Presentation

Facilitating student preparation and learning in chemistry courses with a virtual laboratory guide

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Abstract: Chemistry is a central component of STEM education programs in Norwegian universities. Introductory chemistry courses are offered early in bachelor programs and include practical exercises that often constitute students' first laboratory experience at the university level. Laboratory courses have a high pedagogical value for students. For the faculties, however, they are resource-demanding and require extensive preparation by teachers and technicians. Despite the large amount of information provided through prelab lectures and handbooks, students often come unprepared for practical activities. Consequences include reduced efficiency and learning outcomes, and higher risks of HSE concerns.

Through the project ChemView360, we created a virtual, web-based laboratory guide that allows students to navigate within the teaching facilities before the first practical exercise. They can explore the premises, identify instruments and locate safety equipment. Clickable items embedded in the user interface display information panels with short videos or images. ChemView360 also offers instructional videos introducing the lab exercises. These videos, featuring student partners as the actors, explain the principles behind the experiments, demonstrate the procedures in detail, and present the expected results. In this presentation, we introduce ChemView360 and share our findings on how the platform was received by students and evaluated by staff and assistants.

Keywords: student preparation, virtual exploration, laboratory teaching, introductory chemistry, learning tool

1 Introduction

Chemistry is a central component of STEM education programs in higher education institutions in Norway. At the University of Bergen, introductory courses in chemistry take place early in the student curriculum, mainly during the first year of the bachelor's degree. These large courses include laboratory exercises that allow students to get practical skills while applying in a practical setting the theory they have acquired in textbooks or in the classroom. For most students encountering such a novel context, these activities represent their first exposure to experimental science at the university level. The lack of familiarity with the facilities and tasks to perform may be associated with a negative experience (confusion, nervousness, frustration) that is detrimental to learning (Galloway et al., 2015).

Like other fields in STEM education (biology, geology, geophysics, physics), practical activities in chemistry are both resource- and time-consuming for the teaching and technical staff. On the technical side, they require costly investments in maintenance of both facilities and instruments, and in the purchase of consumables. On the pedagogical side, these activities should be carefully planned to encourage students to adopt a deeper approach to learning. They should involve learning by doing, support skills acquisition, allow students to make mistakes and to learn from them. Also, teachers should design the learning activities according to the principles of constructive alignment, making sure that both their content and their assessment match the intended learning outcomes of the course (Biggs and Tang, 2011; Adams, 2020). In addition, knowledge and awareness of HSE (Health, Safety & Environment) should be constantly emphasized as students gain access to potentially hazardous chemicals, expensive instruments and glassware in an unfamiliar training environment.

To enhance learning and increase efficiency at the laboratory, teachers and technicians work together to develop course materials such as a comprehensive, printed handbook, and to organize prelab lectures. Beyond covering the experiments, their purpose, connected principles, and protocols in detail, these materials also present the expected outcomes, and give guidelines to report and interpret the results. Despite this apparent abundance of information, the staff periodically reports on the observed lack of preparation. Consequences are weak performance at the bench, delays in completion of the tasks, wasted time as exercises must be repeated, and potentially higher risk of accidents due to lack of prerequisite knowledge, tidiness, and awareness.

In past years and especially since the occurrence of COVID-19, the use of digital solutions in teaching at the university level has tremendously increased (Pinheiro et al., 2023). Learning through videos and platforms utilizing augmented or virtual reality has been shown to benefit learning in a broad set of disciplines and activities, and to trigger student engagement and inclusivity (Noetel et al., 2021; Hamilton et al., 2021; Eidesen and Hjelle, 2024).

To help our students in chemistry get better engaged, informed and prepared for laboratory activities, we initiated the project ChemView360 aiming at developing a virtual chemistry laboratory guide. The goal was to combine virtual exploration of the premises with instructional videos and illustrating materials presented in context. This presentation gives an overview of the design and outcomes of ChemView360.

