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Gamification as a Learning Strategy in Organic Chemistry Teaching

Lia Lima Schneider [a]
Arlete Beatriz Becker-Ritt [b]

[a] Secretaria de Estado de Educação e Desporto Escolar (SEDUC-AM) Manaus, AM, Brasil
[b] Universidade Luterana do Brasil, Programa de Pós-Graduação em Ensino de Ciências e Matemática – PPGECIM, Canoas, RS, Brasil

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ABSTRACT

Background: Teaching chemistry to high school students is a challenge. Students do not believe they are capable of learning and believe that the content is not related to their daily lives. **Objectives:** This work intends to contribute to teaching methods, especially in the Chemistry subject, through gamification. **Design**: Using a didactic sequence centred on organic functions, we investigate the effects of gamification and what signs of understanding come from using this methodological resource. We analysed the data found in light of the theory of meaningful learning. **Setting and Participants:** The research was carried out with 3rd-grade high school students from a public school in the format of a didactic sequence contextualising the topic of food and concepts of organic functions, using digital resources and gamified methodologies as a basis. **Data collection and analysis**: Explore and discuss the use of digital information and communication technologies (DICT) in methodological proposals to engage and motivate students in chemistry teaching, making them direct participants in the teaching process with interaction between teacher and student. To direct the research, a qualitative methodology was chosen, with a design characteristic of action research. **Results:** The analysis of the questionnaires answered by the students, together with the observations recorded in the field diary, aroused students' interest in the activities and contributed to the development of new skills, as it allowed the concepts of organic functions to be constructed with meaning in a contextualised way. **Conclusion:** We could observe signs of significant learning. During the organisation of activities in the classroom, we observed the development of social and emotional aspects in students, such as cooperation, argumentation, responsibilities and initiative. The research also contributed so that teachers can analyse and observe which types of new active methodologies fit into their professional context.

Keywords: chemistry; gamification; didactic sequence; organic functions.

Corresponding author: Arlete Beatriz Becker Ritt. Email: arlete.ritt@ulbra.br

Gamificação como Estratégia de Aprendizagem no Ensino de Química Orgânica

RESUMO

Contexto: Ensinar química para os alunos do Nível Médio é um desafio. Os alunos não se julgam capazes de aprender e acreditam que os conteúdos não são relacionados com o seu cotidiano. **Objetivos:** Este trabalho pretende contribuir com os métodos de ensino para a disciplina de Química, a partir do uso da gamificação. **Design:** A partir da aplicação de uma Sequência Didática, centrada em Funções Orgânicas, procuramos investigar os efeitos do uso da gamificação e quais os indícios de compreensão advindos do emprego desse recurso metodológico. Analisamos os dados encontrados à luz da Teoria da Aprendizagem Significativa. **Ambiente e Participantes:** A pesquisa foi realizada com alunos do 3° ano do Ensino Médio de uma escola pública, no formato de uma Sequência Didática contextualizando o tema alimentos, conceitos de Funções Orgânicas, utilizando como base recursos digitais e metodologias gamificadas. **Coleta e Análise dos Dados:** Explorar e discutir o uso das Tecnologias Digitais de Informação e Comunicação (TDIC) nas propostas metodológicas, com a finalidade de engajar e motivar os discentes no ensino de química, tornando-os participantes diretos do processo de ensino com interação entre professor e aluno. Para direcionar a pesquisa optou-se pela metodologia de natureza qualitativa, com um desenho característico da pesquisa-ação. **Resultados:** As análises dos questionários respondidos pelos alunos em conjunto com as observações registradas no diário de campo despertaram o interesse dos alunos pelas atividades e contribuiram para o desenvolvimento de novas habilidades, pois permitiu construir com significado os conceitos de Funções Orgânicas de forma contextualizada. **Conclusão:** Foi possível observar indícios de aprendizagem significativa. Durante a organização das atividades executadas em sala de aula, observamos o desenvolvimento de aspectos sociais e emocionais nos alunos, como cooperação, argumentação, responsabilidades e iniciativa. Além de trazer contribuições para que o docente possa analisar e observar qual tipo de novas metodologias ativas se encaixam no seu contexto profissional.

Palavras-chave: química; gamificação; sequência didática; funções orgânicas.

INTRODUCTION

Chemistry teaching in Brazil is a relatively young science; its knowledge was introduced at the end of the 19th century and taught as a regular subject only in 1931. It was fully disseminated following the reformulation of Brazilian basic education (primary and secondary schools), established by the 1996 Law of Guidelines of National Education (Lei de Diretrizes e Bases da Educação Nacional—LDBEN) (Lima, 2013).

According to Leite and Lima (2015), chemistry teaching in most basic Brazilian schools insists on perpetuating a traditional methodology equipped with a voluminous theoretical framework and focused on memorising formulas, symbols, and laws. Teachers continue to simply "transmit" content, totally disconnected from the students' reality. This practice has contributed exorbitantly to disseminating the notion that chemistry content is hard to grasp and that its knowledge does not make sense in citizens' daily lives.

For Bernardelli (2004), the more integrated practice, theory, and contextualisation, the more meaningful and motivating chemistry learning will become, making the student enjoy studying its contents. Only through a differentiated teaching methodology will students realise that these contents are practical, fun, engaging, pleasurable, and efficient for building a more participatory and citizen world.

Another point that hinders learning in chemistry teaching is the need for more teaching resources in Brazilian schools. As schools present concepts at a microscopic or abstract level, they require simple examples and experiences that establish a relationship between this microscopic (abstract) level and the macroscopic level, i.e., visible to students, and relate the concepts to their daily lives. Furthermore, it is important to highlight how some students have difficulty understanding specific chemistry concepts, which require a demonstration in the form of an experiment so that the student can truly assimilate it. A reflection by Soares (2003) points to the teacher's need to create differentiated mechanisms that develop students' teaching and learning.

Therefore, the need to develop alternative methodologies encompassing innovative pedagogical resources becomes evident. Yirula (2014) points out that traditional methods can no longer efficiently transmit school content. Today's students are born into advanced technological contexts and develop skills that the school environment has wrongly dismissed, disregarding a range of new ways of learning that can develop when we treat technology as an ally. We must renew the school approach to deal with these new technological contexts.

