Enhancing critical thinking and problem-solving skills through active-learning strategies

Armélinda Agnello[1], and Jean-François Focant[2]

1- Department of Chemistry, DIDACTIfen Research Unit, University of Liège, Sart-Tilman B6c, 4000 Liège, Belgium.

2- Department of Chemistry, MolSys Research Unit, University of Liège, Sart-Tilman B6c, 4000 Liège, Belgium.

Background

- First-year university chemistry is often perceived as a "mandatory hurdle" by life sciences students.
- Chemistry is seen as unrelated to their future careers, leading to disengagement.
- Critical thinking and problem-solving skills are crucial in healthcare, particularly in diagnostics.
- Molecular structural analysis parallels diagnostic process.
- Digital technologies offer the potential to improve learning, motivation, and skill development.

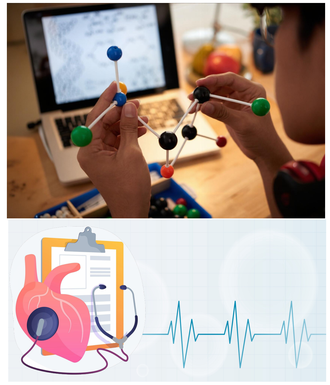
Aims

- **Enhance student motivation** and autonomy by making chemistry more engaging and relevant to healthcare careers.
- **Foster critical thinking, analytical skills**, and deep procedural knowledge through interactive problem-solving in molecular structural analysis.
- **Evaluate different learning methods** (face-to-face, distance, and blended) based on their impact on exam performance.
- **Explore the role of digital tools** in diversifying learning and assessment methods for adaptability in various environments.

Methods

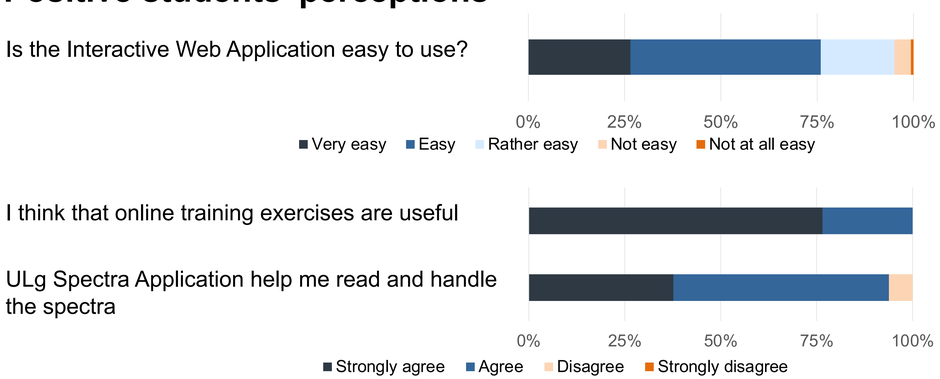
- **Problem-solving** framework: Identify unknown compounds from clues in spectroscopic data (similar to diagnostic processes in healthcare).
- Development of an **Interactive Web Application ULg Spectra** (Agnello et al., J. Chem. Educ., 2020)
  - Replaced traditional textbooks
  - Features: Zoom in on data, explore clues independently, practice problem-solving.
  - Benefits: Asynchronous, flexible, and self-paced learning.
- **New blended learning design**: Traditional lectures, in-person exercise sessions, and independent asynchronous training with the web app.
- **Adaptation during COVID-19:** Fully online delivery with synchronous online exercise sessions and flexible exam formats (online/in-person).

Results



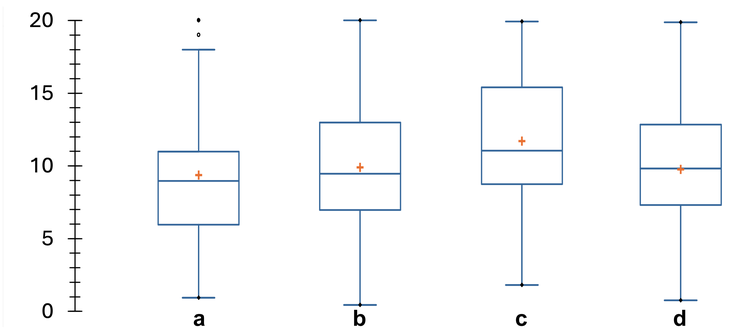
Digital tools provide valuable skills for healthcare careers. There are clear analogies between molecular structural analysis and the diagnostic process: both tasks involve gathering relevant information, developing causal hypotheses and testing them.

Positive students' perceptions



Students' performance and pedagogical flexibility

- **Statistically significant increase in students' performance since the introduction of the new blended learning framework** (Mann-Whitney U test, p=0.040).
- Successful adaptation of the course to a **synchronous** online format during the COVID-19 pandemic :
  - **Online exams**: statistically significant increase in students' performance (Mann-Whitney U test, p<0.0001) probably due to the increased opportunity for unauthorized assistance, given the challenges in ensuring academic integrity.
  - **In-person exams**: students' performance was similar to that obtained in the blended learning format.



Box plot of students' exams performance illustrating mean grades (+) and first and third quartiles. (**a**) June 2017 and 2018 (n=340 – Mean=9.4/20) (**b**) June 2019 and June 2022 to 2024 (n=903 – Mean=9.9/20) (**c**) June 2020 (n=211 – Mean=11.8/20) (**d**) June 2021 (n=187 – Mean=9.9/20)

Conclusion

- Digital tools in chemistry education enhance student engagement in evidence-based argumentation, problem-solving skills, and critical thinking.
- Interactive molecular structural analysis is a practical, engaging approach, that develops students' skills for healthcare careers.
- Significant improvements in exam performance and motivation were observed with the integration of digital tools.
- Adaptability to different teaching environments (face-to-face, blended, distance), including successful online adaptation (with synchronous online exercise sessions) during the pandemic.

Liège université Chimie

Liège université DIDACTIfen

Armélinda AGNELLO
a.agnello@uliege.be