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THE IMPACT OF MODERN TECHNOLOGY ON SCIENTIFIC LEARNING AND EXPERIMENTATION: PERSPECTIVES FROM MATHEMATICS AND SCIENCE FACULTY STUDENTS AT UNIVERSITAS NEGERI MEDAN (UNIMED)

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ABSTRACT

This research explores the impact of modern technology on learning and experimentation among students of the Faculty of Mathematics and Science at Universitas Negeri Medan (UNIMED). Using a mixed-method approach, the study collected quantitative data through surveys and qualitative data through semi-structured interviews. The findings reveal that technological tools significantly enhance students' understanding of scientific concepts, improve experimental accuracy, and bridge the gap between theory and practice. However, challenges such as limited access to resources, insufficient training, and inconsistent integration of technology into the curriculum were identified. Recommendations include increasing resource availability, implementing structured training programs, and fostering consistent use of technology across courses. This study highlights the transformative potential of technology in science education and provides practical strategies to address existing barriers, ultimately preparing students for a technology-driven scientific landscape.

Keywords*: Modern Technology, Science Education, Laboratory Practices, Technological Impact, Student Learning.*

INTRODUCTION

The 21st century has witnessed rapid advancements in technology, revolutionizing various sectors, including education. In science education, technological integration has reshaped the way students learn, conduct experiments, and engage with complex concepts. Laboratory practices, which are integral to science education, have particularly benefited from these advancements, allowing for more accurate experimentation, enhanced learning experiences, and the fostering of innovative thinking among students.

The Importance of Technology in Science Education

The integration of technology in educational settings bridges the gap between theoretical knowledge and practical application. According to Garrison and Anderson’s Community of Inquiry framework (2003), technology enhances cognitive presence by providing tools that support deeper understanding and application of concepts. In laboratory settings, these tools improve students' ability to observe, analyze, and interpret scientific phenomena with greater precision.

For instance, digital microscopes allow for high-resolution visualization of microscopic structures, enabling students to explore cellular and molecular details that were previously inaccessible with traditional microscopes. Similarly, simulation software, such as PHET Interactive Simulations developed by the University of Colorado Boulder, facilitates virtual experiments, reducing dependency on physical resources while maintaining the accuracy of outcomes. Such simulations are particularly beneficial for understanding hazardous or resource-intensive experiments.

Enhancing Laboratory Learning Experiences

Modern technological tools make laboratory learning more engaging and interactive. According to Mayer’s (2005) Cognitive Theory of Multimedia Learning, multimedia tools such as animations, simulations, and videos enhance retention and understanding by addressing both verbal and visual processing channels. This theory supports the use of digital tools in laboratories, where students can visualize abstract scientific concepts and processes, such as chemical reactions or genetic mechanisms, in dynamic ways.

Moreover, data analysis tools like MATLAB, Excel, and SPSS streamline the process of collecting, processing, and interpreting experimental data. These tools not only enhance accuracy but also equip students with skills that are relevant in scientific research and industry practices.

Fostering Innovation through Technology

The incorporation of technology fosters a culture of innovation by encouraging students to think critically and creatively. As per Vygotsky’s Sociocultural Theory (1978), tools and technologies act as mediators of learning, helping students engage in higher-order cognitive tasks. In the laboratory, modern devices and software push students to explore beyond traditional methods, allowing them to hypothesize, experiment, and innovate with greater confidence.

For example, 3D printing technology has emerged as a transformative tool in scientific education. Students can design and produce physical models of molecular structures, prototypes, or experimental setups, thereby gaining a hands-on understanding of complex concepts. Similarly, tools like Arduino and Raspberry Pi provide opportunities for building automated experimental apparatuses, introducing students to interdisciplinary applications of science and technology.

Challenges and Opportunities

While the benefits of integrating technology in laboratories are evident, challenges remain. Limited access to advanced tools, a lack of proper training, and the high cost of procurement can hinder effective implementation. However, as technologies become more affordable and accessible, these barriers are gradually being addressed.

