REVISTA CÁTEDRA

Interactive environments for learning biochemistry: a pedagogical experience with TopWorksheets in higher education

Ambientes interactivos para aprender bioquímica: una experiencia pedagógica con TopWorksheets en la educación superior

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Abstract

Currently, the use of interactive platforms allows students to independently acquire personalized learning. In this context, interactive worksheets managed on the TopWorksheets platform were applied to teach biochemistry to higher education students. Therefore, a quantitative study based on the positivist paradigm and a quasi-experimental operational design was conducted. The study involved 62 students, 35 in the experimental group (EG) and 32 in the control group (CG), who were enrolled in a Biochemistry course at an Ecuadorian university. Knowledge tests on organic biomolecules were administered before and after the study, along with a survey that collected experiences and anecdotes related to the activities using TopWorksheets. The results showed a significant difference between the mean scores after the intervention (5.50 ± 1.81 vs. 7.20 ± 2.23), with the difference being significant in both groups (t = 3.40; p = .01; Cohen's d = 0.83). Regarding the experience, 72% of the students indicated that the interactive worksheets were ideal for reinforcing biochemistry content and for improving participation (89%); and 89% were satisfied with the experience. It is concluded that the use of interactive worksheets as a teaching resource improved biochemistry learning in both the conceptual and attitudinal domains.

Keywords

Biochemistry, chemistry didactics, higher education, chemistry teaching, ICT (information and communication technologies)

Resumen

En la actualidad, el uso de plataformas interactivas permite que los estudiantes, de forma autónoma, adquieran un aprendizaje personalizado. En este sentido, se aplicaron fichas interactivas gestionadas en la plataforma TopWorksheets para aprender bioquímica en estudiantes de educación superior. Por ello, se realizó un estudio cuantitativo sustentado en el paradigma positivista y un diseño operativo cuasiexperimental; se trabajó con 62 estudiantes, 35 del grupo experimental (GE) y 32 del grupo control (GC) que cursaron la cátedra de Bioquímica de una universidad ecuatoriana. Se emplearon pruebas de conocimientos antes y después sobre biomoléculas orgánicas; además de una encuesta que recoge las experiencias y anécdotas de las actividades utilizando TopWorksheets. Los resultados constataron una diferencia significativa entre la media de calificaciones después de la intervención (5.50±1.81 vs. 7.20±2.23), siendo la diferencia significativa en ambos grupos (t = 3.40; p = .01; d de Cohen = 0.83). En cuanto a la experiencia, el 72% de los estudiantes indicaron que las fichas interactivas son ideales para reforzar los contenidos de bioquímica y para tener una mejor participación (89%); y un 89% están satisfechos con la experiencia. Se concluye que el uso de fichas interactivas como recurso didáctico mejoró el aprendizaje de bioquímica en cuanto al área conceptual y actitudinal.

Palabras clave

Bioquímica, didáctica de la química, educación superior, enseñanza de la química, TIC (tecnologías de la información y comunicación)

1. Introduction

Undeniably, digital technologies serve as a medium that transforms and contributes to the optimization of both teaching and learning across all educational levels. Higher education has been a privileged setting for integrating innovative tools with high motivational value for students, aiming to modify traditionalist approaches. In a training shift, science education faces the constant challenges of updating pedagogical strategies in response to the growing complexity of content and the diversity of student profiles. In scientific disciplines such as Chemistry, difficulties in assimilating topics are well-documented; this has driven the need to update the way content is addressed to guarantee quality professional training.

Addressing the use of Information and Communication Technologies (ICT) from an innovation perspective provides a means to reposition teachers based on their didactic knowledge. The significance of incorporating ICT into education lies in creating new learning scenarios; to this end, Del Padre et al. (2022) recommend that educators become familiar with such advancements and implement them in the classroom to render the learning process more appropriate, successful, and engaging (Del Padre et al., 2022, p. 1397). From a techno-educational standpoint, Vásquez and Jaramillo indicate that ICT offers ideal environments for the active construction of knowledge, as it enables interaction among students, access to diversified content, and the possibility of immediate feedback—factors that enhance deep learning (Vásquez & Jaramillo, 2025, p. 183).

The teaching of chemical sciences, particularly biochemistry, faces major challenges due to the complexity of concepts, the need for pedagogical methodologies to facilitate comprehension, low academic performance, and the large volume of content that must be memorized. These deficiencies have eroded the alignment between curricular objectives and learning achievements, thereby affecting the professional preparation of students. It is widely known that biochemistry is a complex science, as it studies the chemical composition of living beings, focusing on specific molecules—such as carbohydrates, proteins, lipids, nucleic acids, and vitamins that form cells and tissues—and how they interact and react with one another. Consequently, the language through which biochemistry is communicated requires dynamic and interactive didactic materials. As noted by Dreon, a student learns a concept when they are capable of endowing the presented material or information with meaning—that is, when they comprehend that material, where comprehension is equivalent to translating it into their own words (Dreon, 2023, p. 10).

