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Use of stories in higher education: an experience in experimental organic chemistry

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ABSTRACT

Developing the ability to think and solve new problems play a key role in student learning, including in higher education. In an experimental Organic Chemistry discipline, 13 Pharmacy students were asked to solve problems described in six fictional stories produced by the professor, according to the "storytelling" strategy in the classroom. We aimed to analyze students' engagement with these activities and their perception regarding their own learning. For this purpose, we identified the resolutions submitted and analyzed a data collection tool (questionnaire) answered by the students once the course ended. The analysis revealed that the challenges proved to be a positive strategy for both student engagement and learning. Thus, we emphasize that the techniques taught in laboratory classes must be understood in the context of students' future work life.
KEYWORDS: Higher Education; experimental organic chemistry; engagement and learning; fictional stories.

Uso de histórias no ensino superior: uma experiência na química orgânica experimental

RESUMO

Desenvolver a capacidade de pensar e de resolver novos problemas ocupa um lugar central na formação de estudantes, inclusive os do Ensino Superior. Em uma disciplina experimental de Química Orgânica, uma turma de 13 estudantes do curso de Farmácia foi convidada a resolver situações-problema presentes em seis histórias fictícias produzidas pela professora, seguindo a estratégia de "contação de histórias" em sala de aula. Desenvolvemos este trabalho com o objetivo de analisar o envolvimento dos estudantes com essas atividades e também a percepção deles sobre a própria aprendizagem. Para isso identificamos as resoluções entregues e analisamos um instrumento de produção de dados (questionário) respondido pelos estudantes ao final da disciplina. A análise revelou que os desafios se mostraram uma estratégia positiva tanto para o envolvimento dos estudantes quanto para a aprendizagem. Com isso, ressaltamos que técnicas ensinadas nos laboratórios de aulas práticas precisam ser percebidas como parte do contexto de trabalho futuro dos estudantes.
PALAVRAS-CHAVE: Educação superior; Química Orgânica Experimental; Aprendizagem e envolvimento; Histórias fictícias.

INTRODUCTION

Higher education, especially in Federal Institutions, has demanded from professors the compatibility of teaching, research, outreach, and orientation activities, especially when they take part in graduate programs. Despite the principle of inseparability between teaching, research, and outreach provided for in Article 207 of the Brazilian Constitution (Brasil, 1988), it is reasonable for a professor to question the feasibility of these activities given the emphasis that has been given to academic production. This emphasis has often compromised the quality of classes. Thus, professors are the sole responsible for making classes more dynamic and more attractive to students and, consequently, producing more learning.

According to Alencar and Fleith (2004), the literature agree that educators must prepare students for a scenario in which the ability to think and solve new problems have a central place. The relevance of this training lies mainly in the fact that it contributes to the development of skills and competencies that will make it possible to tackle situations and solve problems in both work and life in general. Higher education, due to the professional nature of its courses, has an even greater commitment to the development of these capacities.

The construction of meanings for the content explored in classes has been the object of attention of researchers, and our research sought to further study this topic. We believe that, by daring to create or venture creatively in the teaching action, the professor can provide the student with greater involvement with the content and, as a consequence, the production of meanings for what is taught.

From an internal program of continuing education of teacher trainers, a set of activities was proposed for the Experimental Organic Chemistry discipline, aiming to engage students with the content of classes. Notably, although we agree with the existing criticisms in the literature about the division of a given discipline into theoretical and practical, this division was present in this investigation. As an activity of the continuing education course, the professor of this discipline developed fictional stories that challenged students to solve the problem depicted by each of the stories instead of a seminar that they would have presented at the end of the course. We developed this study to analyze both the students' adherence to these challenges and their perception of their own learning of the techniques addressed by the experimental discipline from the confrontation of problems found present in the stories.

A LOOK AT THE LITERATURE: NARRATIVE REVIEW

Current literature has shown an increasing production involving storytelling – in the classroom or in diverse learning environments. According to Engel, Lucido, and Cook (2018), storytelling has been used to promote a deeper engagement of students with the content, including in learning Science.