The National Common Curriculum Base (Base Nacional Comum Curricular—BNCC) debates the composition of the school curriculum and its importance for structuring methodologies and selecting topics for work in the school environment. This characteristic aligns with Ferreira and Del Pino (2009), who think it is important to problematise the relationship between science, technology, society, and the environment.

Oliveira (2012) states that "high school students do not always clearly understand the relationship between what they study in chemistry and what is happening around them. Therefore, their learning is often limited to memorising symbols, formulas, equations, and laws," which is a recurring barrier for teachers in primary school pedagogical practices. In this sense, activities developed using gamified tools enable the development of various works that seek to renew and reverse this problematic situation and make learning more organic, fun, and relevant for students. Nunes (2017) proposes that pedagogical games can reformulate chemistry teaching. The author states that games, under a pedagogical interpretation, are a tool for educators to alternate attempts to awaken students' interest and participation in learning. At the same time, Backs and Prochnow (2017) indicate that active methodologies are an option for changing the educational context.

From this perspective, we realise that chemistry teaching has two obstacles to be overcome. The first is students' natural unwillingness to learn the subject, as they find it complicated; in addition, few resources are available to optimise this activity. In this way, games are a device that can equip teachers to overcome barriers that have long been solidified within chemistry classes. The second relates to teachers' difficulty in offering innovative methodologies to their teaching practice.

Aiming at the reality of Brazilian education in the teaching of chemistry, the lack of interest in classes, and the need to improve the teaching and learning of our students, the following questions must be answered: What is the impact of gamification on students' performance and interest in chemistry classes? Can gamification based on a didactic sequence in chemistry classes demonstrate signs of significant learning? This research investigated the effects of gamification as a vehicle for meaningful learning through a didactic sequence.

Gamification in chemistry classes

Sousa, Moita, and Carvalho (2011, p. 136) state that gamification in chemistry teaching is expected to "explicit its dynamic character so that chemical knowledge is expanded [...] as a set of interactive teachings". Chemistry in the classroom needs more dynamism, as it is always reduced to abstract concepts and complex scientific formulas. Gamification shortens the distance between chemistry and students' individual experiences.

Chemistry comprises several theoreticians who discuss new ways to make classes more effective in transmitting knowledge to students. Among the proposals are the use of experiments, games, the insertion of chemistry in daily contexts, and, more recently, gamification, which seeks to mix elements of virtual games with teaching practice. The elements that mobilise motivational points, combined with the aesthetic elements of virtual games, aim to motivate and awaken students.

Educational games can and should be used in chemistry teaching as a teaching resource for learning concepts. Games are a needed resource for chemistry classes, serving as a rehabilitator of learning through student experience and activity. According to Lopes (2022), chemistry teachers find it difficult to pass on the contents of the component to their students, as they demonstrate little interest and claim that the subject is difficult to understand, which generates a high failure rate. The teacher's methodology justifies part of this lack of interest. Gamification, therefore, appears as a methodological strategy to contribute to the teaching and learning process and arouse students' curiosity.

Silva and Bedin (2019) emphasise that chemistry is a fundamental science in human life and education. It is part of our daily lives and deals with natural and artificial materials. Following this point of view, it is pivotal to emphasise that students have problematised that type of teaching. However, the authors also say that teachers and the school must stimulate specific knowledge of chemistry and approach and apply innovative methods.

Freire (2002) says the teacher must be willing to change and believe in it. Thus, knowing how to innovate their teaching techniques is necessary to guarantee significant learning and good academic performance. On the other hand, one must be aware that this responsibility should not be attributed solely to teachers. Freire (2002) also states that teachers must be prepared to apply techniques that attract students' attention and stimulate their curiosity. So, the teacher and students must share curiosity because, without it, there is no restlessness and no inquiry, which are essential for developing a class, teaching, and learning. Therefore, gamification is a new method that can stimulate this curiosity, enabling students to have quality learning in chemistry teaching.

From the viewpoint of the teacher-researcher and the participants, we researched the efficiency of new methodologies, in this case, gamification, in chemistry classes in a public high school in the North of Brazil. To support the proposed practice, we organised the theoretical foundation into secondary sections: a) The Playful Process in Chemistry Teaching; b) The Use of Active

Methodologies for Chemistry Teaching; c) What Gamification is; d) Gamification as a Pedagogical Resource in the Teaching of Organic Chemistry; e) The Contributions of Gamification to the Chemistry Teaching and Learning Process, according to the Context of Meaningful Learning.

The Playful Process in Chemistry Teaching.

The idea that playing and learning are opposite actions was generalised and is still in force in some pedagogical situations. Until recently, we believed the classroom was not a place for playing and that playing and learning demanded separate spaces (Antunes, 2017). Although playing is essential for overcoming teaching barriers, Soares (2015) stresses that some limits must be safeguarded between playing and the educational field. Using games in class is not merely rule-free entertainment, meaning some elements must be observed when using this resource. Games cannot be mandatory, becoming just another traditional teaching resource. Likewise, the playful element cannot override the educational aspect. This configuration risks the purpose of using games, given that playing cannot safeguard the expected learning by itself. Therefore, a balance between education and playfulness is necessary, as one element can disperse the other when excessive. According to Vygotsky (2007), games play an important role in the outcome of a zone of proximal development, as children experience situations of decision-making and pressure that they will take as an experience for their social lives. Moreover, games take on a teaching and learning role, as the Chemistry subject requires students' attention and commitment due to its complexity and abstraction. According to Cardoso et al. (2020, p. 1705), "Educational games can assist in the gamification process in a given context, as it promotes skills such as participation and engagement, as well as an improvement in students' motivation and cognitive aspects toward understanding the content addressed."

The Use of Active Methodologies for Chemistry Teaching.

