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Artigo Original

Technology integration in chemistry teaching — A case study in an blended undergraduate course

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Abstract

Technological integration in the teaching process is part of the duties of any teacher today. Interacting with technological tools in a comfortable and safe way is a need that requires the integration of different knowledge bases. This article presents an assessment of technological integration, according to the theoretical model *Technological Pedagogical Content Knowledge* (TPACK), of learning units of a basic chemistry online course offered for undergraduate Biology degree. We identified that the course presents strong technological and pedagogical integration of the content, but not exemplary. It has primarily distributive and interactive features in its activities and with little space for online collaboration. The results obtained with this research are relevant to the development of teacher training strategies for the use of technologies in distance learning lesson and chemistry teaching.

Keywords: Distance Learning; Teacher training; chemistry teaching; TPACK.

1. Introduction

The integration of technologies in teaching is a reality that has become increasingly indispensable in the daily lives of teachers. However, the literature points out that technology needs to be associated with a context to promote learning (PAVANELO; KRASILCHIK; GERMANO, 2018) and it must be integrated into pedagogical actions (SAMPAIO; COUTINHO, 2015). Identifying how these technologies are integrated into teaching practice is a current demand, especially in a Licentiate course. It is also essential to develop actions that help the university professor to implement Information and Communication Technologies (ICTs) in classes, especially in the blended mode, in order to result in an effective teaching-learning process. Knowing how teachers and students make use of technology can contribute to the development of teacher training strategies for the use of these technologies.

One of the strategies to analyze teaching practice with the use of ICTs is the theoretical model *Technological Pedagogical Content Knowledge* (TPACK) (MISHRA; KOEHLER, 2006). This model was proposed using as a basis the model of Shulman (1986), in which teacher education must integrate pedagogical knowledge with a deepening of specific conceptual knowledge. Shulman established three knowledge bases: Content Knowledge, Pedagogical Knowledge and Pedagogical Content Knowledge.

The TPACK model, on the other hand, emerged to insert technology in this context, raising from three to seven the bases of knowledge necessary for the teacher to teach effectively with the use of technologies. They are: Pedagogical (PK), Content (CK), Pedagogical Content (PCK), Technological (TK), Technological and Pedagogical (TPK), Technological Content (TCK) and Technological and Pedagogical Content (TPCK), (MISHRA; KOEHLER, 2006).

In Figure 1, we have the representation of these seven knowledge bases.

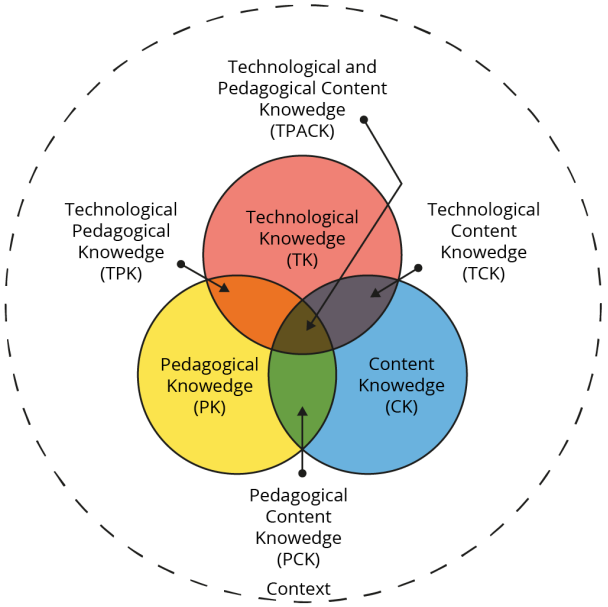

Figure 1 — TPACK Model
Source: Using... (2011, on-line).

This article presents an assessment of technological integration based on the TPACK framework of the Learning Units (UAs) of a General Chemistry course offered in blended teaching (EaD) for a Degree in Biological Sciences. It is intended, with this assessment, to seek elements that for a better understanding of the teacher/technology relationship within the context of blended teaching, in which technological resources are essential as the main means of communication and interaction for pedagogical practices.