We have searched the Education Resources Information Center (ERIC), a bibliographic database in the field of education, using the term *storytelling* and the markers *article journal* and *higher education*, without defining an initial period, which also enabled us to know the time when this subject became part of research

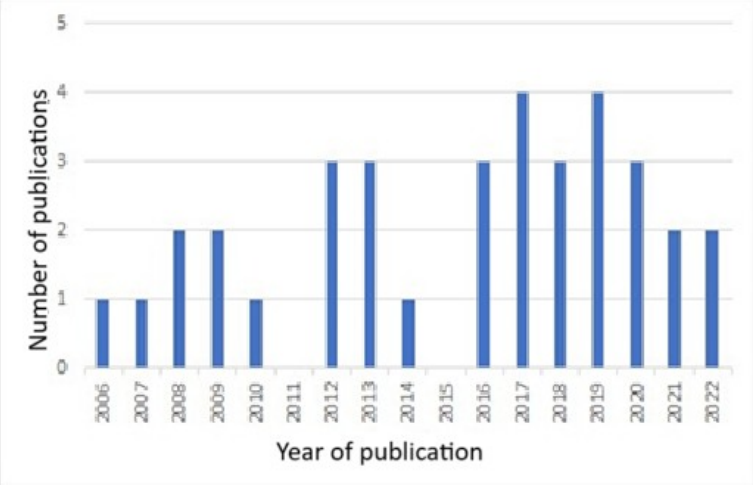
in higher education classes. This search was carried out in May 2023, this being the final period.

We found a total of 79 peer-reviewed articles. After reading the abstracts, we observed that 36 of them reported activities carried out outside the classroom, even if they were linked to universities, that is, they involved other work or training environments, noting that many of these texts were undergraduate thesis from students of Law, Business Informatics, Economics, Journalism, Administration, Arts, among other courses. Another eight articles brought stories that addressed some type of violence (most of them involving racism), and that did not intend to focus on the teaching and learning processes of specific scientific concepts in the classroom, an aspect of interest of this study.

Of the remaining 35 articles, storytelling was used in higher education disciplines, the first of which was published in 2006. Figure 1 shows the publications grouped by year in which they were published.

Figure 1

Graph with articles grouped by year of publication



Source: Authors (2022).

We know that storytelling is a costume as old as humanity itself. The use of this practice in the classroom, however, is much more recent. The field of Linguistics has introduced storytelling with a view to enhancing people's ability to communicate. According to Wu and Chen (2020), in the 1980s the arts began to appropriate storytelling by taking this activity to digital media (films, videos, etc.) and creating what is now known as digital storytelling. Gradually, other areas were experimenting with storytelling in the classroom.

In higher education – which has an adolescent/adult audience –, the insertion of activities with storytelling was somewhat slower. In Figure 1 one can see that this insertion was recent among the selected studies, that is, less than two decades ago, and that the number of studies produced each year was small.

Among the 35 articles selected, 15 of them explore digital stories that are associated with the use of technologies. For McLellan (2007), digital storytelling

represent the art of exploring different media and software to communicate stories in a creative and powerful way. According to her, the term "digital storytelling" was coined in the 1980s by Dana Atchley, a North American artist and media producer. He acted as a storyteller and, realizing the potential of computers and multimedia tools, began to associate his own storytelling performance with technological tools in a very creative way.

In the last two decades, this technique has been introduced in disciplines of various areas, by podcasts, videos, short films, among other formats. In six of the studies that address digital storytelling (Alexander & Levine, 2008; De Rossi & Restiglian, 2019; Kobayashi, 2012; Kortegast & Davis, 2017; Ribeiro, 2016; Torres, Ponce, & Pastor, 2012), students were asked to create stories, aiming at the development of specific skills. In another five (Chan, Churchill, & Chiu, 2017; Lowenthal & Dunlap, 2010; Pardo, 2014; Sahin & Coban, 2020; Shelton, Warren, & Archambault, 2016), professors brought digital storytelling to classroom, with concepts considered key to the discipline. One article (Austen, Pickering, & Judge, 2021) investigates the experience of first-year students with digital storytelling in higher education. The other three articles are theoretical (McLellan, 2007; Robin, 2008; Teckchandani & Obstfeld, 2017), the first of which shows a variety of applications of digital storytelling in higher education.

Conventional (non-digital) storytelling was found in 16 articles. Three of them (Chawla, 2018; Gowen, 2019; Torres & Pruim, 2019) involve the creation of stories by students, and another five (Kalogeras, 2013; Medina, 2021; Ripani, 2022; Scutt & Hobson, 2013; Tajeri, Syal, & Marzban, 2017) have professors using storytelling in the classroom. Four of the texts are theoretical (Annacontini & Paiano, 2019; Gachago & Livingston, 2020; Jørgensen, 2018; Washburn, 2007) and four others address the use of storytelling with teachers in training, two of which are in continuing education (Curtin, 2013; Hirumi, Sivo, & Pounds, 2012) and two in undergraduate studies (Diaz, 2016; Yasar-Akyar, Rosa-Feliz, Sunday-Pereira, Oyelere, Muñoz, & Demirhan, 2022).

