

DISSEMINATION AND USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICTS) FOR CHEMISTRY TEACHING IN BASIC EDUCATION

DISSEMINAÇÃO E USO DE TECNOLOGIAS DE INFORMAÇÃO E
COMUNICAÇÃO (TICS) PARA O ENSINO DE QUÍMICA NA EDUCAÇÃO
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ABSTRACT

The use of Information and Communication Technologies (ICTs) in Chemistry teaching has expanded the possibilities for representing, interacting with, and contextualizing concepts that often present a high degree of abstraction for basic education students. This paper discusses and expands the results of an extension project focused on the dissemination, selection, and use of virtual learning objects, especially simulations, to support Chemistry teaching. The original study involved searching for digital resources in national and international repositories, evaluating them for content accuracy, graphical presentation, ease of use, and suitability for classes, followed by workshops with teachers at Dr. Brunilo Jacó Public School in Redenção, Ceará. The expanded version presented here incorporates an updated discussion of digital educational resources, virtual laboratories, augmented reality, virtual reality, active learning, teacher education, digital inclusion, and artificial intelligence. Recent literature indicates that digital technologies can foster conceptual understanding and the articulation of different levels of chemical representation, provided that they are integrated with clear pedagogical objectives and accompanied by teacher mediation. Limitations related to infrastructure, unequal access, material quality, digital literacy, privacy, and the responsible use of artificial intelligence are also discussed. It is concluded that learning objects are relevant pedagogical resources for Chemistry teaching, not as automatic substitutes for teachers or face-to-face experiences, but as elements of a planned, contextualized, inclusive, and learning-oriented instructional strategy.

Keywords: ICTs; Chemistry Teaching; Learning Objects; Simulations; Digital Technologies.

RESUMO

O uso das Tecnologias de Informação e Comunicação (TICs) no ensino de Química tem ampliado as possibilidades de representar, interagir e contextualizar conceitos que frequentemente apresentam elevado grau de abstração para estudantes da educação básica. Este artigo discute e amplia os resultados de um projeto de extensão voltado à divulgação, seleção e uso de objetos virtuais de aprendizagem, especialmente simulações, para apoiar o ensino de Química. O estudo original envolveu a busca de recursos digitais em repositórios nacionais e internacionais, a avaliação destes quanto à precisão do conteúdo, apresentação gráfica, facilidade de uso e adequação às aulas, seguida de oficinas com professores na Escola Pública Dr. Brunilo Jacó, em Redenção, Ceará. A versão ampliada aqui apresentada incorpora uma discussão atualizada sobre recursos educacionais digitais, laboratórios virtuais, realidade aumentada, realidade virtual, aprendizagem ativa, formação de professores, inclusão digital e inteligência artificial. A literatura recente indica que as tecnologias digitais podem favorecer a compreensão conceitual e a articulação entre diferentes níveis de representação química, desde que sejam integradas a objetivos pedagógicos claros e acompanhadas de mediação docente. Limitações relacionadas à infraestrutura, ao acesso desigual, à qualidade dos materiais, ao letramento digital, à privacidade e ao uso responsável da inteligência artificial também são discutidas. Conclui-se que os objetos de aprendizagem são recursos pedagógicos relevantes para o ensino de Química, não como substitutos automáticos dos professores ou das experiências presenciais, mas como elementos de uma estratégia instrucional planejada, contextualizada, inclusiva e orientada à aprendizagem.

Palavras-chave: TICs; Ensino de Química; Objetos de Aprendizagem; Simulações; Tecnologias Digitais.

1. INTRODUCTION

Information and Communication Technologies (ICTs) have progressively changed the ways knowledge is produced, accessed, shared, and represented. In the educational context, this transformation does not simply mean replacing the board, book, or notebook with a screen. The challenge is to understand how digital resources can contribute to concrete learning objectives, increase student participation, and foster the construction of scientific knowledge. This issue is particularly relevant to Chemistry teaching, a discipline in which many phenomena cannot be directly observed and must be interpreted through models, symbols, equations, graphs, and representations of the submicroscopic world.

School Chemistry involves a continuous articulation between what can be directly observed, explanations related to particles and entities that are not visible to the naked eye, and the different languages used to represent phenomena. For this reason, digital resources such as animations, simulators, molecular models, videos, virtual laboratories, and interactive environments can expand opportunities for visualization and experimentation. However, the mere presence of technology does not guarantee learning. The resource must be associated with an instructional proposal that considers students' prior knowledge, curricular objectives, the level of complexity of the content, and forms of assessment.