In conclusion, the integration of technology into science laboratories is not merely an enhancement but a necessity for modern education. By improving precision, deepening understanding, and fostering innovation, technology empowers students to become competent and creative scientists. As educators continue to adopt and adapt to these advancements, the potential for transformative learning experiences grows exponentially.

Technological advancements have significantly transformed the educational landscape, particularly in science education. Tools such as simulation software, digital data collection systems, and virtual laboratories have become integral to modern teaching methods. However, much of the existing research has focused on the general benefits of technology in education or its impact on primary and secondary school students. Studies specifically examining how these technological tools influence laboratory practices at the university level remain scarce, especially in the context of developing countries like Indonesia.

Laboratory practices play a critical role in shaping the scientific acumen of university students, bridging the gap between theoretical concepts and real-world applications. Yet, the integration of technology into these practices is often underexplored, with limited understanding of its direct impacts on students' learning processes, experimentation accuracy, and overall scientific competence.

Moreover, the unique challenges faced by students in accessing and utilizing modern technology in Indonesian universities have not been adequately addressed. For instance, infrastructure limitations, inadequate training, and varying levels of digital literacy may affect how students perceive and benefit from these technological advancements. This research aims to fill this gap by focusing specifically on the students of the Faculty of Mathematics and Science at Universitas Negeri Medan (UNIMED), providing a localized understanding of the role of technology in enhancing laboratory-based learning.

METHOD

Research Design

This study employs a mixed-method research design that combines both quantitative and qualitative approaches. This design allows for a comprehensive exploration of the impact of modern technology on scientific learning and experimentation among students in the Faculty of Mathematics and Science at UNIMED. The quantitative survey provides measurable data on student perceptions, while the qualitative interviews offer nuanced insights into their experiences and attitudes. This dual approach ensures a well-rounded understanding of the research problem.

Sampling Techniques

The participants of this study are undergraduates students from the Faculty of Mathematics and Science at UNIMED. This includes students majoring in Mathematics, Physics, Chemistry, and Biology, who are actively participating in laboratory practices as part of their coursework.

The study utilizes stratified random sampling to ensure a diverse and representative sample. Stratification is based on:

a. Major (Mathematics, Physics, Chemistry, Biology, etc.)
b. Academic year (from first-year to final-year students)

This approach ensures that the sample reflects the varied experiences and perspectives of students across different disciplines and stages of their academic journey.

Data Collection Methods

To ensure comprehensive and reliable data, this study employs both quantitative data collection methods, aligning with its mixed-method design.

Quantitative data are collected through an online survey distributed to students from the Faculty of Mathematics and Science at UNIMED. This survey includes Likert-scale questions, allowing participants to express their perceptions on a scale from 1 (strongly disagree) to 5 (strongly agree). The questions are designed to capture key aspects such as the impact of technology on their learning processes, its role in improving experimental efficiency, and the challenges they face accessing and using technological tools. The use of online surveys ensures accessibility and convenience for the participants while also facilitating efficient data collection and analysis.

To complement the quantitative findings, qualitative data are collected through semi-structured interviews with a purposive subsample of 20 students who participated in the survey. These interviews provide an in-depth understanding of individual experiences and attitudes toward the use of technology in laboratory practices. The interview guide focuses on themes such as detailed accounts of using technology during specific experiments, personal reflections on its effectiveness in enhancing learning, and suggestions for improving its integration into lab activities. By encouraging open-ended responses, the interviews allow students to share nuanced perspectives that may not be fully captured through the survey.

This combination of data collection methods ensures that the study gathers both measurable trends and detailed insights, offering a robust foundation for addressing the research question.

Data Analysis

The data analysis process in this study is designed to integrate findings from both quantitative and qualitative methods, ensuring a comprehensive understanding of the impact of technology on scientific learning and experimentation.