The last four studies bring a storytelling experience from more experienced people to less experienced people: being one from successful students to other students (Storrs, 2009); one from successful researcher to graduate students (Gregson, 2020); one from successful teachers to teachers in training (Franz, 2016); and one from distance learning students to first-year distance learning students (Otto, 2018).

Of the publications listed in this review, only two report experiences related to the teaching of Natural Sciences: one (Gowen, 2019) addressed the support that librarians could provide for the science curriculum and the other (Torres & Pruim, 2019) examined the results of a workshop on the construction of scientific dissemination narratives offered to undergraduate students. Overall, we can observe that this selection has no examples of storytelling as a strategy in Chemistry, Physics, or Biology classes in higher education, this being a gap in the literature included in this review.

Storytelling and the field of Natural Sciences

The fact that there are few studies involving storytelling in higher education Science classes led us to highlight some works involving school science as a whole. Howe and Johnson (1992) suggest that storytelling can be used to: present a scientific problem in the form of a story for students to solve; provide an accessible explanation of a complex process; provide an element of human interest in a topic, for example by using roleplay and incorporating scientific issues that people face in their everyday lives. To this list of possibilities, Rowcliffe (2004) adds: put what is being learned in a historical context; provide entertainment and fun for students and professors so that they become emotionally involved and so that their imaginations promote learning; provide mental triggers that keep the learned concepts in the students' memory.

Howe and Johnson (1992) report a study of 11 and 12 year-old children who prepared a story that explained an electrical circuit using terms such as "army of volts," "electron babies," and "big, brave battery". Parvin (1996 *apud* Rowcliffe, 2004) brings several examples in which concepts were addressed from poems or book stories. In one of them, the biker character of a book inspired the study of the speed of an object. Lana and Silva (2019) also explored storytelling using works by Monteiro Lobato to explore the playfulness, creativity, and imagination mobilized by third-year middle school students, exploring concepts from these stories.

For Rowcliffe (2004), storytelling can motivate students to be interested in the subjects covered in classes. He lists some sources (programs, websites etc.) considered powerful to stimulate professors and students in the construction of scientific stories and suggests an introductory story involving a challenge or problem (falsification of grades, for example). In this story, students are invited to assume the role of a forensic scientist, using chromatography to identify the ink on the suspect's hands. According to Rowcliffe, there are many possibilities to build and use stories containing scientific concepts and laboratory techniques that can be used in the classroom.

Hoffmann (2014), when analyzing the narrative found in scientific articles in Chemistry, states that the scientist becomes the channel through which the history of nature is told. Hoffmann (2007) uses storytelling to associate Chemistry with Economy, Literature, Art, Society, and History. By narrative stories associated with complex formulas and diagrams, in an attractive and understandable way, he makes some scientific concepts –that were previously enveloped by an aura of inviolability – accessible to the reader. Green (2012) produced an Organic Chemistry work in textbook form by using storytelling in a historical approach. The book's synopsis clarifies that students who used it found it attractive and effective for learning Organic Chemistry and that teachers believe the book increased interest and appreciation in Organic Chemistry. These are two examples of researchers who are successful in their research and who have appropriated narrative language to tell stories that allow the reader to learn Chemistry.

Based on the aforementioned researchers and on our own conceptions and experiences, we hypothesize that inserting storytelling in higher education Chemistry classes can be a positive strategy both in the involvement of students and in the learning of concepts or, in the case of this work, in the learning of laboratory techniques.

METHODOLOGICAL PATH

The investigation carried out has qualitative research characteristics, since the researchers are more interested in the process than in the product. Data were analyzed interpretatively and descriptively; the results are situational and, although generalizable, are limited to the context (Lüdke & André, 2013; Symon & Cassell, 2012).

Considering that the professor of the discipline Experimental Organic Chemistry has an affinity with storytelling, she has produced a set of short stories, rich in detail, in which characters experience a conflict whose resolution or understanding involves techniques commonly addressed by the discipline taught by her.