Active methodologies can present several possibilities. Among the various possibilities are: Peer Instruction, Just-in-Time Teaching, Project-Based Learning, Problem Based Learning, Maker Movement, Blended Learning, Flipped Classroom, Game Based Learning, Bring Your Own Device - BYOD, Design Thinking, Challenge Based Learning, Observation and Verbalization Group (GV/GO) and gamification, which will be the strategy used in this research. Gamification is an example of active methodology because, by using game elements and dynamics to engage students to solve problem situations outside the gaming environment, it boosts students' interest in the class, increases participation by promoting dialogues between them and gives students autonomy in their decision-making in the activity, accepting possible "mistakes", not in a negative way, but as a form of learning. Didactic games have already been proposed for chemistry teaching, and several authors have presented works that insert them into their practice and stress their efficiency in arousing students' interest. This interest comes from the joy games provide, which positively impact schooling. Those authors highlight games as facilitating elements of the teaching process, illustrating their advantages and applications by analogising them with the concepts involved. Silva (2017) singles out the importance of playful activities as tools that attract, motivate, and stimulate knowledge construction; i.e., playful chemistry teaching and learning have a high potential to develop cognitive competencies and skills. Thinking about more active methodologies connected to this new century that stimulate students' interest is a challenge for everyone involved in global education. According to Beck (2018), we must seek a methodology that privileges students, helping them develop skills and competencies and seek autonomy. In active methodologies, we will find a way to achieve that goal.

What is gamification?

Vianna (2013), according to whom gamification can also be called playfulness, analysed that, in recent years, games have turned toward variable fields of society, such as health, education, public policies, and sports. The author also mentions that despite being used for the first time in 2002, the relevance of the terminology was recognised only eight years later by Jane McGonial, a famous game designer.

Huizinga (2000) says that gamification has a theory known as the magic circle; this ideology shows that we can solve our problems in the real world by solving problems in a fantasy world. Through a playful experience – and we mean games– we can solve obstacles in the real world, as both have similar characteristics but are in opposite worlds, such as challenges, problems, reflections, and skills, among other conditions. Games always have some meaning; they are not just games. Something at stake goes beyond life's needs, and non-material elements are present in its experience. A reflective and critical look can change the meaning of games, as they are fundamental factors in today's world. The author also states that games influence the development and emergence of civilisation.(Huizinga, 2000).

Gamification as a pedagogical resource in chemistry teaching.

Gamification as an educational tool configures an update of the ideas of educational psychology for today's society in the information age, and its application can be based on these aspects in common with consistent and effective learning theories for use in the classroom (Aguiar Valiante 2021). However, what do teachers and students understand by gamification? "Gamification applied to education is not about transforming the classroom into a place of pure entertainment, much less into a LAN gaming centre where students just play and have fun" (EUGENIO, p. 60, 2020). Gamification must be applied to education to motivate students through the language of games, valuing the teacher's pedagogical intentionality. For example, a strategy used in gamification is scoring players' achievements to motivate and encourage them through rewards (OLIVEIRA, 2018). Lopes (2022) tells us that gamification is linked to digital games as a pedagogical strategy in teaching chemistry because, as chemistry content is considered complex in high school, gamification and games can bring a new look to chemistry teaching, providing meaningful learning and improving students' performance. This method will draw everyone's attention, even because it is new in the educational field. We believe new approaches generate curiosity and can be a facilitator for other teachers who still do not know it.

The contributions of gamification to the chemistry teaching and learning process according to meaningful learning.

David Ausubel is considered responsible for the essential characteristics of meaningful learning. Ausubel proposed the theory of meaningful learning (TML) in 1963 in *The Psychology of Meaningful Verbal Learning. In* the theory of meaningful learning, new concepts will be organised into an existing cognitive structure, thus enabling knowledge expansion. Therefore, the teacher must use previous organisers to facilitate meaningful learning. Previous organisers will anchor new learning, leading to the development of subsumers, serving as a cognitive bridge between what is already known and what should be known (MOREIRA; MASINI, 2006). Da Rocha (2021) suggests a relationship between the TML and gamification based on some of its characteristics. The researcher starts with prior knowledge and sees what each student brings to the subject studied. Subsequently, students answer a diagnostic test in which they are exposed to questions relating to the subject that will be taught. This step aims to reference students' prior knowledge and experience with games. Finally, gamification is adopted as the primary means of obtaining playful learning, using the learning objectives of players and the target audience.

METHODOLOGY

This investigation is approved by the Human Research Ethics Committee of the Lutheran University of Brazil - ULBRA, via Plataforma Brasil, under number CAAE: 46569621.2.0000.5349

The research observed students attending the 3rd grade of a secondary military school in the regular public state network in Amazonas, the northern region of Brazil. Developed with a class in which the researcher teaches and during her class time, this audience was chosen because the researcher needed to provide a constructivist teaching approach based on David Ausubel's TML. Due to the pandemic and other school activities, only 12 students participated in one of the phases of this study. This research was carried out between June and August of 2022.

Carrying out a proposal based on gamification tools within a sequence of classes organised as an intervention measure in chemistry teaching falls within the framework Thiollent (2022) described regarding action research. That said, by applying the steps developed in the planning phase, we analysed the difficulties faced by students in teaching and learning chemistry from a new perspective.

Wordwall (http://wordwall.net/pt) is a platform for creating personalised activities using a few words in a gamified model (CIENSINAR, 2020). One can create games, quizzes, competitions, word games, and more. It is an effortless way to create teaching resources and prepare personalised activities for in-person or remote classes. There are several templates for teachers to access and create games. As it is a versatile platform, teachers can create activities for any subject, which can be applied online in synchronous and asynchronous moments or printed when students cannot access the Internet.

After choosing the activity/game model, the next step is to "insert the content," such as images, texts, special symbols, and even equations. For this application, it is not necessary to know codes or game design; everything is available in the models offered by the platform, which makes this platform easy to use and applicable. *Wordwall* was chosen because it has a simple language while offering the necessary resources to be developed in accordance with what was proposed in this project: to qualify students' learning with entertainment and fun, assuming a facilitating and motivating character in the interactions shared in classes. As the platform has more interactive tool options, it guarantees better student performance and participation. In addition, it can be used in in-person or remote classes.

It is interesting to recover here the elements proposed by Werbach and Hunter (2012) when analysing the structure of games used in gamification. We realised that the game structured here to transmit content related to organic functions presents some of the traits listed by the authors. Therefore, we defined the elements used and their respective applications in the game, considering the dynamics, mechanics, and components presented in Table 1.