For the quantitative data, responses from the online survey will be analyzed using descriptive and inferential statistical techniques. Descriptive statistics, such as mean and standard deviation, will be employed to summarize participants' perceptions and attitudes toward technology in laboratory practices. Additionally, inferential analysis, particularly correlation analysis, will examine relationships between variables, such as perceived cases of using technological tools and their impact on learning outcomes. This statistical approach provides measurable insights into how students view and experience the role of technology in their academic practices.

For the qualitative data, a thematic analysis will be conducted on the transcripts from the semi-structured interviews. Thematic analysis involves a systematic process of identifying, analyzing, and interpreting patterns or themes within the data. First, the transcripts will be read multiple times to ensure familiarization with the content. Next, meaningful sections of the data will be coded and grouped into broader themes. For example, themes might include "Technology as a learning enhancer," "Barriers to technology adoption," or "Suggestions for improved implementation." These themes will then be reviewed and refined to ensure they align with the research objectives and are strongly supported by the data.

By combining these approaches, the study will integrate quantitative trends with qualitative insights, offering a holistic narrative. This integration not only highlights general patterns in student experiences but also captures the depth and complexity of individual perspectives, ensuring that the research questions are fully addressed and well-supported by evidence.

RESULTS AND DISCUSSON

Quantitative Findings

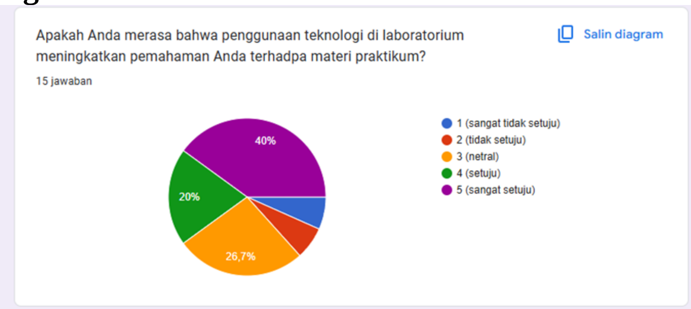

Figure 1 : Respondents from the 1st survey question

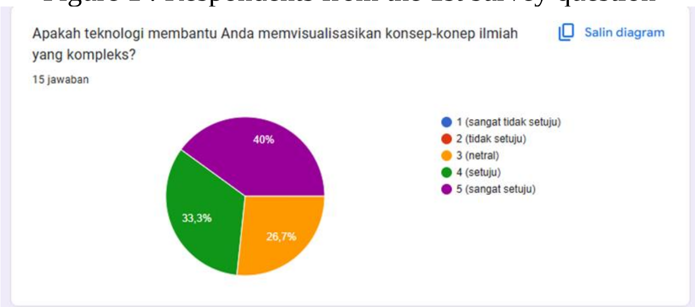

Figure 2 : Respondents from the 2ndt survey question

Figure 3 : Respondents from the 3rd survey question

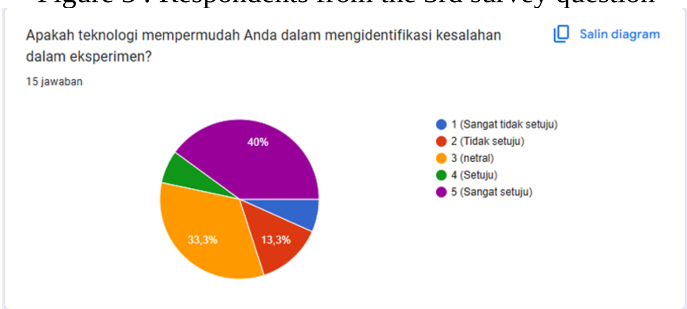

Figure 4 : Respondents from the 4th survey question

The survey results revealed that a significant percentage of students perceive technology as beneficial to their learning experiences in the laboratory. Approximately 80% of respondents agreed or strongly agreed that the use of technology enhances their understanding of complex scientific concepts. Among these, 60% strongly believed that technology helps bridge the gap between theory and practice, indicating a strong positive influence on comprehension and application of scientific principles.

