the huge gaps in teacher training, especially at the high school level in Brazil, is to include the pedagogical use of learning technologies as a necessary competence in teacher training. Technology can contribute substantially to active learning, being used as an aid in the teaching and learning process and promote interaction between content and students, students and students and students and teachers. Learning technologies can also increase educational productivity by expanding the learning experience, increasing student engagement and motivation, and accelerating learning [4,5]. In turn, schools can use technology resources in various ways to support the educational and schooling process. Despite the merits already seen in the use of learning technologies in school practice, the challenge remains to expand its use.

In Brazil, access to the Internet in the workplace is apparently not an obstacle, it is available to 92% of teachers who teach in public schools and 95% of those who teach in private schools [6]. One of the main problems is to motivate teachers to explore digital technologies in their teaching activities. Regarding the teaching of Chemistry, teachers use almost exclusively traditional methods of teaching [2,7,8]. And when they make use of the tools available on the Internet, at least in the Brazilian context, their preponderant use is limited for use in social networks; research on search engines and downloading materials [9].

Aiming to overcome the challenge of using learning technologies among Chemistry teachers, the Federal

University of Rio de Janeiro has offered an online professional development course on "Strategies and Innovative Instructional Resources in Teaching Chemistry." It was designed as a continuing education course for Chemistry teachers mostly in the State of Rio de Janeiro. The main objective is to broaden and deepen the teaching knowledge and pedagogy when teaching Chemistry and at the same time consider cultural, historical, social, epistemological and methodological aspects involved in the teaching and learning process. With this in mind, the course offers both a theoretical basis on the importance of the use of learning technologies in the classroom, and opportunities for practice through the use of technological tools for teaching and learning.

This analysis is a culmination of working with these Chemistry high school teachers for the last six years to identify the main features exhibited by learning technologies that Chemistry teachers actually use. The applications analysed here exhibit main features that supports teaching and learning in the Chemistry classroom. These applications are not exclusive to Chemistry, but Chemistry teachers have been evaluating and testing them and proposed these as the most promising technologies for their contexts of practice. Even though there are already reviews completed on chemistry apps for smart phones [10] this analysis is not limited to mobile applications, but to the plethora of learning technologies used.

2. Materials and Methods

The methods used in this research are essentially qualitative. For the last six years, a total of 80 Chemistry high school teachers in Brazil were interviewed to determine their experiences on using learning technologies and define the characteristics of applications that they found more useful. Since most of these teachers did not have much experience on using learning technologies, their voices are particularly important on this analysis. With the help of the teachers interviewed a list of characteristics of applications was created. The main characteristics identified were:

- Ease: An application, to be widely accepted by students and teachers, must have an intuitive and dynamic interface as well as decomplicated access.
- Flexibility: The application should preferably be compatible with the main equipment options available in the schools, so that the existence of different operating systems is not a limiting factor.
- Cost: Considering the reality of resource limitations in Brazilian public education, zero or reduced cost are a priority. Applications need to offer free essential functions. Additional costs can be included for advanced features, but teacher will not use them.
- Organization: The applications should offer features such as, personalization of materials, sharing among users, import and export of files.

Based on these characteristics and on teachers' input, series of applications have been selected for a deeper analysis on its functionality and effectiveness in the Chemistry classroom, targeting the high school teachers, which may exclude educational applications used in higher education. While taking the online course on "Strategies and Innovative Instructional Resources in Teaching Chemistry" teachers were expected to experiment and demonstrate the use of applications in the classroom, to discuss their advantages and disadvantages, and to collect peer evaluation on each application and its different pedagogical uses. In order to increase accessibility in the Brazilian education system, applications should, whenever possible, be compatible with the three main operating systems. They are: Windows, iOS and Android. The use of environments such as blogs, *YouTube* and social networks were not addressed in this analysis, since they have already been the object of investigation by several authors [11,12,13].

3. Results

In order to better identify the functionalities available in the selected learning technologies, the following key was created on Table 1:

- DB – Database: Storage of resources and activities newly created and/or modified;
- IE – Import/Export Files: Allows the transfer of files in different formats (text, audio, video, etc.);
- VI – Virtual Interaction: Spaces for interaction among users, exchange of information and content, and collaboration;
- LC – Choice of Language: Different languages to choose from, in addition to English;
- C – Customization: Customization and dissemination of content in different formats (text, audio, video, etc.);
- SO – Sharing Options: Exchange of content among users of the application and/or software;
- EF - Extra Features: Advanced versions and/or features that required additional costs;
- MS – Mobile Support: Available in mobile devices.