Table 1

Elements of the dynamics, mechanics, and components of the game "Pac-Man: Pursuing Organic Functions"

	Dynamics
Restrictions	By answering the questions, get to the correct answers without bumping into enemies scattered throughout the maze.
Narrative	The game occurs in a maze, where *Pac-Man* must look for the fastest way to the correct answers and try to save himself from enemies spread throughout the place.
Progression	With each correct answer, the player is shown their progress in the score and the increase in level and enemies in the game. The time in which the game is played will determine the winner.
	Mechanics
Challenge	Dodge enemies and get the correct answers as quickly as possible.
Feedback	Immediate feedback for each correct answer; if they miss the answers, they will remain in the same phase until they hit them.

Reward	For each correct answer, a medal (point) is awarded.
Chance	The player will only have three lives to complete the game.
	Components
Avatars	*Pac-Man* (main character) and NPCs (enemies).
Boss Fights	With each statement, the game level increases with the insertion of more enemies.
Unlocking content	Players can only pass the stage if they hit the question. Otherwise, they will remain in the game until their lives end.
Scoreboard	In the last phase, players can check their score and game time, as well as that of other players.
Stages	The game features four levels or phases.
Scores	Each hit is awarded 1 point.
Exploration	Players must get to the correct answer to the question asked, escaping from enemies through the maze.

Therefore, we have a gamified resource from the combination and organisation of the elements. About *Dynamics,* the game contains a narrative interwoven into the content, designed to awaken students' curiosity. In this case, we are talking about the structure of the traditional *Pac-Man* game. In this scenario, students must answer the questions correctly to advance. In *Mechanics*, feelings of cooperation and competition can be mobilised to achieve the best individual performance, a factor that directly impacts the correct retrieval of the content taught. Finally, regarding *Components*, the authors point out the need to build a network of achievements, scores, and points that serve as a reward, albeit symbolic, for the performance resulting from the activity. Virtual games, as we can see, act systemically by integrating structural elements, such as those that make up the game itself (phases, challenges, commands, etc.), and subjective elements that are beyond the device screen, such as students/players' relationships, desires, and feelings.

Throughout the research, different data creation instruments were used, such as direct observation –with records in a field diary and structured and semi-structured questionnaires (via Google Forms) to verify from students' prior knowledge to the knowledge they acquired later and diagnose the class profile.

The six questionnaires used as data collection instruments and their objective, will be presented below: Questionnaire 1 (Q1) – Socioeconomic diagnosis of the class: applied with the purpose of diagnosing the class profile; Questionnaire 2 (Q2) – Diagnosis pre-test to the game: to probe students' prior knowledge of the content of organic functions; Questionnaire 3 (Q3) – Post-test diagnosis of the game: survey of knowledge acquired by students of organic functions content after classes, and use of gamified activity relating to the subject; Questionnaire 4 (Q4) – Pre-game diagnosis: to diagnose students' opinion about how the chemistry subject is taught, such as the use of gamification in chemistry classes; Questionnaire 5 (Q5) – Post-game diagnosis: to diagnose students' opinions regarding the gamified methodology applied in chemistry classes; Questionnaire 6 (Q6) – Diagnosis of the use of gamification in the classroom: to diagnose students' opinions on the use of active methodologies, in this case gamification, as a motivating way of learning in the classroom.

According to Yin (2001), using different sources of data collection allows more dedication to the diversity of historical, behavioural, and attitudinal issues. It also presents the advantage of varied lines of investigation that ultimately converge. As already stated, several factors, including social, family, and infrastructural elements and impasses linked to teacher education, prevent students from achieving proficiency in chemistry. For this reason, the constituted data attempts to design a global network of information that groups together the elements that are in favour or missing in implementing learning.

The results were analysed descriptively and interpretatively from the perspective of the teacher-researcher as an active participant among the students. After being applied to SD and gamified games, the results were treated and analysed according to their descriptive and interpretative nature (Yin, 2016).

We used this method to verify how students felt when using gamification in the educational context and whether the knowledge acquired from this teaching methodology was significant.

As can be seen, our research is inserted in this diverse context that mixes results based on interviews, historical data about chemistry teaching, and numerical results represented by students' performance in the practical activities developed. In other words, the description of the data proposed by

Yin serves this research as a support for interpretation, which works in parallel with the action research proposed by Thiollent (2022).

As a methodology, we used a contextualised didactic sequence, aiming to create favourable conditions for the student to learn the content in a meaningful way, which, according to Krasilchik (2016), are differentiated activities that motivate students and foster learning. Below, we present the sequence of activities developed during the approach to *food*, based on the study of organic functions.

Proposed didactic sequence: What organic functions are present in food?

Title: "Do you know the foods you eat?"

Target audience: Thirty-two students enrolled in the third grade of high school in the morning shift.

Competence: Understand methods and procedures specific to natural sciences and apply them in different contexts and through different media and digital information and communication technologies (DICT).

Skills: Relate information presented in different forms of language and representation used in physical, chemical, or biological sciences, such as discursive text, graphs, tables, mathematical relationships, or symbolic language. Relate the physical, chemical, or biological properties of products, systems, or technological procedures to their intended purposes.

Problematisation: Aiming to contextualise the concepts related to organic chemistry to students in the third grade of high school -contents that in this stage of teaching are present in the 2nd quarter, according to the school's teaching plan- we will study the organic functions present in the participants' daily lives to add meaning to their learning, presenting the content in a simplified way, a methodology that is in line with the theory of meaningful learning (TML) defended by Ausubel (1968). To achieve the objective, we selected the topic of food, bringing to light its chemical composition and raising the following questions: "How can organic chemistry concepts be presented in a simplified way based on contextualisation with participants' eating habits? How do organic chemistry concepts relate to students' nutrition? Is it possible to introduce concepts beyond the curriculum proposed for this grade using a more simplified approach, considering the TML? Moreover, does interactivity mediated by the use of gamification contribute to the intellectual development of these students following the principles of the TML?"

Aiming to answer these questions, the proposed didactic sequence presents organic chemistry content in the context of foods consumed by students, introducing the concepts of organic functions, their classifications, and nomenclatures. To this end, our general objective was to understand the presence and importance of organic functions in maintaining life based on contextualisation with the eating practices of the students involved.

As support, we have developed the following specific objectives:

- ✓ Diagnose students' preconceptions about the contextualised theme and organic functions;
- ✓ Build concepts relating to the study of food based on the study of organic functions (alcohols, phenols, aldehydes, ketones, ethers, esters, amines, and amides), incorporating new elements to the concepts seen in chemistry classes;
- ✓ Identify and classify the organic functions present in food using active methodologies;
- ✓ Evaluate students' learning based on the development of the gamified game "*Pac-Man*: Pursuing Organic Functions," which was developed on the *Wordwall* platform.