Additionally, when comparing responses about tools used during experiments, students who frequently utilized advanced tools like simulation software or automated equipment reported higher satisfaction levels (70%) compared to those relying primarily on traditional methods (45%). Furthermore, nearly 85% of participants felt that technology expedited data analysis, demonstrating its efficiency in handling experimental results.

Qualitative Insights

From the open-ended responses, several recurring themes emerged regarding the benefits of technology in laboratory practices. Many students highlighted the efficiency of using modern tools, which allowed them to complete experiments faster and more accurately. For example, one student mentioned that technology significantly "increased precision and minimized human errors," while another noted that it "enabled visual learning through simulations, making abstract concepts easier to grasp."

However, the challenges faced by students were equally notable. A common concern was the learning curve associated with new technologies, with some students expressing difficulties in adapting to complex equipment without prior training. Others pointed out resource limitations, such as outdated tools or insufficient numbers of devices in the laboratory, which hindered their ability to fully utilize available technology. A few respondents mentioned feeling overwhelmed by technical glitches or lack of guidance during practical sessions.

Key Findings

The analysis revealed several noteworthy trends and correlations. First, students who frequently engaged with modern technology reported a noticeable improvement in their understanding of laboratory experiments and scientific concepts. This indicates that technology not only enhances engagement but also positively impacts academic performance by making learning more interactive and accessible.

Another significant finding was the relationship between access to resources and perceived benefits. Students with access to up-to-date tools consistently rated their learning experiences higher than those who relied on outdated or inadequate equipment. This suggests that the quality and availability of technological resources play a critical role in shaping students' attitudes toward laboratory practices.

On the other hand, challenges like insufficient training and equipment shortages highlighted areas where improvements are needed. These issues often led to frustrations and reduced confidence in using technology effectively. Despite these obstacles, most students expressed optimism about the role of technology in science education, emphasizing its potential to revolutionize learning and experimentation when implemented correctly.

In conclusion, the findings underscore the transformative potential of technology in education while also highlighting the importance of addressing challenges related to accessibility and skill development.

Discussion

Interpretation of Findings

The results of this study provide valuable insight into the role of technology in enhancing learning and laboratory practices among students of the Faculty of Mathematics and Science at UNIMED. These findings align with existing research, which frequently highlights the positive impact of technology on education, particularly in improving student engagement, precision, and efficiency during practical sessions.

One significant observation from the survey is that 80% of students agreed that technology enhances their understanding of scientific concepts, with 60% strongly affirming its role in bridging theory and practice. This aligns with studies by Dory and Belcher (2005), which demonstrated that using simulations and virtual labs helps students visualize abstract concepts more effectively, resulting in improved comprehension. For example, a respondent noted that tools like simulations "make it easier to understand the chemical processes" they previously struggled with when using only textbooks or traditional methods. This finding emphasizes the importance of integrating interactive tools into laboratory designs to support conceptual clarity.

The survey also revealed that students using advanced tools like data loggers or automated software reported higher satisfaction levels (70%) than tose relying on manual methods (45%). This echoes the findings by Mushra and Koehler (2006), which advocate for the Technological Pedagogical Content Knowledge (TPACK) framework, emphasizing how appropriate technology mentioned how modern tools saved time during data analysis, with one stating, “The calculations are so much faster and more accurate with the software, allowing me to focus more on interpreting results.” This efficiency supports a shift toward incorporating more technology-driven approaches in laboratory designs to optimize learning outcomes.

However, challenges such as the learning curve and limited access to tools also emerged as critical barriers. About 35% of respondents highlighted difficulty in adapting to new equipment, while several others cited insufficient resources as a major concern. One student commented, “There’s only one functional spectrophotometer in our lab, and it’s always a hassle waiting for my turn.” Such issues underline the need for better infrastructure and training programs to maximize the potential benefits of technology. These findings parallel studies by Kirkwood and Price (2014), which point out that inadequate access or lack of familiarity with technology can hinder its effectiveness in educational settings.