As for the conceptual focus, it was decided to analyze a General Chemistry course offered to students of the Biological Sciences Degree. This discipline has the historical profile of high failure rates, considered as complex and difficult to understand by several authors, especially when directed to students of courses in which Chemistry is not the main focus, as is the case of the object of study of this article (CHAGAS, 2020; SARON; AMARAL, 2016).

This same difficulty is also identified in the teaching of chemistry for high school, in which one of the common difficulties is for the teacher to know how to leave the traditional abstraction and calculations to bring chemistry to the student's daily life (CHAGAS, 2020). However,

these students, who already do not have a solid conceptual basis of Chemistry, will come across the discipline of General Chemistry in the initial periods of graduation, since it is fundamental knowledge for the continuity of studies in higher education.

With the growing interest in the use of technologies, the TPACK model has become the focus of research in several countries, becoming one of the most important theoretical references for research on the integration of technologies in teaching and teacher training for the skills of the century. XXI (ROLANDO; LUZ; SALVADOR, 2015).

Harris, Grandgenett and Hofer (2010) proposed and validated a rubric to assess the quality of integrating key TPACK knowledge bases into lesson plans. This rubric was translated into Portuguese with permission of the authors by Souza and Salvador (2021). We chose to use this rubric to evaluate the technological, pedagogical and content integration of the CUs of the Elements of General Chemistry (EQG) subject, as it is a validated instrument in the literature for application in classroom lesson plans, and it is promising to verify its suitability for the evaluation of UAs in courses in the blended mode.

2. Methodology

In this case study, analyzes were carried out with an exploratory and descriptive approach (YIN, 2015). Data collection took place within the Virtual Learning Environment (VLE) of a discipline in a blended format, in which each of the AUs of the discipline was evaluated based on the rubric of integration of technology, pedagogy and content proposed by Harris, Grandgenett and Hofer (2010). Data collection was authorized after approval by the Research Ethics Committee in accordance with the attributions defined in CNS Resolution n. 466/2012.

2.1. Research context

The research was developed in a discipline of General Chemistry of a Licentiate in Biological Sciences in blended mode. The purpose of the course is to introduce basic principles of Chemistry, which are useful

in understanding biological phenomena. The teaching team is made up of a coordinator and pedagogical mediators who work remotely and in person. The platform used allows each teacher to have a differentiated access profile with greater or lesser permission to act within the classroom, allowing the coordinating teacher to coordinate the teaching team and develop autonomy in the construction of the online classroom environment. In a previous data collection, it was identified that, in the semester of 2018, 864 students were enrolled, distributed in 20 face-to-face centers. The dropout rate in this period was 49.92% and the pass rate was 11.6%, being the subject with the lowest pass rate of this course.

2.2. Data survey

In order to apply the evaluation instrument, it was necessary to have the details of the AUs of the discipline, considered as "lesson plans". In the case of a blended model, an Instructional Design Matrix was used as a resource based on the material presented in the VLE, adapting this matrix to a model that contemplated the main information that guides the organization of the online classroom, the know: class number; theme; objective; material; distance activity; Evaluation.

2.3. Technology Integration Assessment Instrument (AIT)

To evaluate the technological, pedagogical and content integration (TPACK) in the AUs, the rubric proposed by Harris, Grandgenett and Hofer (2010), translated by Souza and Salvador (2021) was used. According to the authors, for this instrument to be applied with greater reliability, it is necessary that the plans are well detailed, in order to enable the evaluator to make well-informed choices on each of the four dimensions of the rubric with a scale of points that ranges from 1 to 4 for the constructs, namely: 1. curriculum goals and technologies (TCK); 2. Instructional Strategies and Technologies (TPK); 3. technology

selections (TPCK) and 4. integration (TPCK). The higher the assigned value, the more favorable the technology is in relation to the analyzed constructs.

