

MODERN TECHNOLOGY'S ROLE IN ADVANCING SCIENTIFIC LEARNING AND EXPERIMENTATION: INSIGHTS FROM MATHEMATICS AND SCIENCE STUDENTS AT UNIVERSITAS NEGERI MEDAN (UNIMED)

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ABSTRACT

The integration of modern technology into education has profoundly influenced the teaching and learning processes, particularly in mathematics and science. This study explores the role of technological tools in enhancing scientific learning and experimentation among students at Universitas Negeri Medan (UNIMED). A mixed-methods approach was utilized, combining quantitative survey data and qualitative insights to capture a holistic understanding of students' experiences. The findings reveal that advanced tools such as simulations, virtual laboratories, and data analysis software enhance students' conceptual understanding, foster engagement, and bridge the gap between theoretical knowledge and practical application. However, challenges persist, including limited access to updated equipment, inadequate training, and technical malfunctions, which disproportionately affect Physics and Chemistry students. To address these issues, the study recommends upgrading laboratory resources, implementing comprehensive training programs, and establishing technical support systems. This research highlights the transformative potential of technology in higher education and provides actionable recommendations to optimize its integration, contributing to the advancement of scientific education in Indonesia.

Keywords: *Education Techonology, Scientific Tools, Virtual Labs, Student Engagement*

INTRODUCTION

1.1 Background

The rapid advancement of modern technology has significantly changed various aspects of human life, including education. In the field of learning and scientific experimentation, technology has redefined traditional pedagogical approaches and introduced innovative methods that enhance the teaching and learning process. Particularly in math and science education, technological tools such as simulation software, data analysis platforms, and virtual laboratories provide students with opportunities to explore concepts and conduct experiments beyond the constraints of physical resources. At Universitas Negeri Medan (UNIMED), the integration of technology into the academic environment has been embraced by both faculty and students. Students of the math and science faculties, in particular, have benefited from the use of digital tools and platforms that encourage interactive and engaging learning experiences. However, while the potential benefits have been widely recognized, challenges such as digital literacy gaps, access to resources, and educator and learner readiness are still important issues to address. This research aims to explore the impact of modern technology on the learning and experimentation process among mathematics and science faculty students at UNIMED. By examining their experiences and perspectives, this research seeks to identify the advantages and challenges of technology integration in these areas. In addition, this study also aims to provide insights into how technological advances can be effectively used to improve the quality of scientific education and experimentation in higher education institutions. The findings from this study will contribute to the ongoing discourse on educational technology and its role in shaping the future of scientific learning. By understanding the specific context of UNIMED, this research also offers practical implications for policy makers, educators, and students to maximize the potential of technology in education while overcoming its limitations. Previous research related to the title of this research are The Role of Technology in Enhancing Laboratory-Based Learning Experiences (Ghory, S., & Ghafory, H. 2021), Digital Learning in Higher Education: A Study of Online

Learning Behaviors (Ting, T. T., Teh, S. L., & Wee, M. C. 2022), Utilizing Internet and Visual Technologies in Science Education (Wakil, et al. 2021), Virtual Labs and Simulations in STEM Education: Case Studies and Analysis (Dawson, R. A., & Smith, J. P. 2023).

The Role of Technology in Modern Science Education

Enhancing Science Learning through Technology

The integration of technology into educational environments represents a significant shift in pedagogical approaches, as it not only bridges the often-cited gap between theoretical constructs and their practical applications but also cultivates a deeper, more meaningful engagement with scientific material, empowering students to develop critical thinking skills and collaborative competencies essential for modern scientific inquiry (Schwartz, 2023; MIT Open Learning, 2023). For example, advanced tools such as digital microscopes provide unparalleled high-resolution imaging capabilities that enable students to examine cellular and molecular structures with a level of clarity that was previously unattainable using traditional optical devices, thereby fostering a more profound understanding of biological processes and phenomena (Breazeal et al., 2023). Moreover, the adoption of simulation platforms like PHET Interactive Simulations facilitates virtual experimentation, offering students a safe, cost-effective, and resource-efficient alternative to traditional laboratory setups, which proves particularly advantageous for exploring hazardous experiments or scenarios where physical resources are scarce (Mayer, 2022).