This concern remains current. UNESCO's report on technology in education emphasizes that the effects of digital technologies are heterogeneous and depend on factors such as context, teacher preparation, equity of access, and quality of implementation. The report also highlights the need to place students' needs at the

center of decision-making and to use technology in an appropriate, equitable, evidence-based, and sustainable manner (UNESCO, 2023). Thus, the discussion initiated by the extension project described in this article remains relevant, but it needs to incorporate the advances that have occurred over the past decade.

In Brazil, this discussion has gained even greater relevance with the creation of the National Digital Education Policy (PNED), established by Law No. 14,533/2023, which organizes actions related to digital inclusion, school digital education, digital training and specialization, and research and development in Information and Communication Technologies (BRASIL, 2023a). Similarly, Decree No. 11,713/2023 established the National Strategy for Connected Schools, aimed at expanding quality connectivity and promoting equity of opportunities for access to digital technologies in basic education (BRASIL, 2023b).

Alongside the expansion of connectivity, new technological possibilities have emerged. Augmented reality and virtual reality have begun to be explored more systematically in science education and, specifically, in chemistry education. Recent studies show applications focused on molecular visualization, chemical bonding, reaction mechanisms, laboratories, and the development of visuospatial skills. Generative artificial intelligence has added another layer to this scenario, bringing opportunities for activity design, feedback, and planning support, but also concerns related to response reliability, privacy, authorship, assessment, and technological dependence (UNESCO, 2023; Miao; Holmes, 2023; UNESCO, 2024; Berber et al., 2025).

Against this background, the present paper revisits and expands the project originally developed with a focus on disseminating and using virtual learning objects in Chemistry teaching. The objective is to discuss more broadly the pedagogical potential of these resources, relating the results observed in the project to contemporary literature on educational technologies. It also seeks to systematize criteria that can assist teachers in selecting digital resources and to propose possibilities for integrating these materials into Chemistry classes in basic education.

2. METHODOLOGY

This is a descriptive and reflective study based on the extension project that originated the study and complemented by an updated literature review on digital technologies applied to Chemistry teaching. The original methodology was organized as continuous rather than isolated actions, involving team training, searching for and evaluating learning objects, organizing materials by areas of Chemistry, and conducting workshops with teachers.

In the first stage, scholarship students participated in training to guide the search for virtual learning objects available in digital environments, educational repositories, and virtual university spaces. The resources were examined mainly in terms of content accuracy, graphical presentation, ease of use, and potential classroom applicability. The materials were subsequently organized into areas such as General Chemistry, Analytical Chemistry, Physical Chemistry, Inorganic Chemistry, and Organic Chemistry.

In the second stage, workshops and courses were developed to present the selected objects to teachers. These activities addressed

the content covered, how the resources worked, their possible uses, and their strengths and weaknesses. The third stage took place at Dr. Brunilo Jacó Public School, located in Redenção, Ceará, providing a setting for bringing the project team, digital resources, and school practice closer together.

In the expanded version of this article, the analysis is complemented by a recent literature review, prioritizing institutional documents and studies published between 2023 and 2025 on educational technology, simulations, augmented reality, virtual reality, artificial intelligence, and Chemistry teaching. This update does not represent a new experiment with students. Therefore, the empirical conclusions concerning acceptance of the workshops and selection of objects remain those observed in the original project; the other considerations are theoretical and analytical in nature.

3. RESULTS AND DISCUSSION

According to the initial plan, it was possible to conduct training meetings, searches in virtual environments, and surveys of educational materials. Participants were organized by areas of Chemistry, and the resources found were subsequently shared with teachers at Dr. Brunilo Jacó School. The experience enabled a more systematic engagement with digital repositories and showed that the existence of a large quantity of materials does not necessarily mean that all of them have pedagogical quality.

During the evaluation, important differences were observed among the objects found. Some resources provided good visualization, ease of manipulation, and potential to support the understanding of certain contents; others had spelling problems, unattractive

interfaces, navigation difficulties, or access limitations. This finding is one of the project's main results because it demonstrates that careful resource selection should precede classroom use.

This result remains consistent with current literature. UNESCO (2023) argues that the discussion of educational technology cannot be reduced to the quantity of equipment or platforms available. The quality of the experience depends on pedagogical purpose, teacher preparation, accessibility, and concrete implementation conditions. Thus, the evaluation conducted in the project—content, presentation, and ease of use—can be expanded to incorporate contemporary criteria such as accessibility, privacy, interoperability, offline use, age appropriateness, clarity of instructions, student feedback, and curricular alignment.