The instructional matrix was evaluated by two independent examiners, a member of the teaching staff of the discipline and an external member, both with knowledge about the TPACK framework, generating a score for each lesson plan between 4 and 16 points. Subsequently, these examiners met to compare the results and discuss each criterion analyzed in the disagreements they had. The objective of this meeting was to reach a consensus on the divergent assessments, according to an experiment carried out by Harris and Hofer (2011) and Kopcha *et al.* (2014) who used the same type of rubric and methodology.

The rate of agreement on the first observation of each examiner, before consensus, was calculated. To establish what is considered as agreement, the parameter stipulated by Harris, Grandgenett and Hofer (2010) was used, which validated the rubric with three procedures, among them: the internal agreement rate in which the percentage of agreement between two examiners in each category. For example, scores between 3 and 4 were counted as agreement; between 2 and 4, as non-agreement. Thus, it was established as agreement for this work up to one point of difference in each criterion and two or more points of difference for non-agreement.

The result of the agreement rate between the examiners for the first and second criteria (TCK and TPK) was 94%, with only two points of divergence in each of them in relation to Lesson 7. For the last two criteria (TPCK) , there was 100% agreement.

3. Results And Discussion

The instructional matrix identified a total of 16 UAs within the VLE of the discipline. Considering that the score of each UA can vary from 4 to 16 points (4 points for each criterion), the maximum score for TPACK integration of the UAs is also 16 points, the total of the matrix to be reached would, therefore, be 256 points. A total of 208 points

were found as the sum of the grades of these 16 units (Figure 2), that is, the subject reached 81.2% of the total possible points for the rubric. This value indicates that the CUs of this discipline had a good level of technological integration, with technologies appropriate to the content and the proposed pedagogical process, but not always exemplary for all units.

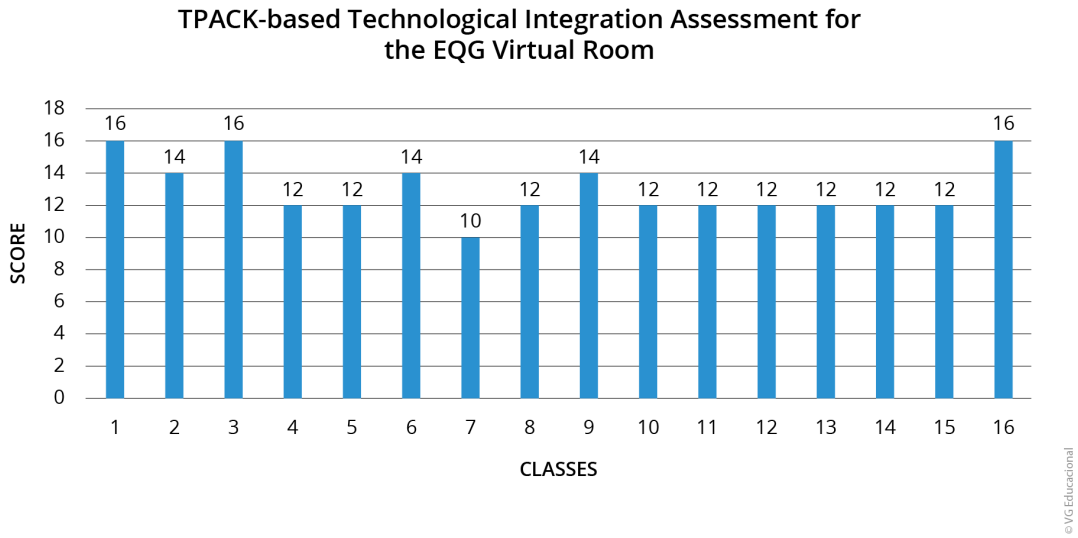

Figure 2 — Scores for AIT based on TPACK, in the AUs (classes) of the EQG discipline
Source: Prepared by the authors.