<u>Stage 1 of the Didactic Sequence</u>: Understanding the Chemistry present in the Foods.

<u>Description</u>: Presentation of the theme and objectives of the study;

Explanation of the concept of organic functions and their characteristics;

Presentation of how organic functions are classified and how they are present in food –through a dialogued expository approach;

Explanation and exemplification of the concepts on the board by the subject teacher.

<u>Activities</u>: Reading the introductory text "Chemistry and Food" in the book Química Cidadã (SANTOS & MOL, 2013, p. 65-66) to arouse an initial discussion between the teacher and students on the topic;

Discussion about the foods present in the students' daily diet –a survey of prior knowledge;

Conceptualisation and visualisation of the structures and names of organic functions and how they are associated with food on the whiteboard;

Display of images on banners (slides) of the food consumed by students;

Contextualisation of the organic functions present in students' diet – informal conversation.

Stage 2 of the Didactic Sequence: Recognising the Structures of the Organic Compounds.

Description: Construction of organic structures based on the selection of the Flashcards item contained in the "As Substâncias Químicas Quiz" application;

By identifying the organic structures, determine the names of substances and their classification of the organic function and their applicability.

Activities: Apply the questionnaire on interest in chemistry and use of gamification before starting the game;

Identify four structures of organic substances that appear on the application screen – in the "As Substâncias Químicas Quiz" [Chemical Substances Quiz] application interface;

Name the four structures identified in the application interface (nomenclature);

Classify according to the type of organic function it belongs to;

State the four molecular formulas of organic functions;

Stage 3 of the Didactic Sequence: Identify Organic Functions with the Help of the *Wordwall* Platform.

Description: Identify and classify organic functions using the gamified game "*Pac-Man*: Pursuing Organic Functions"

Activities: Identify in the game which organic structure the question corresponds to;

Students will have five questions to answer in five minutes on the Wordwall platform interface.

As they hit the answer, they move on to the next one. Otherwise, they remain until they get it right or the game runs out of time.

Assessment: motivation, participation, frequency, competitiveness, content mastery.

The didactic sequence consisted of nine meetings and was planned to contextualise the teaching of organic functions, using food as a theme. Santos and Schnetzler (2020) emphasise the importance of contextualisation in the classroom, so that learning is effective. The results were analysed based on questionnaires and observations by the participating researcher.

RESULTS AND DISCUSSION

The first instrument applied to the participants in this research was a socioeconomic questionnaire. The research was conducted in a 3rd-grade high school class at a public school in Manaus, state of Amazonas, Brazil. The institution adheres to the militarised education system. Thirty participants answered 21 questions, nineteen closed and two open, where we could outline an image of the auxiliary resources available for the educational exercise.

Most students have a stable financial situation, with adequate support to be dedicated mainly to their studies. Since most do not work, they are supported by their parents, who present good numbers in terms of education themselves. Most of the students' guardians have higher education or have completed basic levels of education, which is a positive factor.

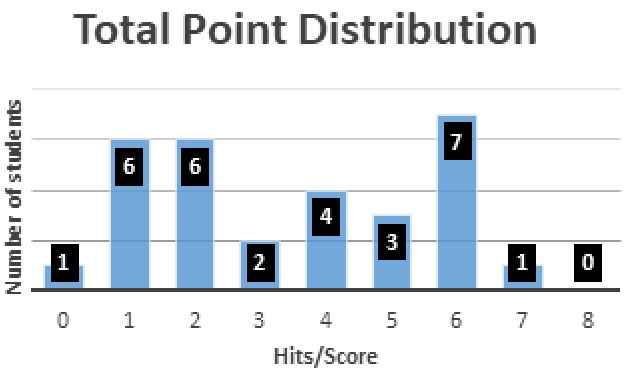
Students have extensive access to technological resources and information tools: most can access the Internet at home and own a computer, cell phone, or other electronic device. Furthermore, when asked about their Internet access use, the answers vary between social networks and entertainment topics. The same applies to each person's use of mobiles, which are predominantly used to share and access social platforms. From this, we can infer that the school still does not use students' interests to engage them in school activities, which harms the process of renewing and implementing teaching.

Émile Durkheim states that "education is the action carried out by adult generations on generations that are not yet prepared for social life" (DURKHEIM, 1973, p. 41). In this way, the social group carries out the educational process through individuals implicitly or explicitly designated for this task. Parents educate children, teachers educate students, and adults educate children.

Before the game was presented, students were invited to answer an introductory questionnaire containing eight multiple-choice questions taken from previous editions of the National High School Exam (Exame Nacional do Ensino Médio - ENEM) and one discursive question. From this, we can see how students still perceive chemistry as a complex subject with little connection to the everyday world. Even though students had complete access to chemistry classes from the 1st grade to the 3rd grade of high school, most showed average performance in the results of the questions (Figure 1).

Figure 1

Pre-test Questionnaire Results



This scenario makes visible the poor effectiveness of traditional, very conservative chemistry teaching methods. The result points to an almost total lack of knowledge of the content since, of the total number of participants who joined the activity, around 60% (18) of the students did not achieve several hits greater than four. Therefore, a problem of assimilation between theory and practice becomes visible.

The questions in this questionnaire are part of the entrance exam selection process, which can be problematic because it suggests students are not developing the necessary skills to solve the proposed exercises. They are not yet prepared to build subsumers, tools capable of systematising knowledge. If we return to David Ausubel's theory of meaningful learning (1968), it becomes clear that the process the author proposed involving the recovery of prior knowledge does not materialise easily in the practical sphere of teaching and learning. Therefore, the doors are opened for the proposed pedagogical intervention. In general, the flat visualisation of chemical functions limits the consolidation of this content in students' minds. That is, other fields of meaning are needed to arouse students' interest and enhance content retention. The mere visual and flat visualisation of functions does not guarantee students' content solidification and mastery. By activating the tactile, visual, and auditory fields simultaneously when working with the free application for the Android system "As substâncias Químicas Quiz," we verified how the content became more palpable for the students, bringing the theory (microscopic level) closer to their real experience (macroscopic level), just as it also occurred when we finished the didactic sequence with the use of the *Wordwall* platform.