This research was conducted in the discipline offered to 13 enrolled and frequent students of the Pharmacy course of the Federal University of Minas Gerais. This discipline is offered regularly in the fourth period of the course and is organized in 15 meetings of four hours (corresponding to 60 hours/class during a semester), in which techniques considered important for the activity of the Pharmacist are addressed. Regarding the content taught, the discipline is divided into two blocks. The first includes six practical classes involving basic techniques often used in Organic Chemistry laboratories, namely: thin layer chromatography; column chromatography; solid-liquid and liquid-liquid extraction; simple distillation; fractional distillation, and steam distillation. The second, in turn, brings a set of classes for conducting organic reactions and isolation of products that are part of the same synthetic route to obtain azo dyes of industrial interest.

At the end of each of the six classes of the first block, the professor proposed to the students the resolution of a problem present in a fictional story that addressed issues related to that class. Students were given one week to solve the problem associated with each story. This activity was proposed to replace a seminar on dyes that would be presented at the end of the semester and was readily accepted by the students. Table 1 shows a summary of each story and the technique needed to solve the problem presented in it.

Table 1

Stories used in the Experimental Organic Chemistry discipline

Technique explored in classes	Summary of the story
Thin-layer chromatography	Cat in serious condition is taken to a veterinary clinic and, after examination by the veterinarian, is treated with *N*-acetylcysteine. The cat owner reports suspicion of intentional poisoning or disease transmitted by a dog bite and claims to have given the animal a painkiller. She has the remains of the pill, but it is not possible to identify it by the label. The resolution involves identifying the active ingredient present in the pill by using thin-layer chromatography and common drug active ingredient standards, and seeking information on the typical use of *N*-acetylcysteine in Veterinary Medicine.
Column chromatography	A scientific initiation student needs to purify commercial ethinylestradiol for a master's student to conduct an experiment, and comment on the new acquisitions of ethinylestradiol of the company from which the product to be purified was purchased. She has standards for estrone and

	estradiol, as well as results of thin-layer chromatography and tests for identification of organic functions. Resolution involves interpreting the test results provided, explaining how to perform column chromatography, and researching the synthesis and degradation products of ethinylestradiol. There are mentions to Pharmacopoeia in the story, aiming to encourage its use as a source of data.
Caffeine extraction	A tycoon suddenly feels unwell after drinking tea in the company of family members, and a detective is called in to investigate the case, which is possibly poisoning. The student must develop hypotheses about what happened and point out suspects among the characters. Resolution involves seeking information about the plant used in the tea preparation and a chronic medicine taken by the tycoon, and also explain how to extract substances from the remaining tea and try to identify them by thin-layer chromatography using alkaloid patterns.
Reactivity of alcohols and Simple distillation	Two pharmacy students, monitors in a laboratory of practical classes, test conversion reactions of pinacol, tert-amyl alcohol, and (*S*)-1-phenylethanol in their respective alkyl chlorides and carry out the distillation of the products. The observations regarding miscibility in water and boiling point during the procedures are not consistent with the formation of the expected products. The reader is invited to help the protagonists develop hypotheses about the identity of the products formed and the problems that may have occurred in the reactions. Resolution involves the interpretation of results of tests for the identification of organic functions and a research on the properties of the expected products, the reactivity of pinacol, and nucleophilic substitution reactions on saturated carbon.
Fractional distillation	Students aim to purify liquor containing a contaminant referred to as verdigris and do so in a laboratory using two types of distillation. Accidentally, one of the students ingests methanol in the laboratory, and it is recommended that he ingests ethanol. The reader is asked to decide which type of distillation is most suitable to purify the liquor, suggest a method to determine the alcohol content of the distillate, and explain why the intake of ethanol was recommended to the student intoxicated with methanol. Resolution involves knowledge on simple and fractional distillation and refractive index, and also a research on methanol poisoning and enzyme inhibition.
Steam distillation	A newly hired pharmacist in a pharmacy must obtain an essential oil that had been obtained in small quantity a few days earlier by an employee who had just gone on vacation. The pharmacist is in doubt between two plants that may be the source of the essential oil and has notes of data that the employee transcribed from the Pharmacopoeia, samples of the essential oil, and standards of natural products. The reader is invited to help the pharmacist find out from which vegetable source the oil should be obtained and to guide her regarding the procedure for obtaining the oil. Resolution involves consulting the Pharmacopoeia, explaining how to obtain information on the composition of the oil sample using thin-layer chromatography, and describing a steam distillation procedure.

