Educación Química

Development, implementation, and evaluation of the virtual platform *Quimieduca* as a didactic strategy for the teaching of Chemistry in high school

Desarrollo, implementación y evaluación de la plataforma virtual Quimieduca como estrategia didáctica para la enseñanza de la Química en la escuela secundaria

Luis Diego Quesada-Soto[1], Wendy Villalobos-González[2], Rodolfo Hernández-Chaverri[3], Eduard Rios-Badilla[4]

Resumen

La evolución de los procesos de enseñanza-aprendizaje y las tecnologías ha impulsado el uso de herramientas informáticas para apoyar la educación. Su uso en la enseñanza de las ciencias promueve el desarrollo de habilidades científicas y tecnológicas. En el presente trabajo de investigación, se diseñó, implementó y evaluó una plataforma virtual llamada ***Quimieduca***, con recursos y actividades didácticas como estrategia de enseñanza alternativa para la enseñanza secundaria de Química en Costa Rica. Se realizó un diagnóstico inicial para determinar la necesidad y viabilidad de implementar la plataforma. Se seleccionaron cuatro temas clave del Programa de Química del Ministerio de Educación Pública para desarrollar los recursos y actividades didácticas en la plataforma. Se diseñó y programó utilizando la plataforma virtual Edmodo. La plataforma se implementó con estudiantes de décimo año del Colegio Gravilias durante el año escolar 2022. Dos clases (10-3 y 10-4) utilizaron la plataforma ***Quimieduca***, mientras que las otras dos clases (10-1 y 10-2) formaron el grupo de control sin acceso a la herramienta. La efectividad de ***Quimieduca*** se evaluó tanto desde la perspectiva de los profesores como a través de los indicadores de logros académicos de los estudiantes. Los profesores calificaron positivamente la plataforma en términos de su forma, contenido y aspectos de diseño. Además, los resultados demostraron que el grupo de estudiantes que utilizó la plataforma obtuvo índices de rendimiento más altos, sugiriendo que el uso de la plataforma facilitó un avance más significativo en el aprendizaje de los indicadores evaluados.

Palabras clave

Educación, Plataforma, Estrategia, Aprendizaje, Virtualidad.

Abstract

The evolution of teaching-learning processes and technologies has driven the use of computer tools to support education. Their use in science teaching promotes the development of scientific and technological skills. In the present research work, a virtual platform called ***Quimieduca*** was designed, implemented, and evaluated, with resources and didactic activities as an alternative teaching strategy for the secondary school teaching of Chemistry in Costa Rica. An initial diagnosis was carried out to determine the need and feasibility of implementing the platform. Four key topics from the Chemistry Program of the Ministry of Public Education were selected to develop the resources and didactic activities on the platform. It was designed and programmed using the Edmodo virtual platform. The platform was implemented with tenth-year students from Colegio Gravilias during the 2022 school year. Two classes (10-3 and 10-4) utilized the ***Quimieduca*** platform, while the other two classes (10-1 and 10-2) formed the control group without access to the tool. The effectiveness of ***Quimieduca*** was evaluated both from the perspective of teachers and through the indicators of students' academic achievements. Teachers rated the platform positively in terms of its form, substance, and design aspects. Furthermore, the results demonstrated that the group of students who used the platform obtained higher performance indices, suggesting that the use of the platform facilitated a more significant advancement in the learning of the assessed indicators.

Keywords

Education, Platform, Strategy, Learning, Virtuality.

[1] Liceo de Santa Ana. Ministerio de Educación Pública.
[2] Escuela de Ciencias Exactas y Naturales, Universidad Estatal a Distancia, Costa Rica.
[3] Unidad de Investigación Bioenergética y Ambiental, Universidad Estatal a Distancia. Costa Rica.
[4] Escuela de Ciencias Exactas y Naturales, Universidad Estatal a Distancia, Costa Rica.

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Introduction

Chemistry is a discipline that has historically been taught masterfully, with the student often functioning solely as a receiver of information. However, due to the curricular transformations of the last decade, there is a desire for students to assume a more active and leading role in their education (MEP, 2017). This educational approach aims to encourage students to engage proactively in various mediated activities and utilize resources proposed by teachers to construct their learning (Pérez, 2021).