2 Developing a digital twin for the chemistry laboratory

2.1 Familiarization through visual exploration of the premises

Considering that newly enrolled students in introductory courses have likely never encountered our teaching facilities, we found it essential to introduce them to the lab, instruments, and other points of interest through a virtual guide. This guide aims to reduce the unfamiliarity they might experience while increasing their awareness of the environment. Besides providing a virtual insight into the lab, we placed special emphasis on addressing 'tacit knowledge' (Glass, 2013) – the kind of knowledge that is difficult to transfer through writing or verbalization. This includes skills, ideas, and experiences that are crucial for learning laboratory techniques and fostering scientific thinking. We found inspiration in the work of Eidesen and Hjelle (2024) and used their approach to create an exploratory guide of our chemistry laboratory. 360-degree pictures of the teaching laboratory were acquired, post-processed and supplemented with "hotspots" (see Figure 1A), which are localized, clickable markers highlighting either a point of interest (for example an instrument or another location in the room) or a safety item (fire safety equipment, emergency showers). Whenever relevant, hotspots display descriptions of items or procedures and illustrate them with pictures or short videos. Navigation menus embedded in the graphic user interface allow for exploration of the rooms, with shortcuts to locations, and general information about the lab course and equipment (Figure 1B).

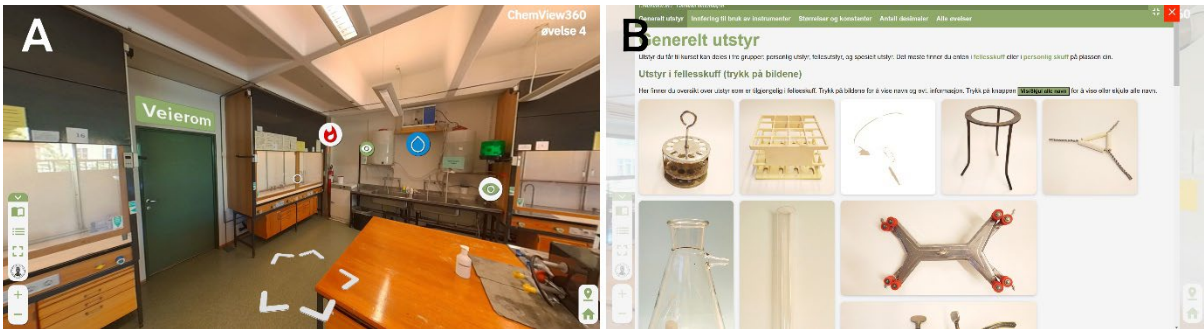

Figure 1. *ChemView360 introduces students to the teaching facilities through a virtual guide with 360-degree pictures.* ***A****: Screenshot of the website showing the laboratory and clickable items (i.e. hotspots) that provide detailed information about equipment and HSE.* ***B****: Screenshot of a menu listing and naming the various items that students get access to when at the laboratory.*

2.2 Preparation for lab experiments through short instructional videos

To enhance student preparation for lab exercises, we created a set of short instructional videos (Figure 2A) that highlight the experimental procedure and outcomes. Videos were built around the 5 following principles. They must 1) convey the purpose of and the principles behind the exercise, 2) demonstrate step-by-step the safe execution of the procedure, 3) present the expected results, 4) guide students into presenting their own results in the lab report and 5) be concise (shorter than 7-8 minutes). Videoscripts were written and reviewed by course teachers and teaching technicians to ensure that the contents were both pedagogically and technically sound. In addition, we designed a set of shorter videos to illustrate the correct and safe use of instruments (e.g. analytic balance) and glassware (e.g. pipette, burette, etc.). Note that all the videos were performed by undergraduate students to make the content more relatable and engaging.