Figure 1. *Presentation of virtual learning objects to the participating teachers.*



3.1. Learning Objects And Pedagogical Mediation

Learning objects can be understood as digital resources designed to support learning situations and may take different forms: simulators, animations, models, videos, interactive activities, applications, virtual laboratories, and other digital materials. The main contribution of these resources lies in their ability to offer students different ways of interacting with content. In Chemistry, this feature is particularly

relevant because certain phenomena need to be modeled so that students can relate macroscopic observations to submicroscopic explanations and symbolic representations.

The pedagogical use of an object, however, should not be confused with simply accessing the resource. The teacher plays a central role in defining the problem, organizing the activity, formulating questions, guiding exploration, and discussing responses. A chemical equilibrium simulator, for example, may allow students to change concentration, temperature, or pressure; however, without guiding questions, students may merely manipulate variables without constructing a scientific explanation. Mediation transforms technological interaction into an inquiry situation.

This perspective also connects with research on the knowledge teachers need to integrate technologies into teaching. Studies on the use of Chemistry simulations indicate that pedagogical decision-making depends not only on knowing how the resource works technically, but also on understanding its possibilities and limitations in relation to learning objectives and student characteristics. In this sense, teacher education needs to go beyond exclusively instrumental courses and address planning, assessment, and strategies for integrating ICTs (KIM; HAN, 2023).

3.2. Digital Simulations And Visualization Of Chemical Phenomena

Simulations constitute one of the most promising categories of virtual objects for Chemistry teaching. They make it possible to represent phenomena that would be difficult, costly, or impossible to observe directly at school. They can be used, for example, to

explore particle movement, bond formation, molecular geometry, chemical equilibrium, kinetics, solution properties, and chemical transformations. The advantage lies not only in animation, but in the possibility of manipulating variables and observing consequences in a controlled environment.

A particularly important dimension is the articulation of multiple representations. Students can observe a color change in a reaction, visualize particles in the submicroscopic model, and simultaneously interpret a chemical equation or graph. Recent studies reinforce the relevance of this articulation. Ye et al. (2025), when investigating microcomputer- and simulation-based laboratory activities with high school students, highlighted the role of representations in understanding chemical processes in solution. The authors observed differences between activity modalities and reinforced the importance of investigating how technological resources function as supports for reasoning.

These results help interpret the experience of the original project. The team's concern with checking visualization, content coherence, and ease of use was not merely an aesthetic issue. In Chemistry, the way information is visually represented can affect students' interpretation. A confusing, excessively dense, or scientifically inaccurate representation may hinder learning rather than facilitate it.

Therefore, teachers are advised to examine the resource beforehand and ask: What concept will be explored? What representation will be presented? Will students be able to modify variables? Does the resource show causal relationships or only animations? Is there enough information to interpret the phenomenon? Is there

feedback? Can students use the material autonomously? These questions expand the evaluation protocol originally used by the project.

3.3. Augmented Reality, Virtual Reality, And Chemistry Learning

The expansion of mobile devices and immersive environments has broadened the possibilities for using augmented reality (AR) and virtual reality (VR) in science education. Augmented reality allows digital information to be overlaid on the physical environment, while virtual reality creates simulated environments in which students can interact with digitally represented objects and situations. In Chemistry teaching, these technologies have potential for working with molecular structures, reaction mechanisms, geometry, bonding, and laboratory procedures.

A recent example is the study by Bullock, Graulich, and Huwer (2024), which developed an augmented reality learning environment for teaching the mechanism of electrophilic aromatic substitution. The resource combined an experiment video, two-dimensional representations, and three-dimensional animation, enabling connections among different levels of representation. The authors reported a significant increase in performance after the intervention, as well as positive acceptance of the technology.

There are also augmented reality applications aimed at visualizing chemical bonds. Jeon et al. (2024) developed and evaluated a mobile application for teaching covalent and ionic bonding in high school. The study reported improvements in academic performance, engagement, and motivation after use of the resource. These findings are particularly relevant to the project discussed in this

article because they demonstrate that interactive visualization can be used to address precisely those contents that, in many cases, are considered abstract by students.

In virtual reality, Echeverri-Jimenez and Oliver-Hoyo (2024) proposed a roadmap for developing virtual learning environments in Chemistry, advocating integration among pedagogical foundations, technological design, and chemical content. This approach is important because it avoids a technocentric view: the goal is not to use VR simply because it is innovative, but to use it when its characteristics provide a concrete pedagogical advantage.

