Comparison of Students' Experiences in Chemistry Laboratory Works in Synchronous, Asynchronous, and Face-to-Face Learning Modalities

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Abstract — This study compares students' experiences in chemistry laboratory work across three learning modalities: synchronous, asynchronous, and face-to-face. The COVID-19 pandemic necessitated diverse instructional approaches, prompting the need to understand their impact on students' engagement, motivation, and satisfaction. Utilizing a mixed-methods comparative design, data were collected from 120 first-year engineering students enrolled in Chemistry for Engineers at President Ramon Magsaysay State University. Findings indicated no significant differences in physical and social experiences across modalities. However, emotional and cognitive experiences varied significantly based on socioeconomic factors such as income, internet connectivity, and device availability. These results highlight the importance of infrastructure support and tailored pedagogical strategies in enhancing students' laboratory experiences. Future recommendations include broadening sample diversity, improving technology access, and integrating more interactive digital tools for remote modalities.

Keywords — Chemistry laboratory, learning modalities, synchronous, asynchronous, face-to-face, student experience

I. Introduction

The global shift to remote learning due to the COVID-19 pandemic transformed traditional education, especially laboratory-based instruction in science courses. Chemistry, being an experimental science, relies heavily on hands-on activities to reinforce theoretical knowledge. The adoption of synchronous, asynchronous, and hybrid modalities introduced disparities in learning experiences due to varying access to resources and interaction levels.

Remote learning during the pandemic magnified existing educational inequalities. Not all students had access to the same quality of internet, devices, or learning environments, which affected participation in laboratory courses. The diversity in access and preparedness emphasized the need to examine students' experiences across different modalities.

In the ASEAN context, these changes further emphasized the digital divide, affecting students' ability to engage in laboratory activities equitably. Traditional laboratories had to be adapted or substituted by digital simulations, video demonstrations, and asynchronous tasks, prompting concerns about engagement and learning quality.

Theoretical frameworks guiding this research are Social Presence Theory, posits that students' sense of connectedness with peers and instructors significantly influences engagement and satisfaction; Self-Determination Theory, highlights the importance of autonomy, competence, and relatedness in fostering motivation; Cognitive Load Theory, emphasizes that students' working memory can be overwhelmed depending on how information is presented; and Experiential Learning Theory: underscores the value of active, reflective learning experiences. This study seeks to determine which modality fosters the most positive student experiences and what contextual factors influence their perceptions. A deeper understanding of these experiences will guide educators in designing equitable, effective laboratory courses.

II. Methodology

The study involved 120 first-year students from Civil, Electrical, and Mechanical Engineering programs at President Ramon Magsaysay State University. These students were enrolled in Chemistry for Engineers during the first semester of the 2024–2025 academic year. The university is a state institution in the Philippines, committed to delivering quality science and engineering education.

A comparative mixed-methods approach was employed to capture both quantitative patterns and qualitative insights. Students were divided into three groups, each experiencing chemistry laboratory instruction through a different modality: synchronous (real-time virtual classes), asynchronous (recorded materials and independent tasks), and face-to-face (traditional, in-person labs).

Students completed three chemistry experiments using each learning modality in rotation. This within-subjects design allowed each student to experience all three formats. Upon completion, participants responded to the online survey distributed via Google Forms. Ethical approval was secured, and informed consent was obtained.

SPSS was used for data processing. Descriptive statistics (mean, frequency, percentage) summarized participant profiles and responses. Analysis of Variance (ANOVA) was employed to test for significant differences in student experiences across the three modalities.

III. Results and Discussion

Results

Participant Profiles

Most participants were aged 18-23 (71.67%), with a majority identifying as male (72.5%). Students were evenly distributed among the three programs. Nearly half (48.33%) had family incomes below PHP 10,000. Wireless internet (48.33%) was the most common connection, and 58.33% reported having 2–4 electronic devices at home.

Physical Experiences

Students in all modalities reported feeling safe and adequately resourced. The face-to-face group rated safety, hands-on practice, and confidence in equipment handling higher than their peers. Synchronous learners appreciated real-time instruction, while asynchronous learners struggled with the independent application of laboratory tasks.

Emotional Experiences

Face-to-face students reported greater satisfaction, motivation, and enjoyment. Asynchronous learners experienced more anxiety and less engagement. Synchronous learning provided emotional support through live feedback but fell short in personalized attention compared to face-to-face.

Rational Experiences

Cognitive understanding was highest among face-to-face learners, particularly in problem-solving and analysis. Internet access and availability of devices influenced cognitive outcomes, as asynchronous learners with limited resources reported difficulty focusing and processing instructions.

Social Experiences

Face-to-face learning promoted the most peer interaction and instructor accessibility. Synchronous sessions offered a moderate level of social engagement, whereas asynchronous learning yielded the lowest ratings due to limited collaborative opportunities.

Statistical Differences

ANOVA tests showed that there is no significant difference in physical and social experiences ($p > .05$), and there are significant differences in emotional ($p = .03$) and rational ($p = .01$) experiences. Income, connectivity, and device availability were significant covariates for emotional and rational domains

Discussion

This study highlights how modality and socioeconomic context affect student experiences in chemistry laboratory work. The strongest outcomes—emotional and cognitive—were tied to in-person learning, aligning with Experiential Learning Theory, which values direct interaction and feedback.

The findings corroborate Self-Determination Theory: students' motivation was bolstered by environments that supported autonomy (face-to-face), competence (accessible materials), and relatedness (peer interaction). Social Presence Theory also found support; learners felt more connected in synchronous and face-to-face settings.

Asynchronous learning, while flexible, was limited by technical and motivational challenges. Students without reliable internet or sufficient devices reported more negative experiences. These findings reinforce the need to address educational equity when planning remote lab courses.

Investing in campus-based or mobile laboratory access for underserved students, providing high-quality simulations and interactive modules for asynchronous learning, and training instructors to facilitate engaging real-time virtual labs for synchronous classes hold practical implications for enhancing STEM education; however, the findings are limited by a sample from a single institution and course, and the potential for bias in self-reported survey responses suggests that future research should include longitudinal tracking to assess the long-term impact on academic performance, retention, and practical skill development across diverse STEM learning contexts.

IV. Conclusion

This study concludes that face-to-face instruction yields the most beneficial outcomes for chemistry laboratory learning, particularly in emotional satisfaction and cognitive engagement. Synchronous learning offers a strong alternative if infrastructure supports are in place. Asynchronous formats must be carefully designed and supplemented with accessible resources to be effective.

Educational institutions must address digital inequities and prioritize inclusive strategies to ensure quality laboratory instruction across modalities. Tailored pedagogy, infrastructure investment, and equitable access are key to future-proofing science education.

V. Compliance with ethical standards

- Disclosure of conflict of interest
- No conflict of interest to be disclosed.oss

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