The use of interactive platforms has consolidated as a pedagogical strategy that allows for the construction of dynamic, meaningful, and student-centered learning environments, fostering exploration and motivation—innovative criteria aligned with technological advancements. In fact, various studies support the effectiveness of digital interactivity in science learning. For instance, Terrado points out that gamification and interactivity increase student motivation and academic performance (Terrado, 2023, pp. 44-45). Furthermore, Chonillo demonstrated that platforms like Liveworksheets allow for the personalization of pedagogical strategies, adapting better to the communication of content and, consequently, favoring the comprehension of chemistry (Chonillo, 2024). For their part, Yustiqvar et al. highlight that the use of digital resources facilitates the visualization of phenomena, thereby improving the understanding of scientific topics through the use of simulations and interactive exercises (Yustiqvar et al., 2019). Similarly, Morgan et al., as well as Rodríguez and Marín, agree that the integration of educational technologies fosters collaborative and dynamic learning environments (Morgan et al., 2025; Rodríguez & Marín, 2019).

Within this framework, the present research focuses on determining the effect of the TopWorksheets platform by managing interactive worksheets to learn biochemistry among higher education students. From a comprehensive approach, the study seeks to provide empirical evidence by offering students pedagogical strategies that integrate interactive technologies to optimize biochemistry teaching, thereby strengthening cognitive and procedural competencies, as well as enhancing motivation and classroom participation.

Regarding the structure of this article, Section 2 (Literature Review) presents the concepts related to the study. Section 3 (Methodology) describes the methodology used to develop this research process, including the intervention proposal. Section 4 (Results and Discussion) shows the analysis and discussion of the findings. Finally, Section 5 establishes the conclusions based on the obtained results.

2. Literature review

2.1. Education in the digital age

Education in the digital era constitutes a process of reconfiguring pedagogical paradigms; it is not merely about incorporating electronic devices into the classroom, but rather about transforming the modes of production, circulation, and appropriation of knowledge. According to Reyero, digitalization has broken the boundaries of traditional teaching, giving rise to personalized and ubiquitous scenarios where learning occurs in both formal and non-formal environments (Reyero, 2019, p. 111). From the perspective of the Escuela Nueva (New School) movement, education must be conceived as a digital ecosystem that promotes connectivity, cooperation, and open access to knowledge. As clarified by Largo et al., digital education opens access to virtual libraries, laboratories, global collaboration platforms, and interactive learning spaces, thereby expanding students' formative horizons (Largo et al., 2022, pp. 281-282).

A proverb states that whoever "integrates the new, transforms the old"; this implies that incorporating strategies through technology redefines the way knowledge is constructed, given that ICT and active methodologies transcend traditional methods, generating more dynamic and meaningful learning environments. Thus, in alignment with UNESCO guidelines, educational practice is transformed into a flexible and adaptable ecosystem, capable of responding to societal challenges and shaping autonomous, competent students committed to their own learning. Therefore, education in the digital era is not a simple process of modernization, but rather a structural change that redefines the purposes, methods, and meanings of teaching (UNESCO, 2024).

2.2. Interactivity in teaching and learning

Interactivity is one of the pillars of educational renewal, as it fosters a dialogic process where students manipulate, explore, and generate knowledge from experiences (Córdova & Lino, 2024, p. 1032). Furthermore, it is defined as the exchange of communication and information between individuals. It is also a way for students to interact with content, develop ideas, and work more dynamically.

Consequently, interactive tools should not be understood as simply the presence of a technological medium, but rather as a pedagogical strategy that places the student at the center of the learning process. To this end, technological resources are a vehicle for knowledge construction, but the essential element is the didactic approach that guides them (Rodríguez-Basantes et al., 2023, pp. 194-195). Furthermore, it fosters the affective-motivational dimension, because the student, by being actively involved in digital and enriching content, develops a sense of agency and belonging to knowledge, generating a virtuous circle between motivation, curiosity and persistence in the task.