Another example is the use of VR as preparation for experimental activities. Mojsoska et al. (2024) investigated an intervention in an Organic Chemistry laboratory in which students completed a virtual experiment before the face-to-face activity. The results indicated increased cognitive engagement with laboratory activities, although the authors also identified technical and pedagogical limitations. This reinforces an important conclusion for basic education: virtual resources can complement real experiences, but they should not automatically be treated as universal substitutes for the laboratory.

3.4. Virtual Laboratories And Experimentation

Experimentation plays an important role in Chemistry teaching because it makes it possible to relate observations, procedures, evidence, and explanations. However, school laboratories face limitations involving infrastructure, safety, reagent availability, time, training, and costs. Virtual laboratories can help reduce some of these barriers by allowing students to explore procedures and phenomena in simulated environments.

A systematic review of virtual Chemistry laboratories identified evidence that these environments can produce learning outcomes equal to or greater than certain passive methods and, in some situations, outcomes comparable to face-to-face laboratories. The review also indicated that the best results tend to occur when virtual laboratories are combined with other strategies rather than used in isolation (Kickhöfel; Graf, 2021). Although this study is not recent, its contribution remains useful when interpreted alongside more current research.

In basic education, one pedagogical possibility is to use the virtual laboratory before the face-to-face activity. Students can become familiar with equipment, anticipate procedures, predict results, and identify risks. The face-to-face class can then focus on observation, manipulation, data discussion, and construction of explanations. Another possibility is to use the virtual environment after the class, allowing students to mentally repeat the procedure, compare results, and review concepts.

The choice between a real and a virtual laboratory, therefore, does not need to be presented as an opposition. It may be more productive to think in terms of complementarity. Technology can extend the time of contact with particular content, allow procedures to be repeated, and support visualization of phenomena that are not directly observable. At the same time, the face-to-face laboratory develops procedural skills and sensory experiences that a simulation cannot fully reproduce.

3.5. Teacher Education For The Use Of ICTs

The project results show that teacher education was a fundamental stage. It was not enough to locate digital objects; it was necessary to present the resources, discuss how they worked, explore the content, and reflect on their possible uses. This finding remains current because the digital transformation of schools depends strongly on the competencies of professionals who plan and mediate activities.

The OECD (2023) distinguishes a simple digital transition from digital transformation. In the former, traditional resources may simply be transferred to digital platforms. In the latter, technology contributes to changing processes, methodologies, and forms of organizing teaching. This distinction is important to avoid the so-called “screen effect”: a conventional lecture projected on a computer remains essentially a lecture.

Teacher education should therefore include at least four dimensions. The first is technical, related to how resources function. The second is pedagogical, involving planning, active methodologies, and assessment. The third is disciplinary, related to the nature of chemical knowledge and appropriate representations. The fourth is ethical and critical, involving privacy, copyright, security, accessibility, information reliability, and the social impacts of technology.

UNESCO (2024) proposes specific competencies for teachers in the era of artificial intelligence, organized into dimensions such as a human-centered mindset, AI ethics, foundations and applications, pedagogy, and professional development. Although the original project was developed before the expansion of generative AI, its teacher-training principles can be updated to address this new reality.

3.6. Artificial Intelligence And The New Landscape Of Learning Objects

Generative artificial intelligence has introduced an important change in the debate on educational technologies. Tools capable of producing texts, explanations, questions, images, and code have become available to students and teachers. In Chemistry teaching, these tools can support the creation of problem situations, study guides, review questions, and different versions of an activity. They can also assist teachers in the initial preparation of materials.

However, the use of artificial intelligence requires a critical stance. Generative systems can produce plausible but incorrect answers, fabricate references, misinterpret concepts, or provide incomplete explanations. Therefore, their use should not transfer the intellectual responsibility of the teacher or student to the tool. UNESCO recommends a human-centered approach, with attention to data protection, age appropriateness, safety, and pedagogical validation (Miao; Holmes, 2023).

In Chemistry teaching, an interesting strategy is to transform an error produced by AI into a learning object. The teacher can present students with an answer generated by a tool and ask them to verify the chemical equation, units, reasoning logic, conceptual coherence, and sources used. In this model, technology ceases to be merely an answer provider and becomes an element for developing critical thinking and scientific literacy.