The diagnostic done with the students shows a gap in the recovery of content seen in previous high school grades, as the results were limited to an average mastery of the assessed content. The scenario presents discrepant percentages in participants who hit and understand the commands of the question and those who select incorrect alternatives. In other words, although the number of students who answered the questions correctly was reasonable, it is still disturbing that students had a much higher error rate than hits in at least four of the eight questions.

At the beginning of the pedagogical intervention, with the help of "gamification" tools, students were encouraged to view the content more playfully, going beyond the flatness of the textbook, momentarily abandoning content-based and technical teaching. Using games in the classroom is already a progress, as it does not start from the commonplace of the expository class followed by theoretical exercise.

The project was carried out with the support provided by *Wordwall,* which allowed for the translation of content fixation exercises that were far from traditional multiple-choice methods. From this, a virtual scenario, including intertextual, was built using a top-rated game, *Pac-Man*, as a model. In this game, the player must escape from monsters while collecting all the pieces left on the virtual board.

When applying the didactic sequence, activities carried out in groups or individually gradually boosted the exchange of information and interaction between students, increasing their confidence and involvement with the activities proposed in the DS. From Nacarato and Custódio's (2018, p. 23) standpoint:

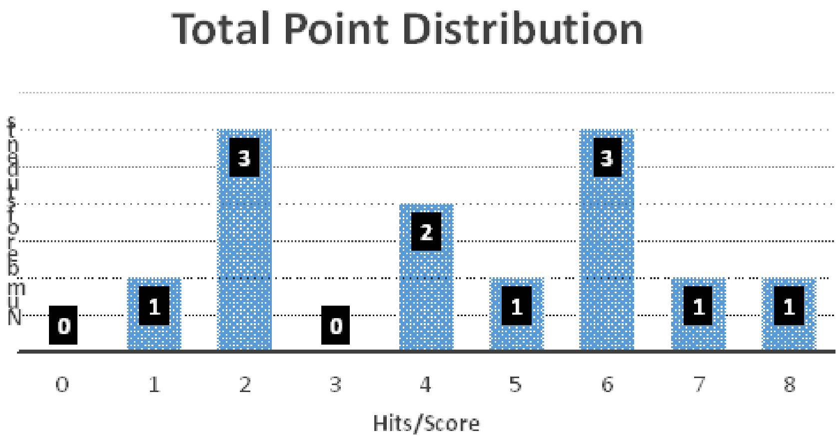
> Students' organisation is critical, as collaborative work allows action in potential development areas. This way, more experienced students can collaborate with less experienced students. The tasks assume that work in the classroom is in pairs or small groups. Many students felt excited, which provoked curiosity and interest in the more shy participants. This fact was observed in their motivation when carrying out the practical activities.

Many students felt excited, which provoked curiosity and interest in the more shy participants, which was observed in their motivation when carrying out the gamified activities.

Once again, the same questions about organic functions were applied at this stage. In this second stage of verification, there was a slight drop in adherence to filling out the forms, and only 12 students participated in this activity. Despite the smaller number of participants, a new picture of those students can be analysed (Figure 2).

Figure 2

Post-test Questionnaire Results



Descriptively, we note the absence of students who completed the questionnaire, a new scenario compared to the first application. There is also an increase in the percentage of students who reached the number of seven hits. Ultimately, there is a balanced increase in the participant/points ratio distribution. Even if the maximum number of hits has not yet been reached, we can see an improvement in overall performance. However, we cannot say that students who did not respond to the post-test are "problematic/unmotivated/uninterested" students in the classroom since the absence did not seriously compromise the result compared to the previous one.

The absence of students in this second stage does not prevent us from stating that gamification is consolidated as an ideal intervention methodology for overcoming barriers in chemistry teaching. Even so, the application of this tool made it possible to improve, albeit initially, the performance of students previously assessed with lower performance. Below is the new table of participants who have continued participating in the research.

We observe an advance, albeit embryonic, in terms of content. The number of hits signals a transformation of the initial stage, as the number of students participating with correct answers above 60% is greater than the number of participants with low results. Of the total of questions applied (eight) in the second assessment, we obtained six hits from 50% of the students who joined the second stage. This new scenario appears favourable for the continuity of work involving games and the Chemistry subject syllabus in the 3rd grade of high school.

Additionally, it is noticeable that the percentage of students who hit the questions equals or exceeds those who still need help recovering the content studied. Compared with the previous scenario in which the error percentages were higher than the correct ones, a movement of balance and development in the responses can be noted.

Therefore, we observe here that most students had higher hits, which signals effectiveness in the research development process, even with fewer participants compared to the pre-test questionnaire. The proposed game tried to insert chemistry in a context where students would free themselves from the resistance they usually show towards subjects in some areas of knowledge, such as natural sciences, including chemistry. With the advent of the *Wordwall* platform, we could build a virtual learning environment that intertwines leisure and teaching.

We must remark that there was no time to review the content before handing students the questionnaire for the second time; that is, the students who participated in this research stage delivered the result based on the knowledge they had acquired during the gamified didactic sequence classes. This factor signals a positive point of the application of the gamified methodology, considering that students had already studied this content in the previous grades and, even so, did not perform well in the pre-test stage, which ensured significant learning, as a new learning idea was related to students' prior knowledge in a situation considered relevant to them. In this process, students expanded and updated the information previously acquired, attributing new meanings to their knowledge.

The idea here is not to hierarchise or discard other teaching methods but to provide educators with another tool for educational work. As can be seen, there is no need to talk about the burden on the educator or the student, as the results indicate favourable aspects arising from including games in the classroom. The presented resources facilitate the teaching and learning process, bringing students and teachers closer. Games dilute the idea of the teacher as the absolute holder of knowledge and encourage learners' discovery.

The analysis of these results allows us to confirm how the lack of applied teaching techniques is more effective than simple theoretical repetition.

Furthermore, it enables the perception of a still unexplored field of educational possibilities in different spheres of knowledge. Teaching and learning is not a static element. Considering this, using games to teach opens the door to recovering students who have long resisted acting actively in their educational processes. As Paulo Freire (1987) analysed, the role of the school is to prepare for life in society from a critical point of view, leaving technical teaching, which focuses on storing content without focusing on its value in the real world, in the background.