In line with the approach, teachers are tasked with developing effective didactic strategies, encompassing techniques, activities, and resources designed to foster learning skills in students (Coria et al., 2021). Within the realm of Chemistry education, the ultimate objective is to cultivate scientific thinking, which, as highlighted by Mendoza and Loor (2022), involves a combination of cognitive and socio-emotional components. Contemporary didactic strategies for teaching Chemistry encompass a spectrum of resources such as games, videos, interactive presentations, simulators, applications, virtual reality, and experiments, among other tools (Téllez, 2016; Simonelli, 2019; Castillo et al., 2016).

These strategies can be implemented using Information and Communication Technologies (ICT) and Technology-Assisted Learning and Knowledge Technologies (TAC). The integration of ICT and TAC in educational contexts is framed within the constructivist model. In the specific context of Chemistry education, the use of ICT and TAC offers numerous benefits (Table 1), contributing to the development of scientific skills such as critical thinking, research, data analysis, and problem-solving (Rivas and Sobarzo, 2018).

Table 1. Advantages and disadvantages of using didactic resources through ICT and TAC for teachers and students. Source: Own elaboration adapted from Montoya et al. (2019), Zambrano (2018), Castillo (2020), Martínez et al. (2018), Plaza (2018).

Benefits for Teachers	Advantages for Students
1. Shift from traditional teaching practices. 2. Creation of curricular content through ICT and TAC. 3. Assistance in class dynamization. 4. Tool to spark students' interest. 5. Aid in explaining abstract or complex theoretical concepts. 6. Facilitation of utilizing resources beyond the classroom, enhancing students' asynchronous work time. 7. Enhancement of technological skills	1. Encourages self-directed learning. 2. Fosters student engagement. 3. Facilitates collaborative teamwork among students. 4. Promotes the acquisition of new knowledge through diverse educational technologies. 5. Enhances the quality of the student's teaching-learning process. 6. Advances in technological skills. 7. Stimulates critical thinking. 8. Enables students to visualize theoretical phenomena through representations, simulations, videos, etc. 9. Sparks learners' interest in the learning process.
Disadvantages for Teachers.	**Disadvantages for Students.**
1. Limitation of the use of technological resources, as they are considered distractions for students. 2. Limited training in the use and application of ICT and CT in teaching and learning processes. 3. Limited access to the internet and technological equipment in educational centers.	1. It could be considered a distraction for students. 2. Cybersecurity: potential exposure of students' personal information, including addresses, ages, and other private data. 3. Dependency on and excessive use of specific tools such as cell phones, computers, and tablets, which have access to resources.

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Educational platforms are examples of TAC. They are online systems or software designed to facilitate the teaching-learning process, as they allow teachers to: 1) create and manage educational content, 2) interact with students, and 3) conduct learning evaluation processes. These tools are known as Learning Management Systems or LMS (Rama et al., 2018; Vargas and Villalobos, 2018). One advantage of using virtual classrooms is having predisposed and organized didactic resources, which can be implemented outside (virtual education) or inside (face-to-face education) the classroom (Cascante et al., 2020; de Freitas et al., 2021).

There is a variety of open educational virtual platforms and other paid platforms, each with different structures and functionalities. Virtual platforms offer the necessary technological support to create learning environments with facilitating and innovative elements for the teaching and learning process in the educational field. Thus, they bring about significant technological and pedagogical changes (De Pablos et al., 2019)

Various national and international experiences have underscored the significance of using virtual platforms and technological resources in scientific subjects to enhance the development of skills and competencies. This, in turn, contributes to improved cognitive performance (Fernández et al., 2016; Godoy and Cedeño, 2019; Lozano Lucia & Sánchez López de Andujar, 2021; Ruiz, 2020). These tools hold relevance in institutions lacking physical laboratory space, enabling virtual experimentation experiences (Brovelli et al., 2018). Additionally, research has shown that the utilization of virtual platforms positively impacts student motivation (Contreras et al., 2020).