2.3. Didactic and pedagogical potential of interactive tools

The potential of interactive tools transcends their instrumental function. Chaves and De la Peña establish that they are part of pedagogical innovation, serving as platforms that integrate multiple languages—visual, symbolic, textual, and auditory—to address the diversity of learning styles present in the classroom. This multimodality strengthens content comprehension and reinforces long-term memory (Chaves & De la Peña, 2025, pp. 37–39). Pedagogically, they align with constructivist and sociocultural approaches, which conceive of learning as an active, situated, and mediated process, where knowledge is constructed through action, reflection, and interaction.

The multiple interactive platforms are not merely teaching resources, but devices that transform the very meaning of teaching and learning. Web 2.0 offers a variety of interactive tools (see Figure 1).).

Figure 1. Interactive tools for the development of learning content

- *WordWall:* Create interactive activities and customizable educational games, such as crosswords, word searches, and quizzes, to reinforce learning dynamically.
- *Liveworksheets:* Transform traditional worksheets into interactive online exercises, allowing for digital responses, self-correction, and tracking of student progress.
- LearningApps: Create interactive micro-activities, such as puzzles, quizzes, and matching games, that can be easily integrated into face-to-face or virtual classes.
- Quizlet: Create flashcards, quizzes, and games to review concepts repetitively and collaboratively, ideal for memorization and self-assessment.
- ExeLearning: Facilitates the creation of structured, multimedia educational content focused on e-learning, with resources such as text, images, and interactive links.
- ProProfs: Manage quizzes, surveys, exams, and online courses, with learning tracking and results analysis features for teachers.
- *Educandy*: Turn vocabulary or concepts into interactive games, such as crosswords or matching exercises, promoting fun and engaging learning.

- *Genially*: Create interactive and visual content, such as presentations, infographics, games, and videos, ideal for enriching teaching with multimedia resources.
- *Educaplay*: Create interactive activities, such as word searches, interactive maps, crosswords, and quizzes, that allow you to reinforce concepts in a fun way.

2.4. interactive tools: TopWorksheets for learning Chemistry

Web-based tools have proven to be strategic allies in overcoming the difficulties students face when learning chemistry. On a motivational level, they have succeeded in sparking interest and curiosity in students, who often perceive this science as excessively difficult. In this way, chemistry becomes a fertile ground for innovation, promoting meaningful learning and building a closer relationship between science, technology, and society.

Among the many available platforms, this study focused on TopWorksheets, a platform that allows users to manage interactive worksheets by creating exercises, questions, activities, and educational games. It integrates diverse multimedia resources, such as sounds, videos, links, images, and audio, as well as activities involving fill-in-the-blank, selection, matching, and multiple-choice questions. Together, its various functionalities foster a more dynamic, participatory, and enriching learning experience. According to Cañar et al. (2024), this platform facilitates the creation of engaging activities with automatic grading, reduces paper consumption by being online, and its free and easy-to-use nature makes it suitable for classroom use.

3. Methodology

In the development of this study, a quantitative approach was adopted, adhering to the positivist paradigm and a quasi-experimental pretest-posttest design with a control group (CG). This involved measuring the dependent variable (biochemistry learning). Subsequently, an intervention was implemented using interactive worksheets to assess its effectiveness in the experimental group (EG). The variable was then measured again, and the learning outcomes were compared between the two groups.

The population consisted of 67 students, distributed as 32 students in the CG and 35 students in the EG, from the 2024-1S academic period, enrolled in the Biochemistry course of the Bachelor's Degree in Chemistry and Biology Pedagogy at an Ecuadorian university. This allowed for a balanced comparative analysis between both groups; no sample was selected, as the research was conducted with the entire study population. To begin the investigation, a 10-question online knowledge quiz about carbohydrates, proteins, lipids and fats, nucleic acids, and vitamins was developed and administered via the Quizizz platform. The quiz covered items related to structure, characteristics, function, and food sources. These tests allowed, firstly, for diagnosing the students' level of knowledge at the start of the study and, subsequently, for evaluating the effect of the intervention. Furthermore, the modern McDonald omega coefficient was used to measure the reliability of the instruments (see Table 1.).

	McDonald's ω	N.º of elements	Interpretation
Survey	0.825	5	Good
Knowledge tests	0.801	2	Good

Table 1. Instrument reliability statistics

Regarding the intervention's development, five interactive worksheets were created and stored (see Figure 2). The worksheets were implemented in ten 60-minute classes over two months. Complementary activities related to the topic were also used (crosswords, word searches, fill-in-the-blank tests, and drawing and painting activities). At the end of each period, each activity was evaluated (post-test) to compare its impact on students' academic performance. Following the implementation, a survey was administered to gather students' experiences using the worksheets, with five response options (Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree).

Figure 2 summarizes the data collection process.