The fourth questionnaire, applied before the games, was used to guide students' subjective relationship with learning chemistry. In it, we found questions regarding the student's view of the subject based on their interest, performance, and teaching experiences throughout their school life. Throughout the analysis of the application of gamification as a pedagogical resource, 21 students (around 56.8%) said that chemical contents aroused their interest and allowed them to visualise them in everyday life. Despite this, 15 students (40.5% of participants) indicated that, albeit interested, they cannot associate with aspects of everyday life, which signals a significant gap between what is taught in classes and what students actually absorb.

Those data can best be seen in Figure 3, which clearly shows the positive distinction regarding the application of the didactic sequence involving games in fixing content.

Another relevant aspect is related to which methodology students consider effective from their perspectives. Based on the data collected, 78.4% (29 students) indicate that students feel more likely to retain the content taught during practical classes. In parallel, we observed that 37.8% (14 students) showed some interest in using games to aid pedagogical practice, as shown in Figure 4.

Specifically regarding these multimodal resources in teaching, around 91.9% (34 students) understand that games can be relevant because they are a different way of learning.

Finally, we verified their bias regarding the use of games in chemistry teaching. In Figure 5, the answers to whether they would like to learn chemistry through gamified games signal a favourable openness to applying these resources since 81.1% (30 students) indicated that games would be a good tool for learning chemistry.

Figure 3

Interest in the chemistry subject

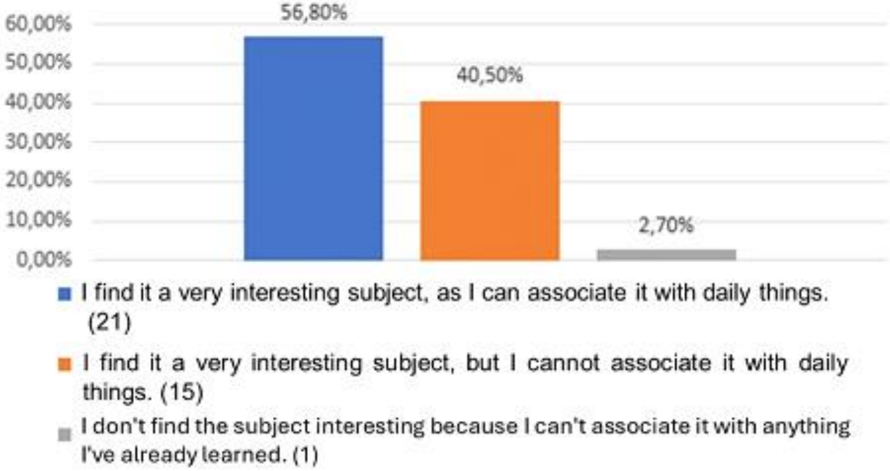


Figure 4

The best way to learn chemistry

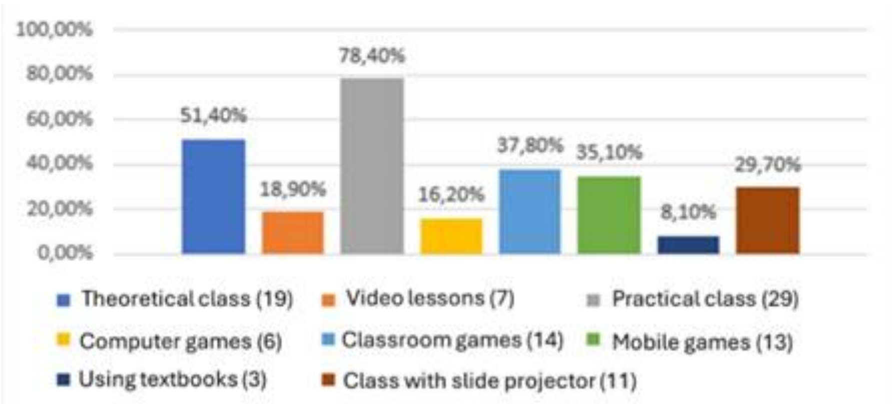
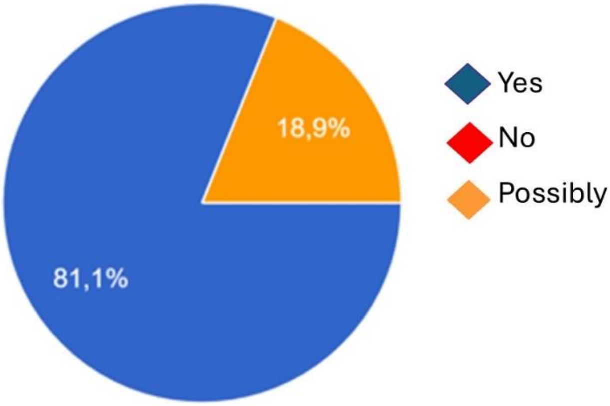


Figure 5

Learn chemistry in a gamified way



Those data demonstrate that, even without having contact with the gamified methodology, students are open to trying it. The possibility of applying new teaching paths can be seen here as something that students expect, considering that traditional methods have proven flawed over the years. Therefore, the mere idea of a new methodology already takes students out of the initial and typical stage of lack of interest in school content.

When we cross-referenced the data presented in Figure 3 with that in Figure 5, we verified a connection between students' interests and the type of methodology capable of arousing their interest. In Figure 3, the most prominent choice is practical classes, with 78.4% of students (29) choosing this option. On the other hand, only 37.8% (14) choose games as the best resource available for learning. In Figure 5, we have data that connects with these previous percentages. When asked whether they would like to learn chemistry with the help of gamified games, 18.9% (7) indicated that just maybe, which denotes a doubt about games being interesting to students as a teaching strategy.

It is crucial to discuss adequacy; therefore, a path between the method applied in the classroom and student participation must be built. One precaution the educator should take is to present the path to be followed as attractive. The option for "Maybe" can be strongly related to a lack of knowledge of different teaching methods, which can leave students a little withdrawn. It is then up to the teacher to show how this resource can be helpful for students, transforming this doubt into certainty about the benefits achieved with the application of this pedagogical resource.

The school tends to silence students and perpetuates an outdated teaching model in which students are recipients and then reproducers of an outdated and ineffective teaching technique. By activating other skills in the classroom environment, we can bring the student and their total capacity closer to effectively achieving scientific content. Teaching as leisure is shown here as a salutary possibility for overcoming difficulties that have long been rooted in educational practice.