Source: Authors (2022).

These stories[1] were produced by the discipline professor and presented in a script in which one of the characters would need to perform a task to unravel the problem presented and, for this, the use of techniques addressed during classes would be fundamental. The use of the technique, however, would require the elaboration of hypotheses to be tested. The resolution, although requiring

knowledge of the techniques presented during classes, was not restricted to it, and involved knowledge of other areas related to the Pharmacy course, such as Pharmacology and Pharmacognosy. For this reason, students were encouraged to perform searches in other sources besides the material used in class. Moreover, elements that would serve as "clues" to guide these searches were intentionally introduced in the stories, such as the term "cholinergic syndrome" and the mention to the Pharmacopoeia. The stories did, in a way, what Howe and Johnson (1992) suggested, that is, they presented a scientific problem for the students to solve. Students were also instructed to discuss the resolution with peers and professors. Although they could argue among themselves, the delivery of the resolution in the form of a written text should be individual.

In addition to submitting the resolution proposal for each of the stories, students were required to anonymously answer a questionnaire, made available to them on the last day of class, with six questions. Four of the questions were to be answered using the Likert scale, one requesting the sources used for research during the resolution of the problems present in the stories, and another requesting students to make criticisms and/or suggestions regarding this type of activity.

In the analysis, the resolutions submitted by students and the data originated from the questionnaire were quantitatively considered. The analysis took place on the students' perception from the comments made in the questionnaire, grouping the opinions by similarity.

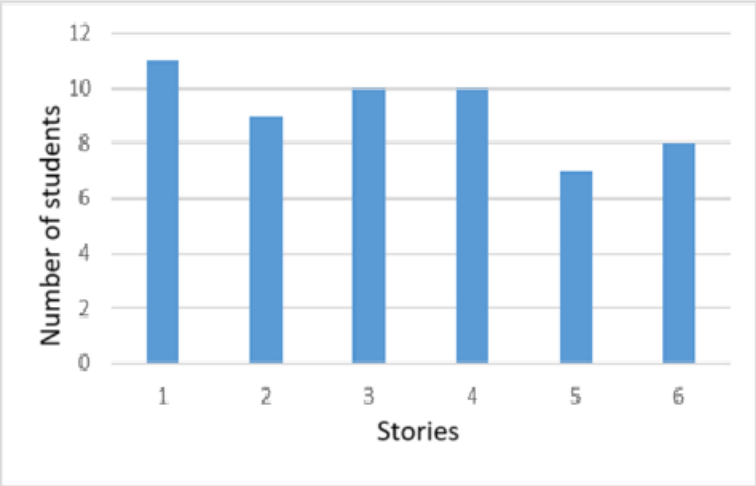
Given the need for authorization for the use of data in a research, we provided the necessary clarifications to the students and asked them to sign an informed consent form, respecting the ethical aspects for research with human beings. The project was approved by the Research Ethics Committee under CAAE 61744122.6.0000.0197.

RESULTS AND DISCUSSION

Since these were six cases of more complex resolution when compared to a traditional report of practical classes, our first look was directed to the number of students who accepted the challenge of solving a problem within a fictional story. Figure 2 shows the number of students who submitted the resolution of each of the stories.

Figure 2

Graph with the number of students who submitted the resolution



Source: Authors (2022).

As can be seen, the students' adherence was significant (considering that there were 13 enrolled and frequent), despite the fact that the grade associated with each of the six activities was small (one point for each activity, out of a hundred points distributed during the semester), which is why this adherence would not be crucial for being approved in the discipline. In the first class, only two of them did not submitted the resolution, thus losing the point, while the other 11 dedicated themselves to solving the problem. In the following classes, there was a small drop in student adherence to the alternative proposal offered by the professor.

Nascimento, Oliveira, Medeiros Junior, and Gurgel (2021), when making an analysis of adherence in a corporate environment, emphasize the feedback as directly related to the phenomenon of adherence. Possibly, the lack of feedback from the professors regarding the resolution of the first problems has contributed to the fact that a few students did not engage in the other proposed activities. This lack of feedback associated with the fact that solving the problem contained in the stories requires a high cognitive involvement may be the factors that led to a decrease in adherence throughout the activities. Most students, however, joined the weekly challenges of solving the problems contained in the stories.