In this research endeavor, an educational platform named *Quimieduca* was designed within the Edmodo application as a didactic strategy, aimed at enhancing the teaching of Chemistry in secondary school. This platform was implemented during the 2022 academic year in two tenth-grade classes at Gravilias School, located in San José, Costa Rica. The project assessed the platform's effectiveness from the teacher's perspective and through the academic achievement indicators of the students.

Methodology

Quantitative and qualitative data are used in this research, therefore, according to Hernández-Sampieri and Mendoza-Torres (2018) it corresponds to a mixed type of research and quasi-experimental design, because the impact of an intervention or treatment (use of the *Quimieduca* platform) on a group of subjects was evaluated.

The hypothesis in this research consists of:

H_0: the development and use of *Quimieduca* will improve the academic performance in the subject of Chemistry of students who make use of the platform, compared to those who do not use it.

H_1: the development and use of *Quimieduca* will not improve the academic performance in the subject of Chemistry of students who use the platform, compared to those who do not use it.

Strategy

"An educational strategy was formulated, with the central focus being the creation of the educational platform called *Quimieduca*." The research project encompassed the following

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stages: a) diagnosing the extent and limitations of ICT and TAC usage, b) developing the virtual educational platform, c) validating the platform with teachers, d) implementing the platform, and e) evaluating the effectiveness of *Quimieduca* using performance indicators. The application of this didactic strategy was specifically targeted at the subject of Chemistry, taught by the science instructor at Colegio Gravilias in Desamparados, Costa Rica, during the 2022 academic year.

Study population

The study population comprises 95 tenth-grade students, organized into four groups (sections): 10-1 (18 students), 10-2 (27 students), 10-3 (26 students), and 10-4 (24 students). Of these students, 51 are male and 44 are female. From these sections, sections 10-3 and 10-4 were selected for the implementation of the educational strategy using the *Quimieduca* virtual platform. Meanwhile, sections 10-1 and 10-2 served as the control group and did not use the platform. The selection of participants was based on access to the tenth level sections, specifically 10-3 and 10-4, which allowed for the application of the *Quimieduca*.

In addition to the students, the study involved 5 teachers from the Science Department of the institution. These teachers, recognized as experts in the field, participated in the study and were responsible for validating the *Quimieduca* virtual platform during the implementation process.

Stages of the investigation

Figure 1 illustrates the scheme that guided the design, implementation, and evaluation of the *Quimieduca* educational platform.

During the initial stage, a survey was developed, validated, and administered to the 95 tenth-grade students of Colegio Gravilias during the 2022 academic year. The survey focused on the following areas:

a. Types and distribution of available technological devices for students.

b. Amount of time spent using these devices.

c. Quality of internet connectivity.

d. Perception of the didactic and technological resources employed by the teaching staff at Gravilias School.

The analysis of these aspects was crucial to ascertain the necessity and viability of implementing the virtual platform *Quimieduca* as an appropriate didactic strategy.

In the second phase of the study, four specific topics from the Chemistry Program of the Ministry of Public Education (MEP) were selected for the development of resources and activities on the educational platform. Subsequently, the necessary graphic materials were created, and the platform was programmed and structured. The platform was designed utilizing the Edmodo app to provide an engaging and organized user experience. The chosen contents from the Chemistry program corresponding to the tenth level of the MEP, as well as the performance indicators employed in this research, are detailed in Table 2.