The average scores for the EQG UAs for each rubric criterion were 3.31 for TCK and TPK and 3.19 for TPACK technology selection and TPACK integration. This result is above the average of what Deng *et al.* (2017) found when analyzing the lesson plan of 280 Chinese teachers of Conservation Chemistry, in which the average scores for the four dimensions of this same rubric were 2.89 (TCK), 2.98 (TPK) and 2.77 (selection of TPACK technologies and TPACK integration). According to the authors, this suggested that the participants, to some degree, were able to design ICT-integrated lessons, but their capacity for lesson design and pedagogical reasoning could be improved. It is to be expected that the results of a blended course will have better evaluations of TPACK integration, since the use of ICTs is inherent to the teaching process in this modality. Another factor to be considered is that the

CUs analyzed in EQG were built by experienced teachers with many years of experience in teaching practice, including the blended model.

In a study with Biology teachers, Mooney (2016) scored 3.33 (TCK), 3.22 (TPK), 3.11 (TPACK technology selection) and 3.22 (TPACK integration). According to the author, the results indicate the alignment of technology with pedagogy, the plans had a variety of technological resources, such as the use of simulators, videos, digital comic book creation software, among other resources. The study found that the technology was well placed and supported the instructional strategies used in the lesson plans.

By observing the individual scores of the 16 AUs of the EQG discipline, it was found that Classes 1, 3 and 16 were the ones with the highest level of TPACK integration, reaching a maximum score of 16 points each (Figure 2).

In UA 1, where the theme was "Welcome", the unit received the maximum score for presenting strategies in line with the goals. In this unit, the student was welcomed through a presentation forum activity and videos on the importance of Chemistry in society and initial guidelines on the discipline were presented. The selected technologies were exemplary when they brought a didactic proposal that allowed greater approximation between the participants. The physical separation in space/time between students and teachers in the blended mode creates gaps that can lead to discouragement. One of the ways that students interact with each other and with teachers in online learning environments is the use of asynchronous discussion forums (ALVES *et al.*, 2015). The presentation forum is one of those spaces for interaction that allows the development of affectivity. The creation of positive affections, according to Duarte (2019), is essential to maintain the student's interest in the subject. The greater your affective matches, the better your performance. This unit was also classified as exemplary, as it presented the use of videos (technological resources) introducing students to the importance of Chemistry in society (content), initiating a contextualized dialogue between Chemistry and Biology issues (pedagogical strategy).

Unit 3 was also classified as exemplary, reaching a maximum score of 16 points. In this unit, the content of stoichiometry and gases was worked, with the provision of interactive exercises, simulators, an online questionnaire, in addition to online video tutoring sessions[1]. Stoichiometry is identified as one of the most difficult topics to be understood within Chemistry (SANTOS, 2019; SANTOS; SILVA, 2013). Therefore, strategies that minimize the complexity of the topic are necessary. One of them is the use of diversified resources with convergence of technologies, which, according to Barros (2018), are fundamental aspects for DE design and contribute to the pedagogical organization of an online course. The use of different media allows the creation of a more diverse study environment (PASSOS, 2018; SANCHES; SANTOS; HARDAGH, 2018). In this learning unit, it was possible to identify this technological convergence with various resources that favor collaboration, such as video tutoring, and interaction, such as the online questionnaire and the simulator. Thus, the characteristics of meaningful learning with technologies were identified in this unit, which was described by Howland, Jonassen and Marra (2012), in which the teacher must lead students to engage in active, constructive, intentional activities , authentic and cooperative.

Finally, Lesson 16 also reached the maximum score. In this unit, the Distance Assessments (ADs) took place in a hybrid way, with previous guidance in the form of videos and PDF material, two practical classes held in person at the support centers under the guidance of the face-to-face mediators and with a report sent by the virtual room. This unit became exemplary in bringing the necessary elements for a perfect hybridization between online and face-to-face activities. In this unit, video content on safety, materials and glassware, files with practice guides and guidelines on the standards and model for preparing reports are available, as well as resources for returning practices that will be carried out in person. The advantages of using videos to guide on safety standards

[1] Video tutoring are called web conferencing sessions with pedagogical purposes (CAMPOS et al., 2015). Distance pedagogical mediators are the conductors of classes who can use resources such as slideshows, chats and recording of meetings to be made available in the virtual room for later consultations..

and materials was the optimization and reduction of theoretical explanations of the discipline, with access to a vast source of information and knowledge (MORAIS, 2004). Morais also identified that students recognize that the presentation of safety videos in the Chemistry laboratory helped them to better learn this topic.

