Interactive Digital Learning Tools: Enhancing Critical Thinking and Problem-Solving Skills in First-Year Undergraduate Life Sciences Students.

Abstract

Background
First-year university chemistry courses, especially for life sciences students, often face a challenge in engaging students who view the subject as unrelated to their future healthcare careers. Many students approach chemistry as a "mandatory hurdle" rather than a motivating subject. Despite efforts by professors to highlight connections between chemistry and the medical field through examples, the course is often perceived as difficult and less relevant. However, the importance of analytical thinking, critical thinking, and problem-solving skills in healthcare is undeniable.[1-3] These skills are essential not only for academic success but also for professional careers, particularly in diagnostics, where the correct interpretation of signs (symptoms) and evidence (such as blood tests, electrocardiograms and imaging) is crucial for making decisions. In organic chemistry, molecular structural analysis, which involves identifying unknown compounds from spectroscopic data, mirrors the diagnostic process. Both require gathering relevant information, developing causal hypotheses, and testing them. Digital technologies can play a key role in enhancing students' learning experiences, motivation, and soft skills.

Aims
This study aims to develop and assess the impact of an innovative approach in teaching chemistry to first-year veterinary students by integrating digital technologies to enhance problem-solving, data analysis, and critical thinking skills. Specifically, the study seeks to:

1. Increase student motivation and autonomy by making chemistry more engaging and relevant to their future healthcare careers.
2. Foster key analytical and argumentation skills through interactive problem-solving tasks in molecular structural analysis, while promoting deep procedural knowledge through more productive practice.[4-7]
3. Evaluate the effectiveness of various learning approaches — face-to-face, distance, and blended learning — in improving exam performance.
4. Examine how digital tools can diversify learning strategies and assessment methods, ensuring adaptability to various teaching environments.

Methods
The approach centered on a molecular structural analysis problem-solving framework, which simulates a diagnostic process. Students were tasked with identifying an unknown molecule from clues in spectroscopic data obtained from the interaction of a sample with an electron beam or electromagnetic radiation. Data are displayed as Cartesian graphs (which can be analogized to an electrocardiogram, for example). The students have to extract relevant information, analyze and organize it to find out an evidence-based chemical structure.

An interactive web application was developed to replace traditional textbooks, allowing students to actively engage in the entire reflexive process.[8,9] Unlike static textbook images, this application allowed students to zoom in on data, explore clues independently, and

practice problem-solving at their own pace. The interactivity fostered deeper engagement, as students could work asynchronously from home, solving a variety of exercises that encouraged flexibility and adaptability.

The course design included traditional lectures on theoretical concepts, in-person exercise sessions, and the use of the web application for independent training. The effectiveness of this blended learning approach was evaluated through statistical data collected over ten academic years. Student feedback was also gathered through surveys to assess their perceptions of the new teaching scenario.

In response to the COVID-19 pandemic, the entire pedagogical framework was adapted to a fully online environment, with either online or in-person exams, depending on the situation.

Results

The integration of digital tools into the organic chemistry course resulted in several positive outcomes. Firstly, the use of interactive technologies significantly increased student motivation and autonomy. Students, who initially found chemistry to be a challenging and irrelevant subject, expressed positive perceptions of the problem-solving tasks combined with digital tools. By highlighting the connections between chemistry and their future roles in healthcare, students became more engaged and motivated to tackle complex problems. The semi-gamified nature of the exercises, along with the play-learning mode they offered, further enhanced engagement and motivation. These findings about gamification are in line with those of da Rocha et al., Verpoorten et al. and Chen et al.[10-12]

Secondly, the problem-solving tasks fostered essential skills such as critical thinking, data analysis, and problem-solving. The molecular structural analysis exercises, when combined with digital tools, allowed students to practice the full spectrum of reflexive thinking necessary for these skills. Unlike traditional textbooks, which have the drawbacks of static images and the necessity to highlight some clues for legibility, the interactive tools enabled students to concentrate on the entire analytical process, leading to a deeper understanding.

Thirdly, statistical analysis of student exam performance over ten academic years showed a statistically significant improvement since the introduction of digital technologies. Several learning approaches, including face-to-face, distance, and blended learning, were compared.