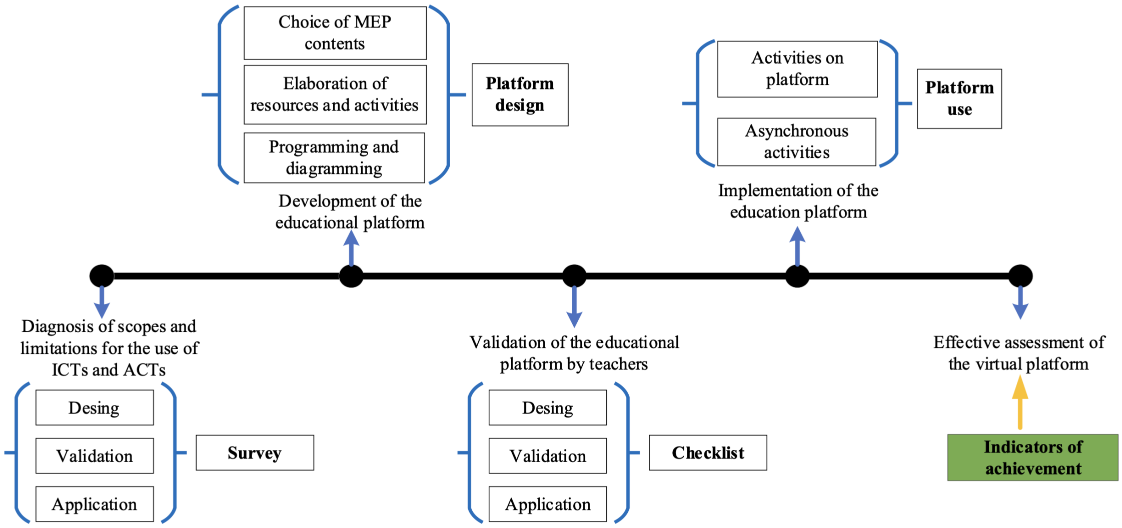

Figure 1. Stages for the design, implementation, and evaluation of the *Quimieduca* virtual platform.

After preparing the platform, a validation process was conducted using a checklist. This validation was carried out by a group of Science Education teachers at Gravilias School. Aspects related to the form, design, and content of the platform were evaluated. Subsequently, in the fourth phase, the educational platform was implemented with students from sections 10-3 and 10-4. The other two sections (10-1 and 10-2) of the tenth grade did not utilize the platform and served as the control group. Finally, in the fifth stage, the effectiveness of the educational strategy was evaluated based on the achievement indicators obtained by the students. Performance levels were compared between the sections that utilized the *Quimieduca* platform and those that did not.

Information Management and Analysis

The diagnostic survey was crafted using Microsoft Word® and administered in person to students. Meanwhile, platform validation employed a checklist created in Forms Office 365®, which was virtually distributed to teachers. In both cases, participants were assured that the data gathered would be solely used for research purposes and treated with the utmost confidentiality, adhering to ethical research principles.

For processing and analysis of information, databases were formulated using Microsoft Excel sheets®. Graphics were generated using EdrawMax® software.

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Theme	Contents	Indicators
Classification of matter and methods of separation.	• Pure substances and mixtures (homogeneous and heterogeneous). • Colloids. • Filtration, evaporation, distillation, chromatography, decantation, magnetization, and sieving.	1. It relates the possible classifications of the elements that are presented in the matter, especially in daily life and existing resources in favor of human beings and nature. 2. It identifies the materials that make up matter in pure substances and mixtures, through everyday representations and in existing resources in favor of human beings and nature.
Periodic table	• Recognition of elements. • Organization of the periodic table • Trace elements and microelements in food consumption.	3. Identify the symbology of chemical elements, their names, and general aspects of everyday life. 4. It classifies metals, nonmetals, metalloids, trace elements, and heavy metals, their location, and characteristics within the table.
The atom and subatomic particles	• Recognition of atomic and mass numbers. • Calculation of subatomic particles. • Calculation of average atomic mass. • Location of chemical elements according to their family and period from their atomic number.	5. It interrelates the basic notions and theory of the atom, subatomic particles, atomic number, mass number, isotopes, and average atomic mass in data, facts, or actions in different contexts. 6. It describes the causes and effects that give rise to the basic notions and theory of the atom. 7. It establishes the known information through graphical processes of the organization of atoms into levels, groups, families, and layers.
Electronic configurations and periodic properties.	• Developed and abbreviated configuration of chemical elements. • Valence electrons and differentiating electrons. • Electronic anomalies. • Electron affinity, metallic character, atomic radius, electronegativity, and ionic radius.	8. Describes how resources or materials are used to solve a problem. 9. Determines the importance of the positive or negative effect of periodic properties on our actions towards the matter around us

Table 2. Topics, contents, and indicators of the tenth-level Chemistry program.

Results and discussion

Diagnosis

The diagnostic process showed that 100% of the respondents (95 students) have mobile devices (cell phones), it is observed that 65% (62 students) have a SMART screen, and 40% (38 students) have personal computers (see Figure 2). It is relevant to note that a significant fact is that 80% of students have 2 or more devices. This figure highlights the great technological availability among the students surveyed, which provides the opportunity to integrate technological didactic resources in the planning of the usual classes.