Transforming Laboratory Experiences

Modern technological advancements have revolutionized laboratory experiences by introducing tools and methodologies that enhance interactivity, precision, and engagement, thereby aligning with Mayer's (2022) Cognitive Theory of Multimedia Learning, which highlights the role of multimedia resources in optimizing cognitive load and improving the retention of complex scientific concepts. For instance, animations and dynamic simulations allow students to visualize abstract phenomena—such as molecular bonding processes or chemical reaction mechanisms—by presenting them in an intuitive, visually engaging format that stimulates both visual and verbal cognitive channels simultaneously, ultimately fostering a deeper conceptual grasp (Stanford GSE, 2023). In addition to these visualization tools, sophisticated data analysis software like MATLAB and SPSS offers students a streamlined approach to collecting, processing, and interpreting experimental data, equipping them with industry-relevant skills while minimizing errors associated with manual computation (MIT Open Learning, 2023).

Encouraging Innovation in Learning

The introduction of modern technologies such as 3D printing, Arduino microcontrollers, and Raspberry Pi systems into the science curriculum has emerged as a transformative force that encourages students to transcend traditional methods and actively engage in creative problem-solving and innovation (Breazeal et al., 2023). These tools not only allow students to conceptualize and construct tangible models of molecular structures or experimental setups but also facilitate interdisciplinary learning by blending principles of engineering, design, and science into a cohesive, hands-on educational experience, thus enhancing their understanding of complex, multifaceted scientific ideas (Schwartz, 2023). Furthermore, the availability of programmable devices enables students to develop automated experimental apparatuses, which not only introduces them to modern engineering applications but also fosters an experimental mindset where they are encouraged to hypothesize, iterate, and refine their methods with a level of autonomy and confidence previously unattainable in traditional learning settings (Mayer, 2022).

Addressing Challenges and Opportunities

While the benefits of integrating advanced technologies into science education are increasingly evident, significant challenges persist, particularly in regions with limited access to resources, such as Indonesia,

where infrastructure deficits, high costs, and inadequate training for educators often hinder the effective

implementation of such tools, thereby restricting their transformative potential (Breazeal et al., 2023). Nonetheless, initiatives such as MIT's blended learning programs, which integrate online and in-person modalities, offer innovative solutions by providing cost-efficient and flexible educational models that aim to democratize access to cutting-edge technology and bridge the gap between resource-rich and resource-constrained educational settings (MIT Open Learning, 2023). These efforts underscore the importance of adopting a holistic approach to addressing both systemic and localized barriers, ensuring that the benefits of technological advancements are equitably distributed across diverse educational landscapes.

The integration of modern technological tools into science education represents not merely an enhancement but a fundamental evolution in pedagogical practices, empowering students to achieve greater levels of precision, understanding, and creativity while equipping them with the skills necessary to excel in the rapidly advancing scientific and technological landscape. As educators and institutions continue to adapt to these advancements, the potential for creating transformative and inclusive learning experiences that address global educational disparities grows exponentially, offering an unprecedented opportunity to redefine the future of science education.

METHODOLOGY

This study employs a mixed-methods approach, combining quantitative and qualitative data collection techniques to explore the impact of modern technology on scientific learning and experimentation, specifically from the perspectives of mathematics and science students at Universitas Negeri Medan (UNIMED). The primary data collection tool will be Google Forms, designed to gather both numerical and narrative responses from the participants. A mixed-methods approach allows for a comprehensive understanding of the impact of technology, as both numerical data and personal insights are essential in assessing how technology influences learning and experimentation. Quantitative data will provide measurable results on the effectiveness of technology, while qualitative responses will enrich the findings with personal experiences and contextual details (Creswell, 2014; Johnson & Onwuegbuzie, 2004). By utilizing Google Forms, data collection is made efficient, accessible, and cost-effective, aligning with best practices in educational research (Nicol et al., 2019; Aydogdu, 2015). The combination of structured and open-ended questions ensures a balance of statistical rigor and rich, narrative data to address the research questions effectively.

1. Research Design

A survey will be administered to a sample of students enrolled in the Mathematics and Science faculties at UNIMED. The survey will include both closed-ended and open-ended questions. This combination will allow the researcher to capture statistical trends as well as personal insights into students' experiences with the integration of technology in their laboratory learning environments.