Table 1 shows all the applications analyzed and organized according to the main features.

There are a variety of other applications that could be included as a focus of interest to the chemistry teacher, however, these were the ones identified by the participating teachers.

4. Discussion

The next paragraphs summarize the applications selected and a brief discussion about its advantages for the Chemistry classroom at the high school level.

4.1. Online Surveys

In this category, five applications - *Google Forms*, *Survey Monkey*, *Socrative*, *Kahoot* and *Mentimeter* – are among the most used and found more useful to teach and learn Chemistry. Some of the main features valued by the teachers are the ability of inserting figures, descriptions, and different response patterns. Teachers also appreciate the fact these applications provide a teacher's restrictive area where they can follow students' progress and completion of activities on the go since all of them are available in mobile devices.

Table 1. Applications and features

Type	Address	DB	IE	VI	LC	PP	SO	EF	MS
Online surveys	www.google.com/forms	X	X		X	X	X		X
	www.surveymonkey.com	X	X		X	X	X	X	X
	www.socrative.com	X	X	X	X	X	X		X
	www.kahoot.it	X	X	X	X	X	X	X	X
	www.mentimeter.com	X		X		X		X	X
Chemistry editors	www.bkchem.zirael.org				X	X			
	www.chemsketch.en.softonic.com					X			
	www.avogadro.softonic.com					X			
Mental maps	www.goconqr.com	X		X	X	X	X	X	X
	www.popplet.com	X				X	X	X	X
Presentation software	www.prezi.com	X			X	X	X	X	X
	www. nearpod.com	X	X						X
Virtual learning environments	www.edmodo.com	X	X	X	X	X	X		X
	https://classroom.google.com	X	X	X	X	X	X		X
	https://www.canvaslms.com/brasil/	X	X	X	X	X	X	X	X
Games and simulations	www. phet.colorado.edu				X		X		X
	www.educaplay.com	X	X		X	X	X	X	X
Vídeos	www. edpuzzle.com	X		X		X			X

Of the five applications reviewed, certainly the most popular is *Google Forms*, part of the Google suite. Its main difference from the others occurs in terms of interactivity by offering the possibility to code the sequence of questions considering the answers obtained from the users. *SurveyMonkey*, which has a limitation on the creation of only 10 questionnaires per user (free version), and the *Mentimeter*, are able to display results in graphs, avoiding export third-party programs or using plug-ins for this purpose. The three applications offer a feature that was previously only available in paid applications, the interactive voting.

In *Socrative*, such functionality is available in the form of a contest, allowing a panel to be visualized by the teacher in real time with a representative image of the participating users that advances according to the correct answers in the questions. It can be designed so that the group follows the development of the participants, making the use of the tool even more interesting.

Following this line, *Kahoot* offers the possibility to create questionnaires, surveys or edit files already created by other users. Using this tool, it is important to emphasize that the teacher can choose to control the gradual release of questions to the users and the time for each response. The application also differs from the others by allowing insertion of videos into questions, easily defining the start and end times of the display. It permits that images and videos to be re-displayed after the students' response to the discussion and before the next question. It should be noted that in order to use *Kahoot*, the teacher needs a projector to show the questions, since the students will only have access to the answer options in their devices. They can only view the questions from the projector.

On the other hand, the *Mentimeter*, with a user-friendly interface, allows teachers to prepare presentations with interaction from their students (e.g. emojis), to count participation in quizzes, to establish a time -frame for answers for different types of questions (e.g., multiple choice and short answers) and to create clouds of words, among other features. The application also stands out for allowing those involved in the activity to receive a link to redirect to the application site and enter responses to the questions, without identifying the participants involved.

In the online surveys category there are a number of other options to create questionnaires that make them available outside of the application platform or the website using, for example, a shareable link, such as *SurveyGizmo*, *SurveyTool*, *Survata*, *Qualtrics* and *Questback*.

4.2. Chemistry Editors

Faced with the need to make Chemistry, a science that is often approached in an abstract manner, more visual for students, *BKChem*, *ChemStetch* and *Avogadro* applications provide features for structural construction and representation of concepts, models, formulas, and molecules. These features make it easy to identify and optimize the chemical structures created, providing rotation tools, representations of the types of links between molecules and markers to highlight atoms. Both *ChemSketch* and *Avogadro* deserve special mention for their visual appeal and numerous possibilities of molecular representations.