Lastly, the introduction of digital tools helped diversify both learning strategies and assessment methods. The flexibility of the interactive web application allowed students to work at their own pace, exploring a variety of exercises. This adaptability was especially valuable during the pandemic, as the course was seamlessly converted to an online format. Assessment methods were also diversified, including multiple-choice questions, and problem-solving tasks, which allowed for a comprehensive evaluation of student understanding.

Conclusions

The integration of digital tools into first-year chemistry courses, particularly for veterinary science students, has been highly effective in enhancing student engagement in evidence-based argumentation, problem-solving skills, and student motivation. The combination of molecular structural analysis with interactive technologies provides students with a practical and engaging way to develop skills that are critical to their future healthcare careers. The flexibility of digital tools also allows for the adaptation of learning strategies to different teaching environments, including face-to-face, distance, and blended learning. A statistical analysis of student exam performance over ten academic years revealed a significant improvement following the implementation of digital technologies. Additionally, the successful adaptation of the course to online learning during the COVID-19 pandemic underscores the versatility of this pedagogical framework. Overall, the findings suggest that digital tools can play a crucial role in fostering critical thinking and problem-solving skills in chemistry education, providing students with valuable competencies for their professional development.

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Summary (A short summary of the session used as a ‘promotion’ to encourage participants to attend. (approx. 100 words))

This session will present a novel approach to teaching chemistry to first-year veterinary students, integrating digital technologies to enhance critical thinking, data analysis, and problem-solving skills. We will highlight how evidence-based student argumentation during molecular structural analysis can simulate diagnostic reasoning and improve engagement. Additionally, we will discuss how the use of interactive tools increases student motivation and autonomy while improving exam performance. Finally, we will explore the flexibility of this blended learning model, which has successfully adapted to both traditional and online formats, demonstrating its effectiveness in fostering key analytical skills for future healthcare professionals.

Main message of the proposal/key takeaways for delegates
(“After this session the participant will know/have experienced/have gained...”) (max. length: 50 words)

After this session, participants will gain insights into how digital technologies can enhance critical thinking, problem-solving, and student autonomy in chemistry education. They will also learn about the benefits of flexible learning strategies—blended and online—and their effectiveness in improving student engagement and learning outcomes in life sciences education.

Topics	x Profiles and needs of current and future first years x Future-proof education and support ☐ Future-proof curricula and institutions
Specific angles	☐ Retrospective angle x Research based - perspective ☐ Cross institutional collaboration ☐ none
Area/field	x Academic integration/belonging ☐ Social integration/belonging ☐ Personal mental health/well-being ☐ Financial needs
Timing	☐ Pre-entry ☐ After enrolment before start ☐ Induction or orientation period ☐ Semester 1 x Semester 2 ☐ Transition to second year ☐ Transition to master ☐ Entire first year
Domain	x Active learning ☐ Counselling ☐ Curriculum ☐ Data/analytics

	☐ Inclusion and diversity ☐ Language (academic) ☐ Learning communities ☐ Library ☐ Mentoring

	☐ Parents ☐ Peer-to-peer ☐ Physical spaces x Research on FYE ☐ Retention ☐ Service learning/volunteering ☐ Study Skills x Technology
Student orientation	x Relevant for all students ☐ Relevant for all students, but with a specific focus on specific groups ☐ Only relevant for a specific group
Specific target groups (opens based on answer of previous question)	☐ Students with a mental health condition ☐ Students experiencing educational obstacles ☐ Students experiencing geographical obstacles (commuter students) ☐ Students from other communities ☐ Students with caring responsibilities ☐ Students who combine work and study ☐ Students from non-academic backgrounds ☐ Students experiencing obstacles based on ethnic-cultural differences ☐ Students experiencing socioeconomic obstacles ☐ International students ☐ Other
Student involvement	x Students as participants ☐ Students as volunteers ☐ Students as leaders ☐ Students as organisers/owners ☐ No specific student involvement
Relevant for	x Academic adviser x Academic teaching staff ☐ Administrative staff x Education leaders ☐ Library staff ☐ Research staff x Student ☐ Student mentor/tutor ☐ Student politician ☐ Technical staff