When we read about the effects of gamification in Lima and Moita (2011), we believe that the partnership between recent technological resources and chemistry teaching must be done to direct knowledge towards a vision for students that considers it valuable and meaningful. In other words, integrating these new tools should guarantee students a connection between what is observed in the school environment and everyday life. When we see the positive results, we highlight how students can get closer to school practice if they are awakened from this state of mere reproduction of theoretical content and disconnected from reality. The authors further state that:

> One way to promote quality teaching is through technologies that serve as a pedagogical tool to promote students' integration in the digital world through the optimisation of available resources, enabling a multiplicity of ways of accessing knowledge in a dynamic, autonomous, pleasurable, and current way. [...] Adopting technological resources in the educational practice of Chemistry classes requires planning, whose methodology is centred on the reality of life and society. Therefore, the teacher's methodology will involve students in the study through the analysis and elucidation of natural and virtual world phenomena, which will help them understand the contours of socio-environmental issues. In this sense, education will fulfil its social function since the proposed teaching is not limited to the mere "transmission" of the contents and approaches covered by the curriculum component. Learning will be developed through a methodological approach inserted into students' lives and connects them to the technological context. (Lima; Moita, 2011, p. 134-135)

It is evident, then, that the teacher must always search for new teaching strategies, update their teaching practice, and use new tools that facilitate the path to be taken with the student. Given that chemistry learning requires understanding abstract concepts –which may be somewhat challenging to students and decrease their interest– several alternatives have been presented to help build knowledge in the subject. Therefore, active methodologies help construct knowledge, encouraging student interaction and autonomy. Problem-based learning, peer review, flipped classroom, and gamification can be mentioned among the various active methodologies currently available, of which gamification proves to be very effective in overcoming difficulties in teaching and learning.

CONCLUSIONS

This work seeks to make students and teachers independent of traditional teaching models, as these have long been showing deficiencies in results. For this purpose, we have the first investigative question: How does the use of gamification interfere with students' performance and interest in chemistry?

Once applied, gamification proved an efficient and meaningful learning strategy that expanded students' emotional and social intelligence through gamified experimentation, encouraging them to create real situations for assertive content absorption. Students' motivation experienced a significant increase as, through the principles of the game, students' commitment and interest intensified. Given this, it is clear how gamification works as a pedagogical instrument for developing essential skills for learning, such as autonomy, creativity, and attention.

In the context of high school, gamified classes help to expand new paths and opportunities. In these classes, complex projects of contextualisation with students' reality are applied to offer the skills that current socialisation requires for cooperation between individuals, for example.

Thus, it is noticeable that gamification, like other teaching strategies, can modify the conceptions that students acquire; through it, it is possible to affirm that chemistry can be seen differently through the combination of gamification and digital games. These tools renew the school's teaching space and insert students into new knowledge-understanding scenarios. Gamification allows the teacher to intervene in traditional teaching models, configuring an attempt to overcome the obstacles encountered in chemistry teaching.

Games are a positive alternative to the innovation of teaching and learning practices. With them, we have a gateway to a new universe of possibilities for teaching and learning. It was possible to awaken students' interest in chemistry classes by addressing the benefits of using gamification as a teaching resource and highlighting its limitations in renewing the school environment. Furthermore, this research presented the process of constructing a didactic sequence (DS) to teach chemistry in a way that prioritises protagonism and promotes students' autonomy based on the insertion of active methodologies.

When we chose the topic, we considered the importance of contextualisation. We aimed to present significant theoretical-scientific concepts of the curriculum component and relate them to phenomena that involve the students' daily lives. This didactic sequence was based on strategies that sought to promote factors such as students' interaction, engagement, and active participation, placing them as active agents in the search for knowledge.

Contextualising the content allowed students to be interested, which can be seen through their active participation in the knowledge construction process, enabling them to actively participate not only as listeners but also as citizens, capable of expressing their experiences and opinions. We sought to develop competencies and skills necessary for the conscious exercise of citizenship based on the generating theme in conjunction with Organic Chemistry content.

Therefore, chemistry teaching cannot fall short of what has been scientifically and technologically advanced in relation to teaching. It requires new methodological alternatives since students actively use different technologies, such as mobile devices, the Internet, applications, and social networks. Therefore, it is necessary that teachers not only understand the programmatic content but also promote the interaction of content and digital technologies with students to motivate students to participate more actively in classes.

This research showed that gamification is a method directly involved in students' daily lives through digital games. It could also verify that teachers must have theoretical and practical knowledge of the game to enable a meaningful student learning process. When we use students' knowledge of the world, as in the case of eating habits, we activate their ability to establish connections between school and life.

As a positive result regarding gamified games in teaching, the scientific community eventually realises that technological resources, through their operating structure, can be adjusted to teach other content. Our research was directed towards chemistry teaching; however, it can be extended to different areas of the teaching degree and maintain the structure of the game presented. It is also worth highlighting that this study meets some of the objectives proposed by BNCC, such as "designing and putting into practice situations and procedures to motivate and engage students in learning" (BRASIL, 2018, p. 17).

As a social contribution, we consistently developed a little-explored topic regarding the types of food students consume daily. We hope that, in the future, we can reach more students as this study is disseminated. In favour of this, we highlight the evidence of students' learning and engagement as the leading recognition of the work, highlighting the need to expand to more students and contribute to their learning.

Therefore, we hope that the results presented here bring significant reflections regarding the need to improve chemistry classes and that this proposal can be used in other school spaces, providing opportunities for participatory, critical, reflective, constructive, and human teaching to promote meaningful learning in the context of basic education.

Therefore, our work opens doors to interdisciplinary views of educational dilemmas. Gamification is not restricted to chemistry teaching; other branches of knowledge can use this tool to overcome barriers in the teaching and learning process. From this perspective, a new possibility of action is opened to a little-explored resource to date, gamification, which can be expanded and reinterpreted in the light of other school subjects, consolidating it as a universal pedagogical resource.

AUTHORSHIP CONTRIBUTION

LLS and ABBR conceived the idea, reviewed the literature, and wrote the manuscript.

DATA SHARING POLICIES

Not applicable.

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