Classes 2, 6 and 9 also had a high score (14 points), indicating an adequate profile of technology integration. These classes deal with the contents: general properties of matter and numerical relationships; dilution and mixtures of solutions; and periodic properties and chemical bonds. Classes 2 and 6 had the following resources: summaries of content in PowerPoint (ppt.), video tutoring sessions, online questionnaires, videos and an in-person practical activity. Class 9 has a summary in slideshow, video tutoring sessions and a digital learning object in simulator format in which the student worked on issues related to the polarity of molecules. These classes were well evaluated in the rubric. Using simulators as learning tasks helps understanding and fixation as well as transferring learning more consistently to new situations. (HOWLAND; JONASSEN; MARRA, 2012). In Chemistry classes, simulators facilitate the interpretation of phenomena allowing the student to make the corresponding associations on the cognitive plane when visualizing chemical phenomena through chemical representation (macroscopic, microscopic and symbolic) (LABRADA *et al.*, 2020). These classes also presented diversified technological resources with characteristics of active collaboration and interaction methodologies (HOWLAND; JONASSEN; MARRA, 2012). However, not all the technologies used were exemplary, with the goals and teaching strategies and strongly embedded (content, pedagogy and technology) within the teaching plan, receiving a score of 3 in this rubric criterion.

Classes 4, 5, 8, 10, 11, 12, 13, 14 and 15 had a score of 12 points. These classes received 3 points in all the criteria of the rubric, evidencing a lower technological integration. Some aspects were relevant to this classification. In some units, only distributive technologies were used in relation to the available digital materials, for example, Classes 4, 12, 13 and 14 had only slide and text presentations. Howland, Jonassen and Marra (2012) state that technology cannot teach students alone;

moreover, they point out that the most productive and meaningful uses will not occur if they are used only as vehicles for delivering instruction. Another example related to the diversification of technologies was evidenced in Class 12, which used simulators to work on the application of the theory. Although the use of this technology is admittedly favorable to the construction of knowledge, an adequate instructional design must contemplate different approaches, considering the heterogeneity of the learning characteristics of individuals (PASSOS, 2018; SANCHES; SANTOS; HARDAGH, 2018).

Class 7 (The atom is divisible!) was the one with the lowest score, with ten points. This unit received two points in relation to the first two criteria of the rubric (TCK and TPK), evidencing that the selected technologies were partially aligned with the curricular goals and the use of these supports, at least, the teaching strategies. It also received three points on the other two criteria (TPACK), indicating that this selection of technologies was not exemplary given curriculum goals and teaching strategies, and that content, technology, and teaching strategies were not tightly integrated within the curriculum. teaching plan. In this unit, no activities were assigned to encourage students to apply the concepts discussed, with a diversity of resources that meet the different learning styles as recommended in the literature (PASSOS, 2018; SANCHES; SANTOS; HARDAGH, 2018). The absence of these activities did not allow the creation of a learning space for the student to put into practice the contents studied and, consequently, obtain feedback that guided the construction of knowledge.