From this first look, we sought the students' point of view concerning these activities. For this, we used the answers provided in the discipline evaluation questionnaire. The four questions related specifically to the stories addressed their role in the following aspects: encouragement to study; return to laboratory techniques addressed in the discipline and, consequently, an increase in learning; involvement with additional topics related to the content of the discipline, but not present on the syllabus; adequate level of depth in terms of content. Table 2 summarizes the responses, considering the Likert scale.

Table 2

Number of participants' responses about the role of the stories

Effect of the storytelling activity	Totally disagree	Partially disagree	I don't know	Partially agree	Totally agree
Encouragement to study		1		4	8
Return to content				2	11
Knowledge of additional topics		2		2	9
Adequate level of depth		2		6	5

Source: Authors (2022).

Although two students chose not to engage with the stories in the first activity (see Figure 1), they ended up adhering to the others. However, the "partially disagree" answers are not necessarily from these two students. Considering the answers obtained, we can see that two students judged the level of depth of the problem contained in the stories as not adequate, which may have contributed to some resolutions not being submitted. These same students disagreed with the claim that they knew additional topics to those normally worked on in the discipline, and this can be attributed to the fact that they did not join the challenge. Numerous studies in the literature indicate that student involvement depends on both factors external and internal to the institution. An external factor is the case of employed students and who have little time available for educational activities. Internal factors include all sorts of incentives provided in the institution for this involvement. Although they cite different factors, Astin (1984) and Kuh *et al*. (1991) agree that student learning and development are closely associated with active participation in the various tasks present in academic life.

Most participants considered that the problems contained in the stories had an adequate level of depth and that the involvement with these activities enabled them to address topics beyond those that are part of the discipline. Certainly, these themes were associated with the laboratory techniques that were studied in the discipline of Experimental Organic Chemistry, since they claimed to have returned to this content as a strategy for solving the problems contained in the stories.

Regarding the sources consulted to help solve the problems in the stories, the questionnaire offered several options and a space for students to report other sources than those listed. With this, they should mark/describe all the sources consulted, which means that each of them could mark more than one option. Table 3 shows the options and the number of students who reported using these sources.

Table 3

Reference sources used by students during the activity with stories

Source consulted	Number of students
Websites	12
Discussion with colleagues in the discipline	11
Handout of practical classes	10
Discussion with course colleagues	7
Professor of the discipline	7
Scientific articles	7
Organic Chemistry textbooks	4
Textbooks from other disciplines	3
Other sources	2
No source	-

Source: Authors (2022)

As can be seen, the internet was the source most consulted by students. Concerning sources other than those listed, two students referred to specific materials from the field of Pharmacy. In general, we can state that these students sought diverse sources and that the discussion with peers (of the discipline and the course), the bibliographic material indicated in the discipline, the scientific articles, and the professor of the discipline herself were the sources used by more than half of them.

Regarding the dissertation question that asked participants to point out criticisms and suggestions, we obtained 11 responses. These comments related the stories to the future professional field, to greater learning, to the time of dedication necessary to solve the problem, and also to the challenge that this activity represented for some of them.

Concerning the association with the professional field, we selected the comments from S4 and S11, which are representative of the comments of other responding students:

> Cases are much better and more useful than a seminar. I learned a lot from them and found them fun too. I confess that I tend not to like Experimental Chemistries, but dealing with more reality-oriented content that we will have in the future made me more excited and interested in the course. (S4)
>
> It's a good strategy that should be implemented in the discipline, since it makes new knowledge acquired in the classroom applicable. (S11)

In these comments, the students emphasized the relationship of the activity carried out with the professional field. In speaking of their little appreciation for what they call "Experimental Chemistries," S4 was certainly talking about a personal perception arising from the little relationship of the content with their future field of work. However, in addition to emphasizing their own learning, their involvement with the story seems to have been very positive. This is an indication that the stories inserted in the discipline promoted entertainment and a certain degree of fun for these students, in addition to an emotional involvement that

generated learning (Rowcliffe, 2004). S11, in turn, defended the use of these stories in the discipline precisely because they saw in them the applicability of laboratory techniques in their future profession. According to Yasar-Akyar *et al*. (2022), the insertion of stories in the classroom creates more inclusive environments, since it provokes changes and builds learning. For students who perceived the relationship of the techniques studied in the discipline of Experimental Organic Chemistry with their future field of work (here represented by S11 and S4), the knowledge of these techniques was more valued. Dealing more specifically with the learning resulting from dealing with the stories, we selected the comments made by students S1 and S12:

> The case strategy was a great idea, since I had a better learning experience than if we had to make reports. (S1)
>
> Challenging activities. Great way to stimulate study, as it increases the frequency of study, in addition to being contextualized in the synthesis module. In the rest of the discipline I suggest perhaps explaining with flowcharts the role of some key reagents/processes, to improve our understanding. (S12)

S1 stated they had the opportunity to learn more by comparing the use of stories with the traditional reports commonly used in practical classes. S12 commented that the activities with stories made them have to access the content of the classes more frequently, stating that this stimulated their study. Furthermore, this student also spoke of context, probably referring to the fact that solving problems requires laboratory techniques.

Ribeiro (2016) reports that in an experience in which students created digital stories, they engaged in a serious and productive debate that enabled them to build new meanings and generated learning beyond what would be possible in a class anchored in knowledge transmission. Kortegast and Davis (2017) also report that when dealing with narrative stories, students engaged in a reflective process and demonstrated the ability to apply the theoretical knowledge developed in class to their personal experiences. The responses of S1 and S12 address the learning factor or involvement with the studies, as took place in the studies by Ribeiro (2016) and Kortegast and Davis (2017). Thus, we can state that the stories helped the students to see meaning in the laboratory techniques that until then seemed abstract to them. In Miranda, Corrêa, and Quadros (2022), the third fictional story used in the discipline was analyzed in terms of student learning. The analysis showed that, when facing a case, unraveling its history, the students better understood the techniques taught in the discipline of Experimental Organic Chemistry.

As already mentioned, the resolution of the problems present in the stories may have required a great dedication in terms of time, especially for those students who did not see the relationship of the content with their context, both personal and professional. In this regard, we highlight the comment made by S6:

> The strategy is good, but we attend many disciplines and the time dedicated to cases was relatively long, since it was necessary to consult various sources, it perhaps should be appropriate to simplify some of them, which are more elaborate. (S6)

In this comment, despite judging the strategy as appropriate, S6 warned of the degree of difficulty imposed by the resolution of problem situations. For S6, the

stories should be kept, as long as some were simplified, so as not to require such a long time for resolution. We know that these students attend several discipline in a single semester, and that each of them has activities that require dedication on their part. Dealing with these many activities certainly requires organization. In the research reports present in the literature review, we observed that, when referring to the production of stories, the professors mentioned the "time" factor (Hirumi *et al*., 2012; Curtin, 2013). In this context, the authors suggested websites who have "storytelling databases" as an alternative to helping professors not have to spend a relatively large amount of time creating stories.

As already said, the stories presented a problem situation that should be solved by the students. In their comment, S5 mentioned these problem situations:

> The cases were very well put together, but they scared us a little. I can't say whether it was the lack of practice we have at the university of dealing with problem situations like these or something to do with mixing content with the stories behind the cases, but I felt, and I talked to colleagues who also felt this, that the cases were very difficult. But after racking my brain I saw that it was not that complicated, the difficult thing was to figure out where to start the reasoning. But I was very grateful for the opportunity to think outside the most common model used in graduation, of simply reproducing the content. (S5)

As can be seen, S5 emphasized the degree of difficulty in solving the problem situations present in the stories made available to them. She even tried to justify this difficulty, using both the innovative character and the insertion of laboratory techniques in the context to be solved. However, the opportunity to deal with these situations seems to have been evaluated by S5 as positive. Debald and Golfeto (2016), when analyzing experiences in which higher education students were placed as protagonists, state that these students were receptive to the innovations implemented and appropriated the knowledge necessary to solve the problems present in challenges that were proposed to them throughout the classes. S5, like her colleagues, was also challenged in solving problem situations, which led her to overcome the initial barriers.

Finally, we bring a brief comment done by S7, which confirms a hypothesis we had at the beginning of this research: some students do not spontaneously establish a relationship between the contents developed throughout disciplines with their professional field, especially those that have no apparent relationship with their future activity. S7 said:

> I felt dumb, I gave up after the 3rd case. (S7)

In this case, when challenged S7 ended giving up the activity instead of overcoming the obstacles. As a result, she wasted the opportunity to see the applicability of the knowledge developed in the experimental discipline. We believe that in this context the professor could have offered some type of support to this student, to provide her with security, making her feel able to solve the problem situations.