The implications of these findings are profound for both pedagogical methods and laboratory designs. On a pedagogical level, the positive response to technology suggests that instructors should integrate more digital tools into their teaching strategies. For example, incorporating virtual simulations or data analysis software in lectures can help students develop practical skills before stepping into the lab. This approach not only builds confidence but also prepares students for modern scientific practices.

From a laboratory design perspective, the results emphasize the importance of investing in up-to-date and accessible equipment. Ensuring that students have hands-on opportunities to use these tools is essential to fostering an environment that encourages exploration and innovation. Moreover, addressing the learning curve issue requires implementing training workshops or guided tutorials, allowing students to become proficient in using complex devices.

In conclusion, the findings of this study align with existing literature on the transformative potential of technology in education. By addressing challenges such as accessibility and training, educators and institutions can harness the full potential of technology to revolutionize learning and laboratory practices, preparing students for a more tech-driven scientific landscape.

Practical Implications

The findings of this research highlight both the benefits and challenges of using technology in laboratory settings. To ensure students can maximize these benefits wile overcoming the barriers, several strategies can be implemented. These recommendations focus on improving accessibility, skill development, and the overall integration of technology into lab practices.

One of the most pressing issues mentioned by students is the limited access to modern tools and equipment. Several respondents noted that they often had to wait their turn to use key instruments due to an insufficient number of devices. For instance, one student shared, “We only have one functional device for chromatography, and the queue delays our work.” To address this, institutions should prioritize investing in additional resources and ensuring an even distribution of tools across different labs. Establishing partnerships with external organizations or funding bodies can help secure modern equipment without imposing a financial burden on the institution.

Another challenge is the lack of technical proficiency among students when using advanced tools. About 35% of respondents indicated that they struggled to adapt to new technology without prior guidance. One student stated, “I felt lost the first time I used the data logger because no one explained it properly." To tackle this issue, universities can introduce regular training workshops tailored to specific tools or software commonly used in their laboratories. These workshops should focus on hands-on learning, enabling students to practice in a controlled environment. Additionally, offering online tutorials or user guides can help students revisit the material as needed.

Feedback from the survey also highlights the need for structured integration of technology into the curriculum. Many students expressed that while technology was useful, its application felt inconsistent or limited to certain courses. One respondent mentioned, "In some classes, we use software for analysis, but in others, we go back to manual methods, which feels inefficient." To optimize the use of technology, educators should collaborate to create a consistent plan for integrating tools into both theoretical and practical components of the curriculum. This might include using software for simulations in lectures or requiring students to submit digitally analyzed data as part of their lab reports.

Accessibility also plays a key role in ensuring students can effectively use technology. Responses from students suggest that resource availability outside scheduled lab hours would make a significant difference. For example, one participant proposed, "If the lab could stay open for longer hours, we could experiment more freely and explore the tools on our own." Institutions could address this by extending lab hours or creating a booking system that allows students to reserve time with specific equipment.

Lastly, fostering a supportive environment for troubleshooting is essential. Technical issues are a common source of frustration, with one student commenting, "When the software crashes, there's no one around to help, and we lose so much time." To mitigate this, labs could employ trained assistants or provide on-call technical support during lab hours. This would ensure that students can quickly resolve issues and maintain their focus on learning.

In conclusion, optimizing the use of technology in laboratory settings requires a multifaceted approach. Increasing the availability of resources, providing comprehensive training, integrating tools consistently across the curriculum, and offering technical support are key strategies to enhance the student experience. By implementing these measures, universities can empower students to fully leverage the benefits of technology, ultimately improving their learning outcomes and readiness for future scientific challenges.