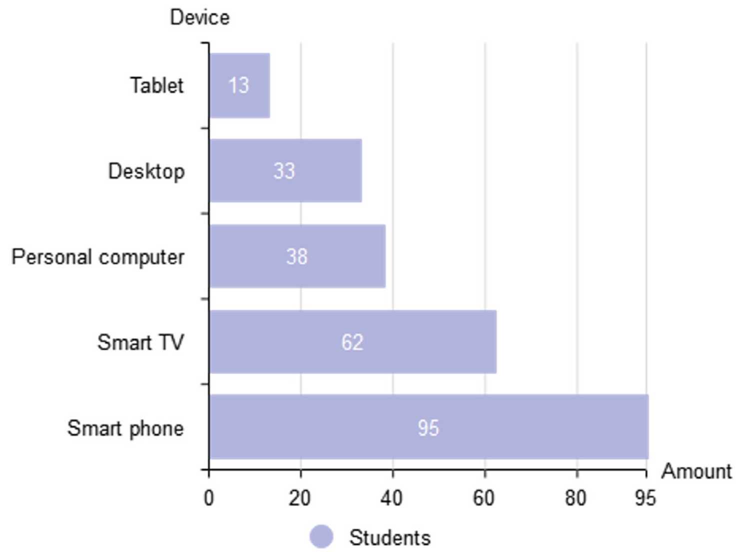
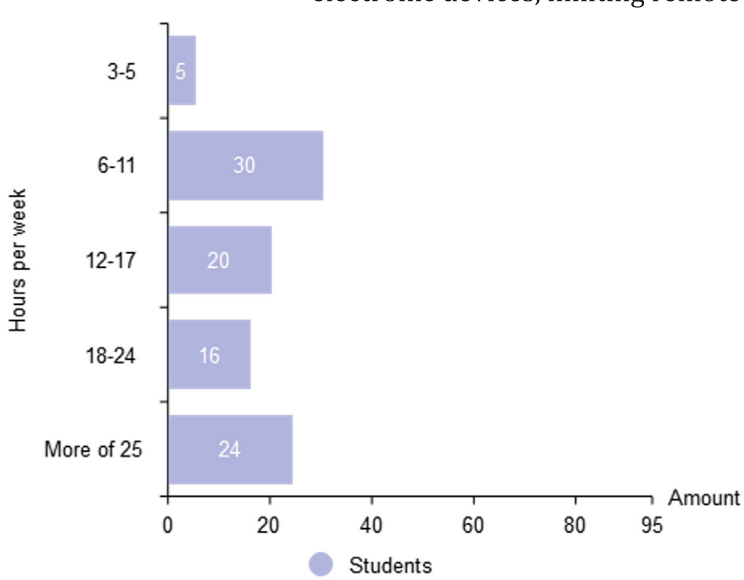


FIGURE 2. Types and distribution of ICT devices among tenth-year students of Colegio Gravilias.

Regarding internet connectivity, 93% (88 students) indicated that they have internet access and 8% (7 students) do not have internet access. Access is a major limitation according to the Eighth State of Education Report 2021 (CONARE – PEN, 2021), The MEP has identified numerous students without internet access or with difficulties obtaining electronic devices, limiting remote education during the pandemic.

FIGURE 3. Hours of Use of Technological Devices by Students.



63.2% of students' report using technological devices for more than 12 hours, while 25.3% use such devices for 25 hours or more per week. These data are relevant considering the research of Orben et al. (2020), cited by Celis et al. (2022), which suggests that excessive use of technological tools can negatively affect students, causing isolation behaviors and feelings of loneliness.

Development of the Quimieduca Platform

Once the feasibility of using a virtual platform with the tenth-level students of the Gravilias School was determined from the diagnosis, resources, and didactic activities were developed to be included in the virtual platform. Table 3 shows the resources and activities developed for each selected theme of the MEP Agenda.