2. Participants

The target population consists of undergraduate students from the Mathematics and Science faculties at Universitas Negeri Medan. A stratified random sampling method will be used to ensure a representative sample of students from different courses within the faculties, ensuring diversity in the responses. Students will be invited to participate voluntarily via an email or online invitation, and participation will be anonymous.

3. Data Collection

Google Forms will be the primary tool for data collection. The form will be distributed to students electronically to ensure ease of access and to facilitate a broad sample size. The survey will consist of Likert

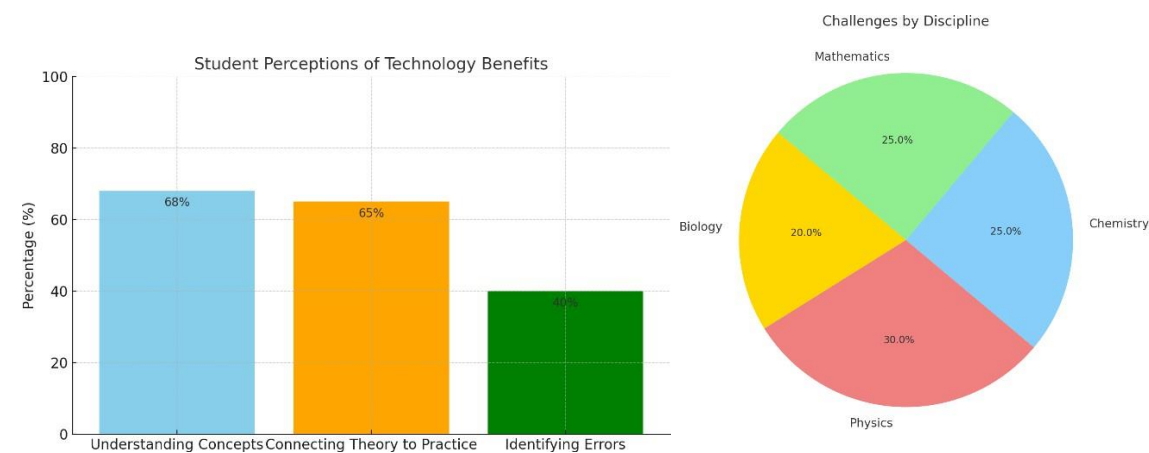
scale questions to gauge students’ perceptions of the effectiveness of technology in their learning process.

4. Data Analysis

Quantitative data from the Likert scale and multiple-choice questions will be analyzed using basic descriptive statistics (mean, frequency distribution, and percentage) to identify trends in students’ attitudes and experiences with technology in the lab. Qualitative data from the open-ended questions will undergo thematic analysis to identify key themes, patterns, and insights about students' experiences. Responses will be categorized into themes such as "access to technology," and "challenges."

RESULTS AND DISCUSSION

RESULTS



Quantitative Analysis

Based on the questionnaire data with 30 Participant

The survey included a diverse set of students from the Mathematics, Physics, Biology, and Chemistry programs at UNIMED, representing varied perspectives on the use of modern technology.

Perceived Benefits of Technology

1. Enhancing Understanding:

a. 68% of students agreed or strongly agreed that technology helped them better understand complex scientific concepts. Visualization tools like simulations and advanced microscopy were commonly cited as beneficial.

b. Theory-Practice Connection:

65% of students agreed that technology improved their ability to connect theoretical knowledge with practical applications.

c. Error Identification:

40% of students gave neutral or negative responses regarding technology’s role in identifying experimental errors, highlighting a potential gap in its effectiveness.

Challenges in Technology Use

1. Physics (30%)

Physics students reported the highest proportion of challenges. These included difficulties in operating advanced tools and understanding their functionalities, as well as frequent technical malfunctions. Students also highlighted the need for better training to maximize the utility of devices used in experiments.

2. Chemistry (25%)

Chemistry students experienced significant barriers related to troubleshooting equipment and adapting to newer technologies. Challenges with outdated devices and a lack of clear instructions were commonly noted.