Key Recommendations

The findings of this research highlight several ways to enhance the use of technology in laboratory settings for students at the Faculty of Mathematics and Science in UNIMED. Addressing the challenges identified in the survey and building on the positive feedback from students, these recommendations aim to create a better learning environment where technology can be utilized to its full potential.

First, improving access to modern tools and equipment is essential. Many students reported that the limited availability of devices often led to long waiting times, which disrupted their learning process. For example, a respondent mentioned the difficulty of conducting experiments when there was only one functional tool for the entire group. To address this issue, the university could invest in additional resources by seeking funding from external organizations or forming partnerships with industry. Introducing a simple booking system for equipment could also help manage access and reduce scheduling conflicts, ensuring that every student gets adequate hands-on experience.

Another critical area is providing students with proper training to use technology effectively. Several students shared their struggles when working with advanced tools without prior instruction. For instance, one participant expressed feeling "lost" when trying to use a data logger for the first time. To resolve this, the faculty could organize regular workshops that focus on specific devices or software. These sessions should emphasize hands-on practice, where students can learn in a supportive environment. Additionally, providing video tutorials or user-friendly guides could give students the flexibility to revisit the material whenever they need extra help.

Consistency in how technology is integrated into the curriculum is also vital. Some students observed that while technology was used effectively in certain classes, it was entirely absent in others. This inconsistency made their learning experience feel fragmented. Faculty members could work together to create a more unified approach, ensuring that both theoretical lessons and practical sessions include opportunities to engage with technology. For example, simulations could be used in lectures to explain complex concepts, while lab experiments could require the use of digital tools for data collection and analysis. This integration would help students see the connection between their classroom learning and practical applications.

Extending laboratory access is another way to improve students' experiences. Many participants suggested that longer lab hours or more flexible schedules would give them the freedom to explore technology without feeling rushed. One student even mentioned that having extra time in the lab would allow them to experiment independently and build confidence. To support this, the university could consider extending lab hours or creating specific time slots where students can work on their own projects. Having trained assistants or technicians available during these hours could also provide quick help when students face technical issues.

Finally, it's important to regularly evaluate and update the technology available in the labs. Science and technology are constantly evolving, and outdated tools can limit students' potential. By periodically reviewing the equipment and introducing new devices, the faculty can ensure that students are learning with resources that reflect industry standards. This not only prepares them for professional challenges but also keeps their education relevant in an increasingly technology-driven world.

In conclusion, these recommendations focus on creating a more supportive and resourceful learning environment for students. By increasing access to tools, offering proper training, integrating technology consistently, and extending lab hours, the university can empower students to fully utilize the benefits of modern technology. These efforts will not only improve their educational experience but also help them develop the skills needed for future scientific and professional success.

CONCLUSION

The study highlights the significant impact of modern technology on learning and experimentation in laboratory settings among students of the Faculty of Mathematics and Science at UNIMED. The findings confirm that technology enhances students' understanding of complex concepts, improves experimental accuracy, and bridges the gap between theoretical knowledge and practical application. Most students reported that using tools like simulations, data loggers, and analysis software made their learning more efficient and interactive, enabling them to achieve better outcomes.

However, challenges such as limited access to resources, a lack of training, and inconsistent integration of technology into the curriculum were identified as barriers to maximizing these benefits. For example, several students shared frustrations about outdated or insufficient laboratory equipment, which hindered their ability to engage fully in experiments. Others expressed difficulties in adapting to advanced tools without adequate instruction, highlighting the need for proper training.

The study underscores the importance of addressing these issues to fully realize the transformative potential of technology in science education. Recommendations include increasing access to modern equipment, implementing structured training programs, ensuring consistent integration of technology across courses, and extending laboratory hours to provide students with more opportunities for exploration.

In conclusion, technology is not just an enhancement but a necessity in modern education, especially in scientific disciplines. By investing in resources, training, and curriculum development, educational institutions can create an environment where students thrive academically and are better prepared for future scientific and professional challenges. These efforts will not only improve the quality of education but also empower students to innovate and excel in a technology-driven world.

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