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Theme	Teaching resources	Didactic activities	Self-assessment activities.
Classification of matter, methods of separation of mixtures	1. Presentation 2. Video on classification of matter.	1. Home Laboratory. 2. Game "One". Classification of Matter. 3. Game type of mixtures. 4. Game recognition of mixtures. 5. Simulator Interaction of mixtures.	Questionnaire
Learning about the Periodic Table.	1. Presentation. 2. Video 1: Organization of the periodic table. 3. Video 2: Part II. Organization of the periodic table. 4. Interactive Periodic Table.	1. Stop the game of the periodic table. 2. Word Search activity. 3. Periodic table game. 4. Interactive activity of the periodic table. 5. Video game of the periodic table.	Questionnaire
The atom.	1. Presentation. 2. Video 1. Explanation of particles. 3. Video 2. Explanation of calculation of atomic masses.	1. Bingo 2. Simulation builds an atom. 3. Isotope simulation. 4. I play The Atom.	Questionnaire
Electronic configurations – Lewis and Periodic properties.	1. Presentation. 2. Video on explanation of periodic properties.	1. Set electronic settings. 2. Word soup periodic properties. 3. Electronic configurations' simulator. 4. Game periodic properties.	Questionnaire

Table 3. Didactic and technological resources are available on the virtual learning platform.

The *Quimieduca* platform was designed using the Edmodo application to provide students with an engaging experience. To achieve this, special attention was paid to the name and graphic design of the platform. In Figure 4, the general structure of *Quimieduca* can be observed. The platform is organized in tabs, starting with a home tab that gives a warm welcome to students and shows them the way the platform has been organized. In addition, there are four additional tabs dedicated to the selected topics of the MEP Chemistry

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program, which are detailed in Tables 2 and 3. This design seeks to facilitate navigation and access to information, allowing learners to make the most of the resources available for their learning.

Figure 4. Visualization and general organization of the Educational Platform *Quimieduca*.

In addition, each topic (Figure 5) is organized in a clear and structured way with the following sections:

a) Banner with a title for each topic, which provides an overview of the content to be discussed.

b) Folder of didactic resources, where various educational materials are stored and arranged that complement the study of each topic.

c) Didactic activities, carefully designed to encourage student participation and active learning.

d) Self-evaluation activities, which consist of questionnaires that evaluate the contents studied. These questionnaires are based on the topics, contents, and indicators detailed in Table 1 of the methodological framework.

The self-assessment activities consisted of questionnaires designed to evaluate the students’ understanding and assimilation of the contents studied. These questionnaires are based on the topics, contents and indicators detailed in Table 1 of the methodological framework. Their main objective was to measure the students’ level of understanding and how the platform could help with that assimilation, to obtain valuable information to improve the learning process.

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FIGURE 5. Visualization and organization of each topic in the educational platform *Quimieduca*.

Validation of the Quimieduca platform by Teachers

As part of this project, a validation of the *Quimieduca* educational platform was carried out. This phase was carried out by a group of 5 teachers specialized in Science Education. In this validation process, criteria were considered to ensure the effectiveness and quality of the platform (Figure 6).

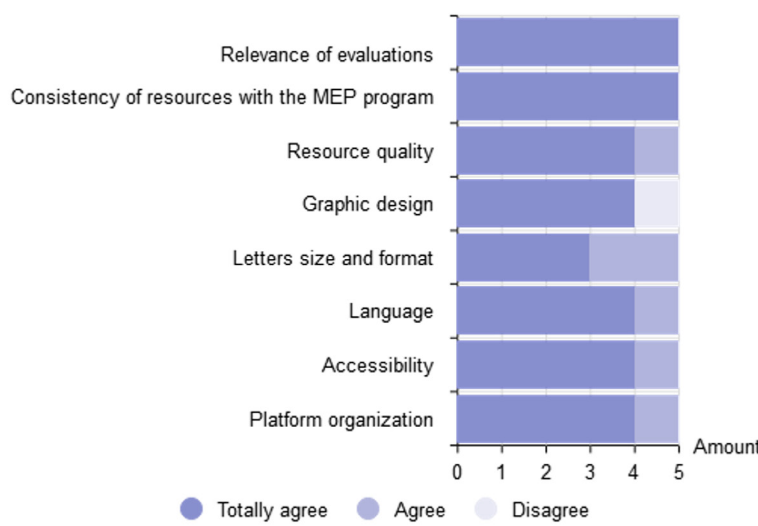

FIGURE 6. Validation of the criteria and indicators of the platform by teachers.