Recent research already discusses the use of AI in Chemistry teaching. Berber et al. (2025) analyzed applications of artificial intelligence in chemical research and their implications for teaching,

highlighting the need to prepare teachers to understand the possibilities and limitations of the technology. Ruff (2024) investigated the use of ChatGPT in writing and assessment activities across the Chemistry curriculum, while Fernández (2024) discussed the use of the tool as an assistant for designing and grading assessments. These studies show that AI has already moved beyond the status of a future trend and has become part of the contemporary pedagogical debate.

Thus, an update to the extension project could include specific workshops on artificial intelligence, not simply to teach how to “use ChatGPT,” but to discuss validation criteria, prompt design, comparison of responses, error identification, authorship, references, and ethics. This approach preserves teacher autonomy and turns AI into another resource within a broad set of educational strategies.

3.7. Digital Inclusion, Accessibility, And Equity

The discussion of ICTs needs to consider existing inequalities among students and schools. A resource that works perfectly in a laboratory with up-to-date computers and high-speed internet may be unfeasible in a school with few devices, an unstable connection, or students who rely exclusively on mobile phones. Therefore, the selection of learning objects needs to incorporate equity criteria.

The National Digital Education Policy establishes digital inclusion as one of its structuring axes and gives priority to more vulnerable populations (BRASIL, 2023a). The National Strategy for Connected Schools also explicitly seeks equity of opportunities for access to digital technologies (BRASIL, 2023b). These policies reinforce that

the discussion of learning objects cannot be separated from the material conditions required for their use.

In practice, this means prioritizing, whenever possible, lightweight, free, or low-cost resources compatible with different devices and offering access alternatives. It is also important to check whether the material has legible text, adequate contrast, captions when videos are used, descriptions of relevant elements, and understandable navigation. Accessibility should not be treated as a later addition, but as a quality criterion from the selection stage.

UNESCO (2023) itself warns that the benefits of technology are not distributed uniformly. Adopting equipment, platforms, or applications without considering inequalities may widen existing differences. Therefore, an ICT pedagogical policy needs to combine innovation with inclusion.

3.8. Criteria For Selecting Learning Objects In Chemistry

Based on the project experience and current literature, we propose expanding the criteria originally used by the team. The first is scientific accuracy: concepts, equations, models, and representations should be consistent with chemical knowledge and appropriate to the educational level. The second is instructional clarity: students should understand what to do, why to do it, and how to interpret the results.

The third criterion is meaningful interactivity. Not every animated resource is interactive in the pedagogical sense. A learning object is more relevant when it allows students to formulate hypotheses, change conditions, compare results, receive feedback, or construct an explanation. The fourth criterion is chemical representation: the

resource should help establish relationships among macroscopic, submicroscopic, and symbolic levels, avoiding representations that merely add visual effects without conceptual function.

The fifth criterion is accessibility and inclusion. Compatibility with available devices, offline use, file size, readability, and accessibility features should be verified. The sixth is reliability and updating. Broken links, abandoned software, and content without clear authorship can compromise the activity. The seventh is data protection and privacy, especially when the resource requires registration or collects student information.

Finally, curricular alignment should be considered. Teachers need to identify exactly which skill or concept will be addressed and at what point the resource will be introduced. A good learning object used at the wrong time may produce results below expectations. Selection should therefore begin with the pedagogical objective and only then choose the technology.

3.9. Instructional Strategies For Integrating ICTs Into Chemistry Classes

Learning objects can be incorporated at different moments of a lesson. At the beginning, a short video, animation, or problem situation can be used to elicit prior knowledge and generate questions. During development, simulators can enable guided inquiry, while molecular models can support the interpretation of structures. At the end, students can use the same resource to test hypotheses, produce an explanation, or review concepts.

A particularly suitable strategy is inquiry-based learning. The teacher presents a question, for example: “How does temperature affect the

rate of a reaction?" Students use a simulator to change the temperature, keep other variables constant, record the results, and formulate a conclusion. In this case, technology is not the objective of the lesson; it is the means that makes it possible to experiment with a relationship quickly and in a controlled manner.

Another possibility is teaching through multiple representations. The teacher can ask students to observe an experimental phenomenon, represent the particles involved, write the corresponding equation, and interpret a graph. A digital object may facilitate one of these stages, but learning occurs mainly through their articulation. This approach is particularly relevant to topics such as solutions, equilibrium, kinetics, electrochemistry, bonding, and molecular structure.

ICTs can also be used in formative assessment. Digital questionnaires, open-ended responses, simulations, and explanation tasks make it possible to identify difficulties before a final assessment. Teachers can analyze errors to reorganize the lesson. When the activity involves artificial intelligence, assessment can include critical comparison of responses produced by different sources, valuing the process of verification and argumentation.