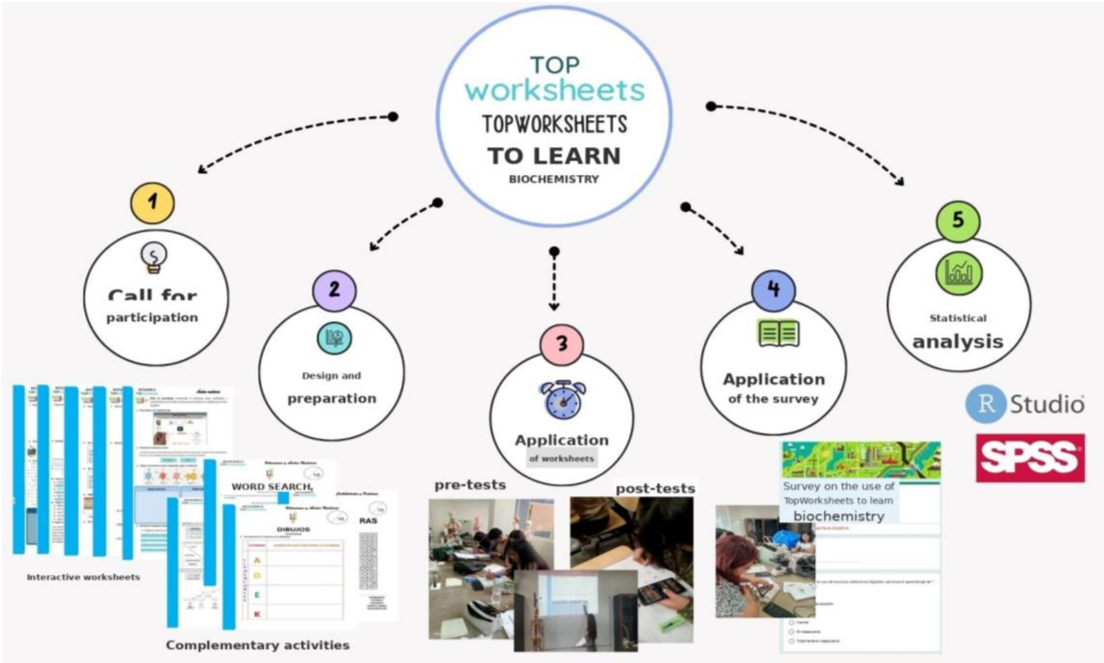

Figure 2. Flowchart of the application of the intervention using interactive cards.

Following the intervention, the tabulated data was used to perform the respective descriptive and inferential statistical analysis, comparatively using IBM SPSS Statistics V.27 and RStudio, to answer the research question: How do the interactive worksheets managed in TopWorksheets promote the learning of biochemistry in students of the Chemistry and Biology Pedagogy program?

4. Results and discussion

Data were collected from 67 students, based on the five topics covered in the syllabus units: carbohydrates, proteins, lipids or fats, vitamins, and nucleic acids. These data were averaged considering the results of the pre-test and post-test assessments, as well as the supplementary activities.

Figure 3 shows the knowledge level of the control group (CG) and experimental group (EG) in relation to the topics covered in the initial assessment. As can be seen, in the CG, 12 students (38%) and in the EG, 11 students (31%) did not reach the required learning levels (NAR, ≤ 4.0). Likewise, in the CG, 15 students (47%) and in the EG, 14 students (47%) were close to reaching them (PAR, 5–6). Similarly, in the CG, 4 students (13%) and in the EG, 4 students (11%) reached them (AAR, 7–8). Furthermore, in the control group (CG), 1 student

(3%) and in the experimental group (EG), 4 students (11%) mastered the required learning (DAR, 9); only in the EG did 2 students surpass the learning requirements (SAR, 10). After an "within-groups" analysis, the absence of statistically significant differences with respect to the initial academic result was confirmed ($t(65) = 0.16$; $p < .84$), showing that the means in the groups were not significant (5.0 ± 1.6 vs. 5.1 ± 2.6/10), which affirms that both groups are equivalent and are in the same conditions to receive the experimental treatment.