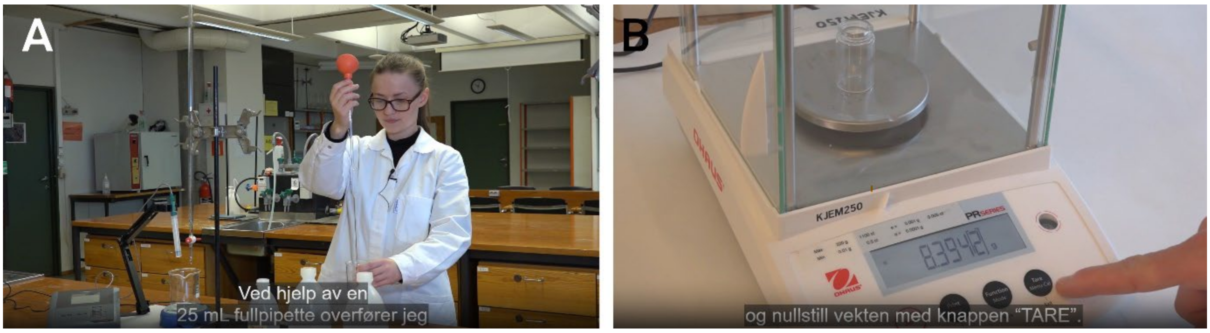

Figure 2. *ChemView360 makes use of short instructional videos to **A**: explain the principles behind each of the course experiments and introduce to the experimental procedure to follow, and **B**: demonstrate the use of instruments and equipment that the students will employ under completion of each of the lab exercises.*

3 Students' use of ChemView360 and their feedback

During fall 2024, we released ChemView360 in one of our introductory courses (four laboratory exercises) in chemistry and surveyed the students on their use and perception of the platform. The platform was presented as a teaching material complementary to the lab handbook, but its use was optional. The survey was anonymous and nonmandatory, and aimed at understanding whether, when and how this digital resource was useful to them.

To the question "Did you use ChemView360 in this course?", 162 of the 168 respondents replied positively. When these 162 students (thereafter referred to as "users") were asked about when they used ChemView360, 99% indicated that they used the platform for preparation, 18% during the lab exercise, and 33% after completion of the lab exercise,

Regarding the exploration component of Chemview360 (i.e., the virtual lab guide), a significant majority (> 80%) of users reported that the platform helped them become familiar with the lab and reduced their anxiety about the laboratory course. A majority (>60%) also reported that the platform helped them locate equipment and instruments, as well as identify potential dangers in the lab.

Concerning the instructional videos available in ChemView360, a significant majority of users (>80%) reported that they enhanced their understanding of lab expectations, visualized the procedures, assisted in both starting and completing the exercises, clarified the underlying principles, and reduced hesitation during the exercises.

In parallel to the survey among students, we gathered feedback from teaching assistants and lab engineers. They observed a noticeable improvement in students' preparation levels. Students waste less time and start their laboratory exercises more quickly. Additionally, there is a reduction in spills and clutter in the lab, contributing to a safer and more organized environment.

4 Conclusion

The development and implementation of a virtual learning platform (ChemView360) for an introductory chemistry course proved highly effective as a supplementary teaching tool. Widely adopted by students, it significantly improved their lab preparation, reduced anxiety, and enhanced safety awareness. The instructional videos were particularly beneficial, aiding in understanding lab expectations and procedures. Feedback from lab staff confirmed these findings, noting improved student preparation, quicker lab starts, and a safer, more organized environment. Overall, ChemView360 greatly enhanced the learning experience and operational efficiency in the lab.

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References

Adams, C. J. (2020). A constructively aligned first-year laboratory course. *Journal of Chemical Education*, *97*(7), 1863-1873. https://doi.org/10.1021/acs.jchemed.0c00166

Eidesen, P. B., & Hjelle, S. S. (2024). How to make virtual field guides, and use them to bridge field- and classroom teaching. *Nordic Journal of STEM Education*, *8*(2), 88-105. https://doi.org/10.5324/njsteme.v8i2.4921

Galloway, K. R., Malakpa, Z., & Bretz, S. L. (2016). Investigating affective experiences in the undergraduate chemistry laboratory: Students' perceptions of control and responsibility. *Journal of Chemical Education*, *93*(2), 227-238. https://doi.org/10.1021/acs.jchemed.5b00737

Glass, R. J. (2013). Tacit beginnings towards a model of scientific thinking. *Science & Education*, *22*, 2709-2725. https://doi.org/10.1007/s11191-013-9622-5

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*, *8*(1), 1-32. https://doi.org/10.1007/s40692-020-00169-2

Noetel, M., Griffith, S., Delaney, O., Sanders, T., Parker, P., del Pozo Cruz, B., & Lonsdale, C. (2021). Video improves learning in higher education: A systematic review. *Review of educational research*, *91*(2), 204-236. https://doi.org/10.3102/0034654321990713

Pinheiro, R., Edelhard Tømte, C., Barman, L., Degn, L., & Geschwind, L. (2023). *Digital transformations in Nordic higher education* (p. 278). Springer Nature. https://doi.org/10.1007/978-3-031-27758-0