The experience of the workshops conducted in the project also shows that collaboration among teachers is important. Instead of each teacher searching for resources on the internet alone, a school can build a small internal catalog of evaluated objects, classified by content, grade level, resource type, technical requirements, and pedagogical possibilities. This procedure reduces search time and encourages the sharing of experiences.

3.10. Limitations And Precautions In The Use Of Technologies

Despite the possibilities presented, it is necessary to avoid an idealized view of ICTs. UNESCO (2023) emphasizes that evidence regarding educational impact is heterogeneous and that not every technology produces learning gains. In addition, implementation and maintenance costs, dependence on connectivity, insufficient training, and technological obsolescence can compromise educational projects.

In Chemistry teaching, there is also a specific limitation: a simulation represents a model and not the phenomenon itself. A student may observe colored particles moving on the screen and interpret the image as a literal photograph of matter. Therefore, it is essential to discuss with students that scientific models are representations constructed to explain certain aspects of reality. Teachers should make explicit what the simulation represents and also what it does not represent.

Another concern involves excessive stimulation. Animations, sounds, movement, and interactive elements may increase attention, but they can also overload students. Design should be subordinate to content. Visually sophisticated resources are not necessarily pedagogically better.

It is also necessary to preserve spaces for human interaction. Technology does not eliminate the importance of conversation, collaborative work, experimentation, writing, argumentation, and the teacher-student relationship. The most productive digital transformation is one that expands these experiences rather than attempting to replace them.

Finally, the use of digital resources must respect principles of ethics, safety, and responsibility. In the case of minors, data protection deserves special attention. In the case of artificial intelligence, transparent rules for use, authorship, citation, and assessment need to be established. These dimensions should be part of scientific and civic education.

3.11. Synthesis Of Results And Implications For The Project

The original experience identified three central contributions. The first was to bring scholarship students and teachers closer to a broad set of digital objects. The second was to demonstrate that material selection requires quality criteria and cannot depend only on appearance or ease of access. The third was to provide teacher education and encourage continued use of digital resources in other areas of knowledge.

With the literature update, these contributions can be reinterpreted in a broader scenario. Virtual learning objects remain relevant, but they are now part of an ecosystem that includes advanced simulations, augmented reality, virtual reality, educational platforms, and artificial intelligence. The main implication is that teachers need to develop a digital curation approach: locating, testing, evaluating, adapting, and contextualizing resources.

Another implication is the need to assess not only user satisfaction but also learning. Positive acceptance of a tool is important, but it is not sufficient to demonstrate pedagogical effectiveness. Future projects could compare performance before and after interventions, analyze student work, observe conceptual difficulties, and monitor resource use over time.

Thus, a continuation of the project could establish a local or institutional repository of evaluated learning objects, accompanied by pedagogical records. Each record could present content, objective, target audience, duration, technical requirements, possibility of offline use, level of interactivity, concepts involved, limitations, accessibility, and a suggested activity. This organization would transform the one-time search experience into a permanent professional development strategy.

4. CONCLUSIONS

The development of the project showed that ICTs and virtual learning objects can contribute to making Chemistry teaching more dynamic, visual, and interactive. The team's research found a wide variety of digital materials, but it also revealed quality problems, such as spelling errors, handling difficulties, and presentation inadequacies. This result reinforces the need for curation and evaluation before resources are used.

The most recent literature broadens this discussion by demonstrating the potential of simulations, augmented reality, virtual reality, and artificial intelligence to support Chemistry learning. However, studies also indicate that technology is more likely to contribute when it is articulated with pedagogical foundations, clear objectives, and teacher mediation. Therefore, it is not the tool itself that produces learning, but the way it is integrated into the educational process.

Teacher education remains a central element. Teachers need to know not only how resources function, but also their didactic possibilities, limitations, ethical implications, and suitability for the

school context. In the current scenario, this training should include digital literacy and, progressively, competencies for the critical use of artificial intelligence.

It is concluded that learning objects can play a relevant role in basic education, especially in Chemistry teaching, provided that they are used in a planned, inclusive, and critical manner. The proposal initiated by the extension project can be strengthened through the creation of systematic evaluation criteria, continuing teacher education, and collaborative construction of collections of digital resources. In this way, ICTs cease to be merely technological tools and become part of a pedagogical proposal aimed at constructing meaningful scientific knowledge.

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