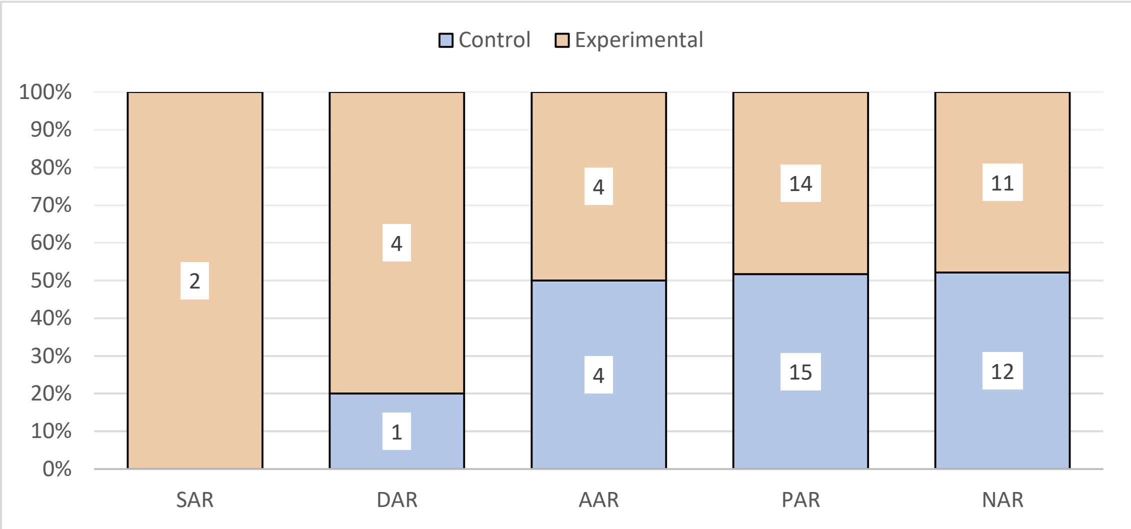

Figure 3. Level of incidence of the application of interactive worksheets for learning biochemistry (pre-test).

Following the intervention, the final evaluation, as shown in Figure 4, reveals that in the control group (CG), 10 students (31%) and in the experimental group (EG), 5 students (14%) did not achieve the required learning outcomes (NAR). Similarly, in the CG, 17 students (53%) and in the EG, 7 students (20%) were close to achieving them (PAR). Likewise, in the CG, 1 student (3%) and in the EG, 9 students (26%) achieved the required learning outcomes (AAR). Furthermore, in the CG, 3 students (9%) and in the EG, 10 students (27%) mastered the required learning outcomes (DAR). Finally, in the CG, 1 student (3%) and in the EG, 4 students (11%) exceeded the required learning outcomes (SAR); this demonstrates a difference in learning levels between the groups.

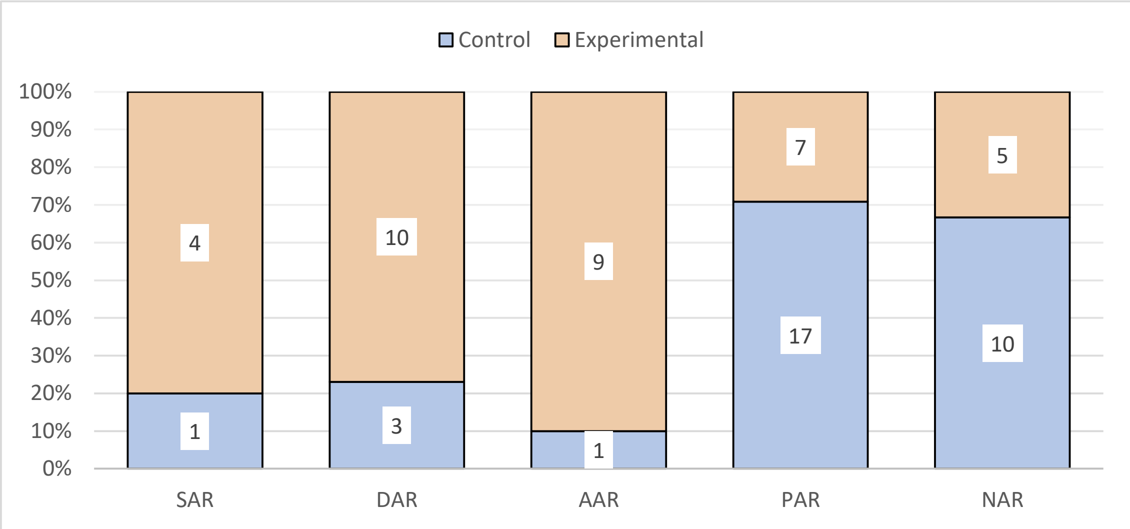

Figure 4. Level of incidence of the application of interactive worksheets for learning biochemistry (post-test).

To verify the effect of interactive worksheets on biochemistry learning, a Student's t-test for independent samples was chosen to evaluate whether there were significant differences when comparing the means of two groups of cases (Guillen et al., 2019).

— Working Hypothesis

H1: There is a difference between students in the experimental group (EG) and students in the control group (CG) with respect to biochemistry learning after the application of interactive worksheets managed through the TopWorksheets resource.