The *ChemSketch*, on the other hand, permits the creation of a molecular structure, provides its name, formula and mass, and also allows to copy it directly to a standard text editor, without the need to save it as an image in the source software. It requires only two clicks on the image to automatically reopen the source program for editing. *ChemSketc* offers representations of orbitals and their interactions, chiral carbons, rotations, molecular geometry, hybridizations, energy calculations. In addition, it provides models, such as laboratory devices, and an online search tool that finds the chemical structure created anywhere in the Internet.

The *Avogadro* application offers a similar representational variety to *ChemSketch*, but other features that can be added such as energy calculations, hybridizations, bond angles, Van der Waals force, hydrogen bonds and crystalline arrangement in molecular agglomerates. It also offers a tool for auto-rotation, allowing the configuration of the molecular structure for a continuous rotation. It is important to emphasize that *Avogadro*, unlike the other two, is restricted to the representation of molecules, not including the chemical reactions.

Of the three applications analysed, *BKChem* is the one that offers the most basic functions and for that reason can be considered the one of more use.

4.3. Mental Maps

Mind maps in the last few years are no longer mere resources for inserting texts into squares or balloons connected by arrows and have gained space in the educational scenario due to their ability to foster the process of knowledge construction [14].

GoCongr, available on the Android system and browsers, allows users to attach flashcards, quizzes, surveys, online notes on the map. In addition, allows the creation of groups and classes for access and availability of materials in a personalized manner. This way, teachers can follow the development of activities and have a quick assessment of students' progress. One limitation of the application free version is the creation of only three groups and use of only 20 features.

Popplet also offers possibilities for inserting additional conetnt such as *Vimeo* and *YouTube* videos, drawing tools and links to other mental maps. In addition, the software relies on a wide variety of forms of sharing and cooperative work.

Both applications have outperformed the static visualization present in most mapping capabilities, and in *GoConqr* it is possible that the teacher still stipulates the display order of their students. Some other options for developing mind maps are *SimpleMind*, *Free Mind Mapping*, *Mindly* and *Mindjet Mindmanager*.

4.4. Presentation Software

PowerPoint, from Microsoft Office, and *Keynote*, from IOs, have been widely used for three decades as ancillary resources in teaching methodological strategies, collaborating to visualize concepts in Chemistry teaching. However, new applications have gained momentum by presenting greater functionality. For example, *Prezi* and *Nearpod*, allow the import of *PowerPoint* files to serve as a basis for development.

Prezi has become one of the most appreciated and requested presentation software to offer specific zoom

in/out capabilities in a single background, which makes the transfer of slides much more dynamic by combining it with the various customization options offered to the teacher.

Nearpod differs from other applications because it allows adding drawings, text and question to be answered by the students, with the results being visualized in real time by the teacher. In addition, it offers a great variety of file sharing and access options. The only limitation of the application is the maximum limit of 30 students per class and 50 MB of storage. However, such characteristics should not diminish the interest in exploiting *Nearpod*'s features.

4.5. Virtual Learning Environments

Widely used around the world, *Moodle* is one of the leading examples of virtual learning environments (VLEs), where users can create collaborative learning sites by offering online courses, chats, forums and providing a variety of dynamic materials to participants. However, taking advantage of all of *Moodle* functionality requires technical expertise that not all teachers have. There is usually no support for the use of this application in Brazilian public schools.

The case is similar to the EDX platform, a MOOC environment produced from the partnership between the Harvard University and Massachusetts Institute of Technology. They made this platform as open source for unrestricted use for educational purposes. Conversely, *Canvas*, a paid VLE, was initially not included in this analysis, like several others of the genre. However, to broaden its interest, the company (instructure.com) provides a free environment for teachers, with limited features, but still with plenty of potential. The system also allows the installation of several add-ons, including activities, contents and other resources for the Chemistry classroom.

Available for Android OS and web browser, Google also developed a free VLE system named *Google Classroom*. Initially this environment was restricted to institutions that owned the Google Suite for Education account, however, in 2017 access became possible to any Google user, with some limitations of use. Its management system has a simple interface and integrates with other resources of Google, such as google docs, spreadsheets, presentations and calendar which expands its possibilities of use. Despite the diversity of resources, it is still a modest platform compared to the aforementioned ones. Another interesting environment for teachers is *Edmodo*. With an interface similar to *Facebook*, this system offers communication, collaboration, and coaching platform to K-12 schools and teachers. Among its features, *Edmodo* allows the creation of private groups, polls, different patterns of questions and answers and offers teachers a monitoring area and different ways of evaluating students' activities. *Nearpod*, described under presentation software, also presents a functionality that makes it a VLE with by enabling the creation of collaborative environments among users.