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According to the criteria of the form of the platform, the evaluation was favorable by the teachers who evaluated aspects such as the clarity of the language used in the contents, the accessibility of the resources, and the organization and general structure of the platform. The teachers indicated that the language used is understandable and suitable for the student audience and that the organization is adequate and allows a fluid user experience.

For the design criteria, special attention was paid to details such as the format of the letters, and the sizes and colors used in the interface, to achieve an attractive and user-friendly visual presentation. In this area, one of the teachers disagreed with the format of the platform, indicating that the colors used were not attractive.

On the other hand, the underlying criteria focused on attention to the quality of the educational resources offered on the platform and it was verified that these resources were relevant and aligned with the MEP program. Teachers rated the underlying criteria positively, with agree and strongly agree.

Implementation of the Quimieduca Platform

The implementation of the *Quimieduca* platform took place during the 2022 school year in sessions 10-3 and 10-4, with an approach that combined work inside the classroom and asynchronous activities outside it. The activities were planned by the teacher as an integral part of their curricular approach, following the guidelines established by the MEP. The teaching-learning process was structured in four stages: focus, exploration, contrast, and application, all integrated with the activities and resources available on the educational platform.

Within the classroom, teachers used *Quimieduca* to focus students' attention on specific topics, allowing them to explore the contents in an interactive and enriching way for their learning process. Then, the development of critical thinking and understanding was encouraged through the contrast of concepts and the application of the knowledge acquired in various situations and self-assessment activities.

Outside the classroom, students had the opportunity to continue their learning asynchronously, accessing the activities and resources prepared on the platform, which allowed them to reinforce the contents and deepen their knowledge.

Evaluation of the effectiveness of the platform

To evaluate the effectiveness of the platform, a comparison of the performance indicators was carried out between sections 10-1 and 10-2, which made up the control group (students who did not use the *Quimieduca* platform), and sections 10-3 and 10-4. Figure 7 shows the performance levels of these sections.

Based on the above, the following results were obtained:

- In sections 10-1 and 10-2, which included a total of 45 students, it was observed that, on average, 51% had an initial (low) level of performance, 29% obtained an intermediate level and 20% (9 students) achieved an advanced performance value.

- In contrast, in sections 10-3 and 10-4, made up of a total of 50 students, it was found that 22% showed an initial level of performance, 34% achieved an intermediate level and the advanced level of performance was reached by 44%.

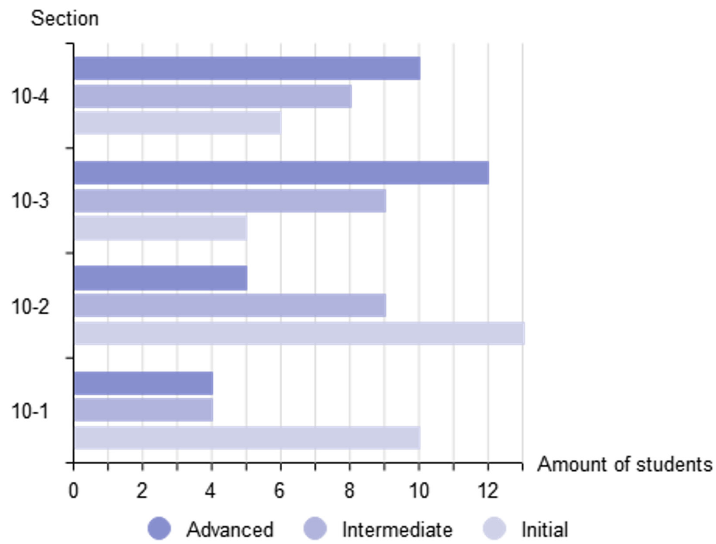

Figure 7. Indicators of performance levels, sections of the tenth year during the 2022 school year.