3. Mathematics (25%)

Challenges in Mathematics were primarily related to the limited integration of technology into the curriculum. Students often found the available tools less relevant to their specific needs, leading to neutral responses in terms of technology's effectiveness.

4. Biology (20%)

Biology students faced relatively fewer challenges compared to other disciplines. While they appreciated the benefits of advanced tools like microscopes and data analysis software, they noted issues with equipment availability and maintenance.

Qualitative

Thematic analysis of open-ended responses revealed three main themes:

1. Positive Impact on Learning:

Students valued technology for improving efficiency, accuracy, and engagement in scientific learning. Many highlighted the potential for conducting innovative experiments and accessing real-time data.

Barriers to Effective Use:

a. Common challenges included insufficient training, technical malfunctions, and limited access to updated tools.

Physics and Chemistry students, in particular, mentioned that a lack of guidance hindered their ability to maximize the use of technology.

2. Recommendations for Improvement

a. Regular workshops to enhance technological literacy.

b. Updating laboratory equipment to meet current standards.

c. Providing user-friendly manuals and technical support during laboratory sessions.

DISCUSSION

The findings of this study, which incorporated both quantitative and qualitative data, shed light on the significant impact of modern technology on scientific learning and experimentation at Universitas Negeri Medan (UNIMED). The combination of structured surveys and in-depth thematic analysis of open-ended responses provided a comprehensive understanding of the benefits, challenges, and students' recommendations regarding the use of technology in their laboratory experiences.

1. Positive Impact of Technology on Learning and Experimentation

The quantitative analysis indicated that a majority of students perceived technology as a valuable tool in enhancing their understanding of complex scientific concepts and facilitating connections between theoretical knowledge and practical applications. Approximately 68% of students agreed that technology helped them better comprehend challenging material, and 65% noted improvements in connecting theory with practice. This finding aligns with existing research that supports the role of technology in facilitating deeper learning and engagement in STEM fields.

The qualitative data confirmed these results by highlighting that students appreciated the role of technology in improving the efficiency of data collection and analysis, allowing for more complex and innovative experiments that would be difficult or impossible without such tools. These findings suggest that modern technology can significantly contribute to the effectiveness of scientific education by providing interactive, simulation-based learning environments and supporting data-driven methodologies. Implications: To enhance these benefits, UNIMED could expand the integration of

advanced tools like virtual and augmented reality (AR/VR) for immersive learning experiences that could deepen students' conceptual understanding.

2. Challenges in Technology Integration

Despite the acknowledged benefits, several challenges were highlighted in both the quantitative survey and qualitative responses. The data showed that 45% of students found it difficult to use certain technologies due to insufficient training, which hindered their ability to maximize the tools' potential. Additionally, technical issues such as equipment malfunctions and outdated devices were frequently mentioned, affecting the overall efficiency of laboratory work.

These challenges were more pronounced in specific disciplines:

- a. Physics reported the highest proportion of challenges (30%), primarily related to the complexity of using advanced tools and troubleshooting when technical problems arose.
- b. Chemistry followed with 25%, with students citing issues like inadequate training and outdated lab equipment.

Mathematics also had 25% of responses indicating challenges, mainly due to the limited use of technology relevant to their courses.

- c. Biology faced the fewest challenges at 20%, suggesting that while students benefitted from technologies like microscopes and data analysis tools, issues with equipment maintenance and availability still existed.

Implications: UNIMED must focus on discipline-specific strategies to mitigate these challenges. For Physics and Chemistry, a stronger emphasis on training programs and routine equipment maintenance is essential. Mathematics could benefit from integrating specialized computational tools that align with their curriculum. Establishing regular workshops and creating a support system, such as a technical assistance team, could provide ongoing help and reduce barriers across departments.

3. Student Recommendations for Improvement

The thematic analysis of the open-ended responses yielded valuable suggestions. Common recommendations included:

- a. Training and Education: Students highlighted the need for pre-lab training sessions to better understand and operate new technologies.
- b. Updated Equipment: Many students called for the provision of modern tools and regular maintenance to ensure reliable lab experiences.
- c. Clear Guidance: Respondents suggested that user-friendly manuals and tutorials should be provided to support students in learning how to use the equipment effectively.