— Determination of (alpha)

$\alpha = 5\% = 0.05$ (admitted error for the statistical test), at a 95% confidence level.

— Statistical Decision

If the obtained probability p-value ≤ Alpha = 5% = 0.05, Ho is rejected (H1 is accepted).).

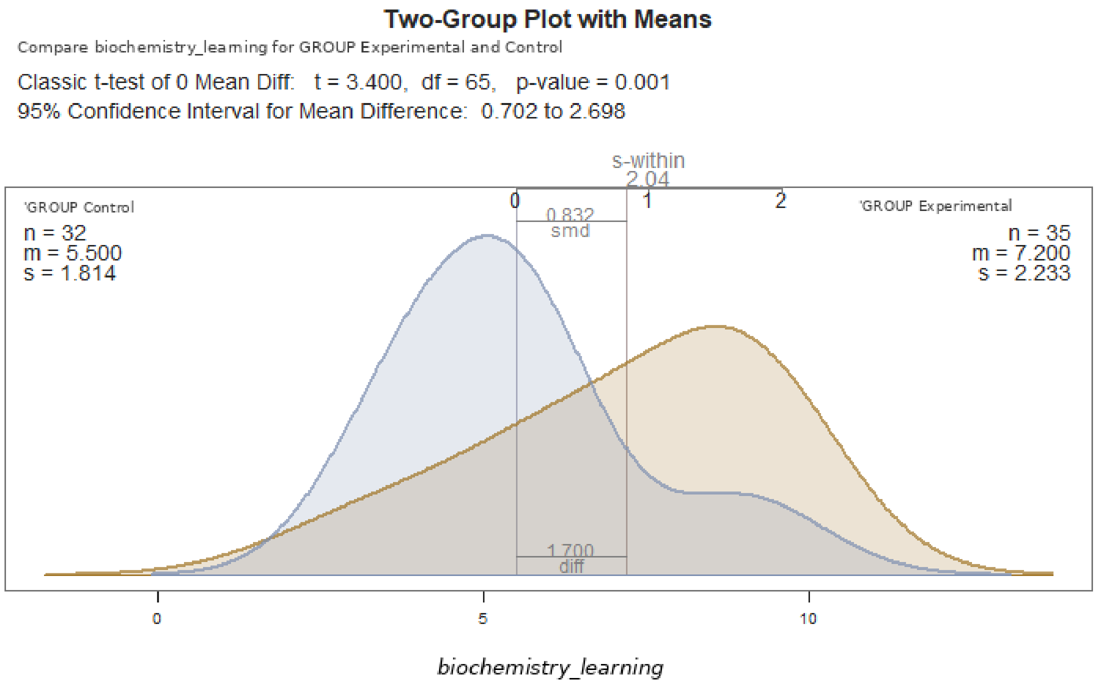

Figure 5. Average biochemistry learning outcomes for different treatments

Depending on the intervention (Figure 5), a difference was found between the mean knowledge test scores for the experimental group (EG) that used interactive flashcards (M = 7.20, SD = 2.23, n = 35) and the control group (CG) that did not (M = 5.50, SD = 1.81, n = 32), such that those who participated in the program obtained better results on the knowledge test. This means that Biochemistry learning was 1.70 times higher on average in the EG compared to the CG. The t-test showed that this difference was statistically significant ($t(65) = 3.40$, $p < .01$, 95% CI [2.70, 0.70]). Because a difference in means was found, Cohen's d was interpreted as an indicator of practical importance for this study, leading to the conclusion that the effect was large ($d = 0.83$, 95% CI [1.33, 0.33], Cohen 2013). Therefore, there is statistical evidence to affirm that biochemistry learning improves significantly after the application of interactive worksheets managed in the TopWorksheets resource.

In line with these results, Delgado-Cobeña et al. explain that digital resources promote dynamic and meaningful forms of learning, which allow students to analyze, discuss, understand, and generate new knowledge (Delgado-Cobeña et al., 2023, p. 21). From a constructivist perspective, Gértrudix and Ballesteros state that ICTs are considered motivating tools for students, as they capture their attention and encourage activity in the classroom (Gértrudix and Ballesteros, 2014, p. 2). A study with Biochemistry and Pharmacy students by Simaluiza established that Web 2.0 platforms are associated with positive and beneficial experiences for students, improving their understanding of the topics covered, teamwork skills, and creativity (Simaluiza, 2024, p. 13). Furthermore, the study explored how the use of Web 2.0 resources impacts motivation and interest in learning.