These results suggest that the sections that made use of the *Quimieduca* platform (10-3 and 10-4) had a higher percentage of students who achieved an advanced level of performance compared to the sections that did not use the platform (10-1 and 10-2). This could indicate that *Quimieduca* had a positive impact on student performance, contributing to higher academic performance (Figure 8) and an improvement in their learning skills. According to Mermoud et al. (2017), the use of ICT promotes greater learning by promoting argumentation and other skills that are enhanced through technology.

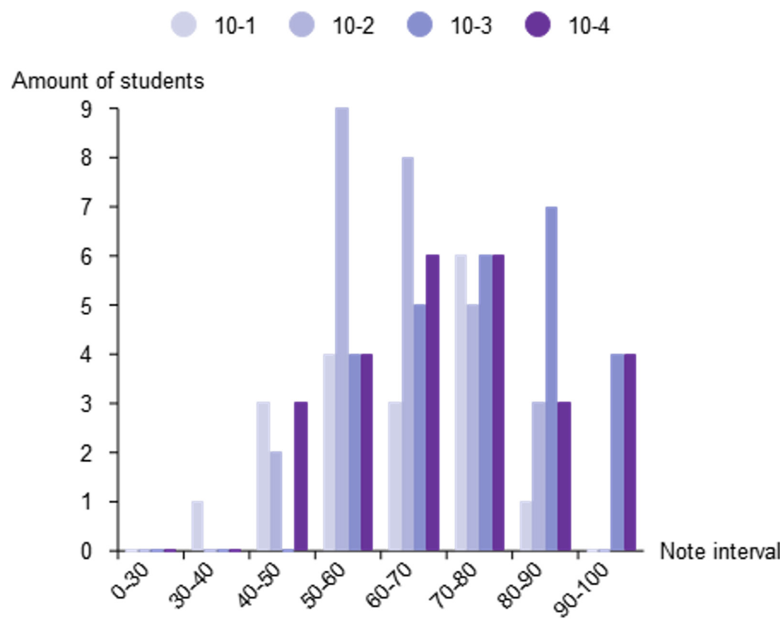

Figure 8. Average of final grades per section in the subject of Chemistry during the 2022 school year.

In the figure above, the academic performance of the tenth-year students of the Gravilias school is presented and classified by sections. It is observed that sections 10-1 and 10-2 have a higher proportion of students with lower grades, ranging between 30.00 and 60.00. In contrast, sections 10-3 and 10-4 stand out for having a higher number of students with higher grades, ranging from 60.00 to 100.00. Overall, students in sections

10-3 and 10-4 demonstrated a higher level of participation during chemistry classes, which translated into an improvement in their academic results. This information suggests that the level of involvement and participation in the learning process positively influenced the academic performance of these sections.

It is important to indicate that the students of these sections (10-3 and 10-4) had greater contact with the contents when using the *Quimieduca* platform in their homes to complete the pending activities, which allowed them to dedicate more time to the study, compared to the control group. However, it is also an indication of how the implementation of *Quimieduca* can complement and enrich the educational process; by giving students the ability to access additional resources and activities from home. Therefore, the platform offers a valuable opportunity to reinforce and strengthen the knowledge acquired in the classroom.

Conclusions

The collection and analysis of the data obtained in the diagnosis were of importance to evaluate the feasibility of implementing the virtual platform as a didactic strategy in the teaching of Chemistry in secondary school at the Gravilias school. Through this process, it was determined that students have technological devices (ICT) and have access to connectivity, which enables the application of the platform both inside and outside the classroom.

The use of the educational platform *Quimieduca* in sessions 10-3 and 10-4 was a factor that may have influenced the learning process of the students. However, it is important to consider that other teaching factors and methodologies may also have contributed to the results obtained in student learning in the 2022 school year.

The use of extra time in asynchronous activities is an external factor, which may have contributed to the better results in sections 10-3 and 10-4, however, it is also an indication of how the implementation of *Quimieduca* can complement and enrich the educational process and enhance interest in activities outside the classroom.

Recommendations

Based on this experience, it is recommended that the MEP consider the acquisition of virtual payment platforms that offer greater potential to work on activities and teaching resources, synchronously and asynchronously. The use of an educational platform as a complement to teaching methodologies has numerous benefits for the teaching-learning process such as cost savings in printed materials, increased student motivation, and greater interaction between teachers and students, facilitating communication and feedback in real-time.

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