There are numerous studies in the specialized literature that analyze the way meanings and understandings are developed in the social context of the classroom, many of them carried out from a socio-historical or sociocultural perspective. In this perspective, the conceptualization process is equated with the construction of meanings (Vygotsky, 1987), which means that the focus is on the

process of signification. In general, meanings are seen as polysemic and polyphonic and are created in social interaction and then internalized by the subjects. Thus, learning is a process of negotiating new meanings in an interactive space in which there is the encounter between different cultural perspectives. The pedagogical relationships between the contents and the context were also analyzed in Organic Chemistry and Pathology classes by Quadros, Silva, and Mortimer (2018). According to these researchers, these relationships – and in this case we are dealing with the future professional context – allow students to perceive the meaning of what they study or how the scientific knowledge to which they are dedicated relates to his world.

Considering the answers provided by the participants and the low score offered for each resolution, we understand that these students liked the strategy. They became involved in the resolution of problem situations to seek knowledge that would help them in this resolution. The handout of practical classes, which brought the techniques present in the discipline, was an important source of consultation, in addition to the colleagues themselves and the internet. The choice of an appropriate technique, among those present in the handout, was essential for solving the problem. Despite the initial difficulties arising from the deepening required in the resolution, the students accepted the challenges and dedicated themselves to unraveling them.

FINAL REMARKS

We developed this study aiming to analyze both the students' adherence to the resolution of the problem present in the stories delivered to them and their perception of the activity especially regarding their own learning of the techniques addressed in the discipline. The stories were inserted into the discipline from discussions made in a continuing education program in which the professor of the discipline participated.

On adherence, we consider it positive given the difficulty that these students claimed to have faced to solve the problems. Except for S7, who gave up after the third story, the rest were involved in most of them. The fact that these stories were made available in the first half of the course (from Week 2 to Week 7) was probably a facilitator, since in the second half both the papers and the tests tend to increase, which would make it impossible to engage more.

From the students' point of view, the strategy was well received by most of them. We highlight the fact that these participants realized that the techniques learned in the discipline of Experimental Organic Chemistry can be very useful for solving future problems. Considering the statement by Alencar and Fleith (2004) about the need to prepare students for a scenario in which the ability to think and solve new problems is central, the comment made by S5 shows that this preparation may fall short of what is expected. Considering the studies of Vygotsky (1987) and the concept of Zone of Proximal Development (ZPD) proposed by him, we emphasize the concept of potential of an apprentice. According to Chaiklin (2011), this "potential" refers to an indication of the presence of certain functions in maturation that can be the target of a significant interventional action so that the learner can ascend to new stages of development. Considering the studies of Vygotsky (1987), we can state that the problem situations present in the stories

were relevant to the intellectual development of the students, who focused on the stories and built solutions to the problems they faced. The stories were situated in the ZPD and probably instigated functions in maturation, thus providing learning.

Still dealing with the students' perception, the difficulty in solving the problem situations was evident. They claimed to have learned much more from these resolutions, but there were suggestions for the stories to be simplified. In the resolution of the problem situations presented, elements of tension, effort, and difficulty were present. And learning to solve a problem is certainly more than learning a lot of skills or techniques. Some students said they felt motivated by the stories. This motivation, which is more than a simple stimulus to interest, involves having reasons to do something, deciding to do something, and also sustaining the effort to do it (Williams & Burden, 1997). Despite being a pleasurable and challenging activity, it does not exclude a certain level of stress, effort, and difficulty, elements that Williams and Burden (1997) affirm that activate long-term memory, providing lasting learning. Probably, the pleasure described by some of them was in the courage to set out to do it, to accept the challenges, and to realize that laboratory techniques had application in their field of work.

We believe that the challenges proposed by problem situations present in the stories are a positive strategy for both student involvement and learning. This has implications for undergraduate courses, since the data clearly showed that the techniques taught in the laboratories of practical classes need to be perceived within the context of students' future work. We believe, nevertheless, that one must discuss the possibilities of resolution with students in the public arena of the classroom so that the challenge does not represent discouragement, as occurred with S7. We propose to expand this experience in further studies, transforming the resolution of problem situations present in the stories into space/time for collective discussion.

NOTES

1. The full stories (cases 1 to 6 in Portuguese) can be accessed at https://drive.google.com/drive/folders/1CHUcVCMQ1EFfjxLxF7ABwJgVPu54AgPO?usp=sharing

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