Innovating the teaching-learning process begins with the creativity applied by the teacher and the selection of resources that are appropriate for new digital models in education. According to Delgado-Cobeña et al., teaching resources must be flexible to achieve a relevant combination with the learning objective; that is, the interaction between the student and the educational material should systematically and substantially generate knowledge (Delgado-Cobeña et al., 2023, p. 43).

4.1. Exploring the experience of the interactive course.

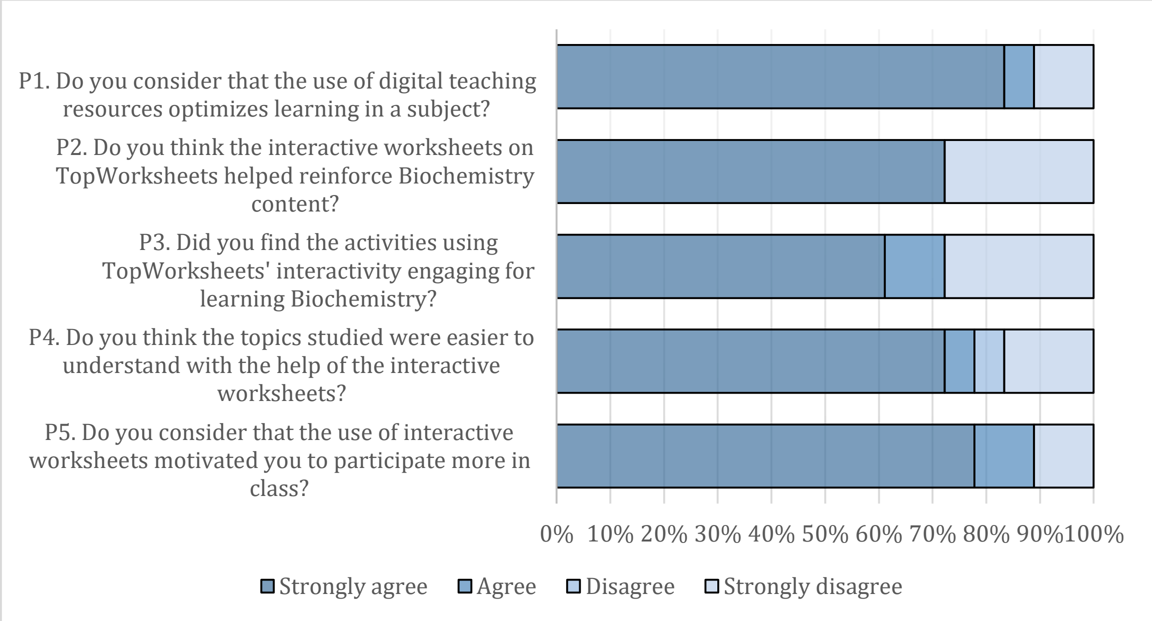

Figure 6. Results of the student perception survey.

In response to the first question, 89% (83% "strongly agree," 6% "agree") stated that the use of digital resources is ideal for optimizing knowledge of a subject. A large proportion of students agreed that digital resources (simulations, interactive videos, and educational applications) offer opportunities to personalize content. Mora indicates that learning can be significantly improved through a variety of pedagogical approaches (Mora et al., 2024).

In response to the second question, 72% indicated that the use of interactive worksheets is very helpful for academic reinforcement in Biochemistry. Many students mentioned that the development of dynamic and creative activities adapted to their learning style, which radically improved classroom participation. Pérez indicates that this strengthens teaching and learning, especially for those students who have greater difficulty understanding the topics (Pérez, 2024).

Regarding the third question, the majority of respondents (72%) mentioned that the worksheets are engaging for learning Biochemistry through interactive exercises. Students gained a better understanding of the material, as Chonillo (2024) notes that interactivity provides an effective learning experience with the content. Tools like TopWorksheets and Liveworksheet allow for the management of interactive PDFs where the self-correction feature helps students better grasp the material.

Regarding the fourth question, the majority of respondents (77.8%) strongly agreed or agreed that the topics studied in the Biochemistry course were easier for them. This was because the worksheets not only facilitated the assimilation of concepts but also made the learning process more engaging. Furthermore, the integration of visual and practical elements in the interactive worksheets helped to better illustrate abstract concepts, making learning a more tangible and concrete experience (García & Santana, 2023).

In the fifth question, 88.9% felt that the topics covered motivated them to participate more actively in the Biochemistry class (77.8% "strongly agree" and 11.1% "agree"). This aligns with Morales et al. (2015), as the use of technology in classes enhances interest, which in turn motivates students to engage in interactive activities; it also prevents boredom and monotony in the classroom.