Technical Support: Establishing a team to assist students with technical issues and provide real-time solutions during lab sessions was deemed necessary.

Implications: UNIMED should consider implementing these recommendations by prioritizing comprehensive training programs, updating lab equipment, and ensuring clear instructions are available. Establishing a centralized technical support unit could also improve the overall student experience and reduce disruptions caused by equipment malfunctions.

4. Discipline-Specific Observations

The study highlighted the importance of tailoring technological strategies to the specific needs of each discipline:

- a. Biology students, who faced fewer challenges, benefited from practical tools that allowed for detailed analysis of organisms. This discipline could serve as a model for others, demonstrating that with the right resources and training, technology can be effectively integrated.

- b. Physics and Chemistry departments require more robust support due to the complexity of tools and the higher frequency of technical issues. Addressing these challenges could involve increased investment in equipment and comprehensive training workshops.
- c. Mathematics could leverage computational software and data visualization tools that better align with their field of study, making technology more relevant and impactful. Implications: Faculty-specific strategies should be developed that consider the unique demands and challenges of each department. Collaborative initiatives and knowledge-sharing workshops across disciplines can also foster a culture of shared learning and continuous improvement.

5. Overall Implications for UNIMED

The findings underscore that while the integration of modern technology in scientific education has substantial benefits, it is not without its challenges. To optimize the use of technology and maximize student learning outcomes, UNIMED should:

- a. Invest in Technology: Ensure that all labs are equipped with up-to-date technology and that maintenance is conducted regularly.
- b. Enhance Training Programs: Offer training sessions that prepare students for using advanced tools and create accessible resources, such as comprehensive user manuals.
- c. Implement Support Systems: Establish technical support teams to assist with real-time troubleshooting and ensure the smooth functioning of lab activities.
- d. Promote Cross-Disciplinary Collaboration: Facilitate knowledge exchange and training across different faculties to standardize best practices in technology usage.

CONCLUSION

This study investigated the role of modern technology in enhancing scientific learning and experimentation among mathematics and science students at Universitas Negeri Medan (UNIMED). The findings reveal that technological tools, including simulations, advanced microscopes, and data analysis software, have significantly contributed to improving students' understanding of complex scientific concepts. These tools have bridged the gap between theoretical knowledge and practical application, enabling students to engage more deeply with their learning material. In addition, the interactive and innovative features of these technologies were found to foster greater engagement, allowing students to explore scientific phenomena and conduct experiments that were previously inaccessible due to physical or resource constraints. Despite the evident benefits, the study also uncovered several challenges that hinder the optimal utilization of modern technology. These include outdated laboratory equipment, insufficient training for students and educators, and technical malfunctions. The impact of these barriers was more pronounced in Physics and Chemistry programs, where the complexity of tools and frequent technical issues were significant concerns. Mathematics students, while benefiting from certain computational tools, reported limited relevance of technology to their curriculum. Conversely, Biology students faced fewer challenges, largely due to the effective application of tools such as microscopes and data analysis software. However, even in Biology, issues such as equipment maintenance and availability persist, highlighting the need for continuous improvements across all disciplines. To address these challenges, this study emphasizes the need for strategic interventions at multiple levels. First, upgrading laboratory facilities with modern and relevant technologies is crucial to ensuring that students have access to the resources they need for effective learning and experimentation. Second, the introduction of comprehensive training programs for both students and educators can help build technological literacy and confidence in using advanced tools. Third, the establishment of dedicated technical support systems is essential for providing real-time assistance during laboratory sessions and minimizing disruptions caused by technical malfunctions. Additionally, tailored strategies should be developed for each discipline to address their unique needs, such as integrating computational software and data visualization tools in

Mathematics, and ensuring the availability of well-maintained, up-to-date equipment in Biology. By implementing these measures, UNIMED can maximize the transformative potential of modern technology, creating an inclusive and effective learning environment that empowers students to excel in their scientific pursuits. Moreover, the findings of this study underscore the importance of continuously adapting educational practices to align with technological advancements, ensuring that students are equipped with the skills and knowledge required to thrive in an increasingly technology-driven world. Future research should explore the long-term impacts of technology integration on academic performance and its applicability in other educational contexts to further strengthen the evidence base for optimizing technology use in higher education.

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