The instructional matrix of the discipline also revealed that all classes were worked with didactic notebooks produced by content specialists and that went through a specific instructional design for distance education, presenting contextualized text structure, dialogic language and commented activities that help the student to evaluate their own progress. These characteristics are fundamental to help the learning process in a printed material for distance education (CASSIANO *et al.*, 2016). However, these contents end up being approached in a more expository way, such as videos, PowerPoint presentations, printed texts and in digital format; As a result, there is a lack of online tools that

privilege collaboration, interaction and active methodologies, which are the trend of blended education in the country (ABED, 2019). Garrison, Anderson and Archer (1999) developed a Community of Inquiry Model that considers cognitive, social and teaching presences as fundamental to structuring a learning community. The integration of these elements allows for bringing to participants critical thinking and the construction of meanings through cognitive presence, social and affective interaction with social presence, as well as support for the learning experience through the teaching presence of teachers and tutors (TRIPANI, 2017).

The results obtained in this case study demonstrate an ideal TPACK integration level of 18.75% of the UAs of the discipline, that is, 3 among the 16 UAs prepared for the discipline. The rest (81.25%) of the AUs presented intermediate, but not exemplary, evaluations. No EQG AU was below ten points. A possible justification for this fact is that the course was designed by a teaching team that has been working in the blended model for more than ten years. In addition, this team is also supported by multidisciplinary teams for the production of specific content, in a model in which the autonomy of the teacher is privileged with a virtual environment that allows an open or contextualized instructional design (FILATRO, 2008). Another aspect to consider is that the rubric proposed by Harris and Hofer (2011) was initially designed to evaluate teaching plans with the integration of face-to-face technologies. It can also be conjectured that, for AIT of UAs created for distance education, more specific rubrics are needed from the qualitative point of view of the impact on learning.

The analysis of the instructional matrix allows us to identify that the pedagogical practice of the discipline presents, preferably, technologies with distributive and interactive characteristics, with little space for collaboration. Only two collaboration tools were identified: 1. video tutoring, which is present in several units, with the use directed to the presentation of content reviews; 2. the discussion forum, used, in the first AU, for the presentation of the teaching staff and students, but not as a space for the development and construction of knowledge. These tools have great potential for collaboration, but depend on the pedagogical use with which they are used. (CAMPOS *et al.*, 2015).

According to the subject assessments carried out with the AIT TPACK rubric, it is concluded that the EQG subject presents appropriate technologies, but not exemplary and fully integrated, considering the curriculum goals, teaching strategies and the selection of technologies in accordance with the objectives of the discipline. In this way, there is a greater frequency of integration of more significant learning practices, such as technologies in all AUs of the discipline, as recommended by Howland, Jonassen and Marra (2012) so that students can engage in more active activities. active, constructive, intentional, authentic and cooperative.

4. Final Considerations

Evaluating a course with all the nuances that surround it is extremely complex and subjective. In this sense, rubrics such as those presented in this study can support this type of assessment. This case study can serve as a basis for the development of training strategies for the use of technologies by the teaching staff of the EQG discipline, as well as other undergraduate disciplines in the blended mode. It is hoped, with this article, to inspire other researchers to use the AIT TPACK rubric to identify the points with less integration in the lesson plans and UAs, thus seeking ways to improve them.

It was identified, in the discipline, a strong presence of the TPACK integration in the UAs, however a smaller presence of the elements for a significant learning with technologies. For more meaningful learning with technologies to occur, the proposed activities should involve more strategies using active, constructive, intentional, authentic and cooperative learning, as proposed by Howland, Jonassen and Marra (2012). The literature points out that collaborative spaces favor a higher level of learning (SALVADOR *et al.*, 2017).

The teaching of Chemistry presents, as a priority and historically, the use of teaching methodologies with distributive and interactive characteristics, with little space for collaboration, which was not different from what was observed in this case study (ROCHA; VASCONCELOS, 2016).

Despite the strong TPACK integration in the activities, few selected the technologies in an exemplary way. In this way, the AIT instrument can be considered adequate as a tool for diagnosing failures and directing the best strategies for teacher training to offer subjects in the blended mode in higher education, especially for those with greater content complexity.

The use of the AIT TPACK rubric in a course offered in the blended modality proved to be an important tool to diagnose the quality of this discipline from the evaluation of the technologies used in the UAs, in particular, in this case study with the discipline of General Chemistry in the modality EAD.

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