A chi-square test was also performed to compare variables (Table 2), comparing the variable "Interactive worksheets on the TopWorksheets platform are attractive for learning biochemistry" with the variable "Consider that the use of interactive worksheets motivates greater participation in the Biochemistry class," yielding the following results:

Chi- square tests	**Value**	**df**	**Asymptotic significance (2-sided)**
Pearson's Chi-square	16.796[a]	6	.010
Likelihood ratio	15.982	6	.014
Linear-by-linear association	.001	1	.970
Number of valid cases	35		

a. 9 cases (75.0%) were expected to be less than 5. The minimum expected result was .06.

Section 2. Association between motivation, participation and perception of interactive data in Biophysics

The chi-square test analysis of association revealed statistically significant results, $\chi^2(6, n = 35) = 16.80$, $p = .010$, indicating a statistically significant relationship between the two variables. In other words, motivation to participate in class is linked to a positive perception of interactive worksheets as an academic support resource, with a strength of association $\Phi = 0.49$; according to this strength index, the association was moderate. Borbor et al. found that technological solutions increase motivation for learning in science (Borbor et al., 2024). Furthermore, they promote cognitive development through participatory activities.

A question was also added asking students to rate their experience using interactive worksheets to learn biochemistry (carbohydrates, proteins, lipids or fats, vitamins, nucleic acids). As shown in Figure 5, the majority of students (89%) rated the learning experience as excellent.

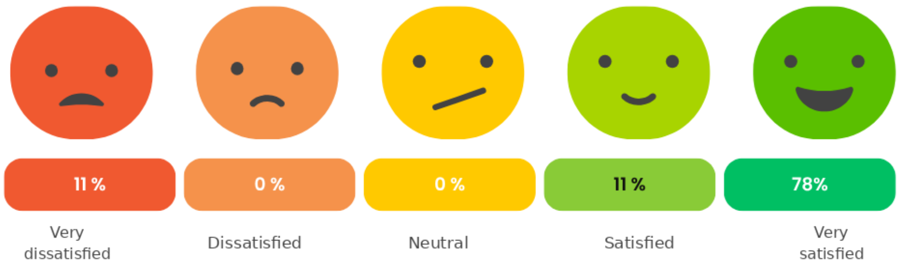

Figure 6. Satisfaction with the use of interactive cards

5. Conclusions

The use of interactive worksheets significantly improved biochemistry students' learning, as it strengthened their understanding of biomolecules (carbohydrates, proteins, lipids, nucleic acids, and vitamins) and enhanced their analytical skills in applying concepts. This finding is supported by the results of the Student's t-test, as well as by the students' experiences gathered in the survey.

The survey revealed that students value interactive worksheets as an effective resource for learning biochemistry, since these activities facilitated a meaningful connection with the content, increased motivation, improved class participation, and contributed to more consistent learning, which is reflected in the post-test scores.

The design and implementation of interactive educational platforms like TopWorksheets offers similar benefits to other digital tools, standing out for its accessibility, immediate feedback, personalization, and flexibility. These characteristics make them valuable resources both inside and outside the classroom, fostering meaningful learning through reinforcement activities, gamification, and independent work.

This research contributes to the literature on innovative teaching methodologies by demonstrating that integrating interactive worksheets into digital platforms promotes active learning. It also confirms that their application has a moderate and significant effect on academic performance, thus providing a basis for future research in other areas of science education. However, future research should consider larger populations to strengthen the external validity of these findings.

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Declaration of Authorization-CRediT

LUIS CHONILLO-SISLEMA: estado de la cuestión, concepts relacionados, Escritura-revisión y edición, metodología, validation, análisis de data, elaboración de material didáctico, visualization, redacción- primer borrador, conclusions, revision de ortografía.

MARÍA CHICAIZA-UQUILLAS: Application of instruments, Escritura- revision and editing, methodology, analysis of data, visualization, redaction- primer borrador, elaboration of didactic material, tabulación of results, conclusions.

ERICK RUIZ-TOTOY: related concepts, methodology, tabulation of results, validation, redaction - primer borrador, revision of spelling.

GENESIS AMAGUAYA-UVIDIA: related concepts, data analysis, visualization, redaction - primer borrador, revision of spelling**.**

Statement on the use of artificial intelligence

The authors declare that they use the ChatGPT version - model GPT-4 (OpenAI), version from June of 2025, exclusively to support the reformulation and improved language of some of the fragments of the manuscript. It is part of the scientific content, results, analysis or interpretations generated by artificial intelligence. All material has been reviewed and validated by the authors, who are responsible for their accuracy and rigor.