4.6. Games and Simulations

The use of educational games in teaching and learning enables those involved to develop curiosity, critical capacity and abstraction, to think about alternatives in problem solving, communication, autonomy, responsibility, teamwork and search for knowledge [15]. Similarly, simulations may represent a more interactive and dynamic way of learning Chemistry. However, according to [16], it is necessary that teachers are aware of the impact of the use of simulations for Chemistry concepts at atomic scale. In this category, PhET stands out, as an online simulation.

PhET is a set of interactive, research-based science and mathematics online simulations [17]. These online simulations have been extensively tested and evaluated to ensure educational effectiveness. The simulations are written in Java, Flash or HTML5, and can be run online or downloaded to a computer. The simulation's open source code allows for modifications and re-designs by teachers and students. As stated by the creators of PhET, it is assumed that PhET simulations "will be used in the context of an educational setting where teachers will primarily provide the scaffolding and goals for the simulation use" [18]. As a result, scaffolding in online simulations can be created or refined by teachers. PhET allows to work with abstract concepts at the microscopic level by offering visualizations of the impact of conditions varying in physical systems. Subjects such as, density, polarity of molecules, acidity and basicity are part of the options of simulations and lesson plans created and available to teachers and students (and anyone interested in this topics).

Another application in this category is *Educaplay*, which make it easy to create groups for dissemination of activities. *Educaplay* provides a wide range of activities that can be created, such as dictation, interactive maps and quizzes. It allows the exchange of pedagogical content among teachers and the collection of tips and tricks from their fellow teachers in order to improve and update the content and learning activities.

4.7. Videos

Aimed at using videos as a supporting tool in teaching, *Edpuzzle* is an effective alternative for teachers who intend to expand the educational use of videos made available in repositories such as *YouTube*, *Vimeo*, and *National Geographic*. In addition to facilitating editing, through *Edpuzzle* the teacher can enter questionnaires, create different meeting rooms, and at the same time monitoring which groups and activities students are accessing to. *Edpuzzle* deserves special attention for the possibility of creating projects where students can choose and edit videos and then submit them to the teacher for review/grading. Certainly, the application fulfils its purpose of adding pedagogical value by allowing teachers to use videos as a learning and teaching approach in Chemistry.

5. Conclusions

The applications analysed in this study shown different characteristics and features that meet pedagogical needs when teaching Chemistry. Teachers, especially in the Brazilian reality, have limited availability of technological and financial resources to excel in their profession. Most of the use of learning technologies by teachers is mostly intuitive and not grounded on what a particular application can make to support their teaching practices. This intuitive

use mainly considers the ease and visual appeal of the applications with very little attention to more sophisticate features and aspects such as, note sharing and the possibility of collaborative activities.

The results of the interviews with the teachers in this study showed that most of them can perceive the usefulness of many applications freely available, but when it comes to pedagogical implementation it can at best be classified as modest.

The use of learning technologies in the teaching of chemistry is not necessarily an approach well received by teachers [19]. This behaviour reflects, at least in part, the feeling among teachers in Brazil for whom the technologies are interesting but involve more work, which is not compatible with their difficult financial situation and long working hours. There is also an extensive debate on the reasons for resistance to the use of learning technologies. For example, [20] examined the middle and high school chemistry teacher concerns and processes of change through the lenses of the CBAM framework [21]. They investigated "the dynamic and changing nature of teacher concerns and found that as teachers became more experienced and skilled with the technology, the intensity of stages expressed earlier decreases while the intensity of advanced stages (Consequence, Collaboration, and Refocusing) increases" [20]. For a more lower percentage of teachers, after initial resistance, there is a sense of gratification in applying the new technological resources in the classroom. They actually use learning technologies to create more interesting lesson plans, centered on a reality that has produced greater student engagement, while also providing greater support in the follow-up of school activities. In addition, with the maturation of the use of some applications, less time was necessary for the expositive work in the classroom, expanding the options of new discussions and activities.

Ideally, it is up to teachers to consider for their classes a critical, creative and dynamic perspective in their methodological approaches so that learning technologies are not simply inserted into a lesson to meet a pre-requisite or standard expectation. Learning technologies should be integrated in a way that adds pedagogical value and contributes to other aspects to the learning and teaching process [22].

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Statement of Competing Interests

The authors have no competing interests.

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