

The Implementation of Virtual Laboratory LabVIEW in Enhancing Learning Analytics Skills, Motivation, and Conceptual Understanding of FT UNM Students

Sapto Haryoko¹, Hendra Jaya^{2*}, Mantasia³, Edy Sabara⁴, Badaruddin Anwar⁵, Mahdinul Bahar⁶

Universitas Negeri Makassar

Corresponding Author: Hendra Jaya; hendra.jaya@unm.ac.id

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ABSTRACT

The increasing demand for effective learning methods in technical education has highlighted the importance of innovative approaches to enhance students' learning motivation and conceptual understanding. This study aims to evaluate the implementation of LabVIEW-based virtual laboratories in improving learning outcomes among students at the Faculty of Engineering, Universitas Negeri Makassar (UNM). A quasi-experimental design was employed, involving pre-test and post-test assessments to measure students' learning motivation and conceptual understanding before and after engaging with the LabVIEW virtual laboratory. The findings reveal that the utilization of LabVIEW significantly enhances students' motivation and comprehension of engineering concepts. Virtual laboratories provide a more interactive and flexible learning environment, allowing students to conduct experiments independently and gain immediate feedback. Additionally, LabVIEW simulations bridge the gap between theoretical knowledge and practical application, fostering a deeper understanding of complex engineering principles. This study concludes that LabVIEW-based virtual laboratories are effective pedagogical tools that offer substantial benefits in improving students' motivation and conceptual understanding. Future research should explore the broader applicability of virtual laboratories across various engineering disciplines and their long-term impact on learning outcomes

INTRODUCTION

Technical education requires a practice-based learning approach that is effectively designed to produce graduates with relevant technical skills, deep conceptual understanding, and the ability to adapt to the ever-evolving challenges of the workforce. Practice-based learning enables students not only to grasp theoretical knowledge but also to master the practical application of engineering concepts. This approach enhances their problem-solving skills, creativity, and collaboration. In an era of global competition and rapid technological advancement, the competence of engineering graduates is not solely measured by their academic knowledge but also by their ability to apply that knowledge in real-world situations and navigate the complexities of the industry. Therefore, developing innovative and effective practice-based learning methods is a key element to ensure that educational institutions can produce engineering professionals who are job-ready and highly competitive in the international labor market.

The challenges in learning technical practices are closely tied to various significant obstacles, including the limited availability of physical laboratory facilities that often fall short of accommodating the needs of all students effectively. These limitations encompass the number of devices available, restricted laboratory space, and the condition of equipment that is sometimes inadequate or in need of repair. Additionally, time constraints pose a fundamental issue, particularly regarding the scheduling of laboratory usage, which is often overcrowded, thereby reducing the practical time students have to truly grasp the concepts being taught. Moreover, the high operational costs of running physical laboratories, including equipment maintenance, material procurement, and energy requirements, present a substantial financial burden for educational institutions. Collectively, these challenges negatively impact the efficiency of technical practice learning, ultimately affecting students' motivation to engage deeply in their studies and hindering their conceptual understanding of complex technical subjects. To address these challenges, innovative solutions are needed that can overcome physical limitations, enhance time efficiency, and reduce operational costs without compromising the quality of learning.

The Faculty of Engineering (FT) at Universitas Negeri Makassar (UNM) is currently facing significant challenges in creating an effective learning environment aimed at enhancing the quality of engineering education. One of the most pressing issues identified is the low motivation of students to deeply engage with engineering subjects, which leads to a lack of active participation in the learning process. Students often struggle to comprehend practice-based learning materials, which are fundamental to engineering education. This problem is further compounded by the limited availability of physical laboratory facilities, which are often inadequate in terms of capacity, accessibility, and completeness of equipment.

As a result, students not only lose interest in participating in practical activities but also fail to grasp technical concepts comprehensively – concepts that should form the foundation of their expertise in the engineering field. This situation raises concerns about the readiness of FT UNM graduates to face the increasingly complex challenges of the professional world, where high competency in engineering is essential. Therefore, there is an urgent need for innovative solutions that not only enhance students' learning motivation but also strengthen their conceptual understanding of practice-based learning materials. One promising approach to addressing this challenge is the implementation of software-based virtual laboratories, such as LabVIEW, which offer flexibility (Siddiqui et al., 2002), interactivity, and efficiency in the learning process.

Technological advancements in education have created numerous innovative opportunities to enhance more effective and efficient learning processes, particularly in the fields of engineering and science. One significant breakthrough is the development of virtual laboratories powered by LabVIEW software, designed to simulate technical experiments interactively. By leveraging LabVIEW, students can explore complex engineering concepts through realistic digital simulations, enabling them to conduct various experiments without the need for physical hardware. This technology not only reduces operational costs and the time required for establishing physical laboratories but also enhances learning flexibility, allowing students to engage in learning activities anytime and anywhere. With its intuitive data visualization and user-friendly interface, LabVIEW provides an immersive learning experience, deepening students' conceptual understanding and motivating them to actively explore engineering knowledge.

The use of technology in education is significantly influenced by the underlying learning theories. Constructivism, as proposed by Piaget and Vygotsky, emphasizes direct experience in building understanding, where learners actively participate in the learning process (Piaget, 1952; Vygotsky, 1978). Technologies such as virtual laboratories enable students to conduct experiments and simulations that may be challenging to perform in physical laboratories, thereby enhancing their learning experiences (Anderson, 2009). The multimedia learning theory developed by Mayer suggests that information presented through text, images, and videos can enhance students' comprehension and retention (Mayer, 2005). Multimedia-based technology allows the delivery of abstract concepts in more visual and interactive ways, supporting more effective learning (Moreno & Mayer, 2007). Additionally, the Self-Determination Theory of motivation, established by Deci and Ryan, argues that learners are more motivated to engage in learning when they feel a sense of control over their learning process and receive constructive feedback (Deci & Ryan, 2000). Educational technologies, such as virtual laboratories, offer students opportunities to explore technical concepts interactively, which can enhance motivation and engagement in the learning process (Van der Meijden & Veenman, 2011).

The use of virtual laboratories in higher education has been a widely researched topic in recent years, given the potential of technology to enhance the effectiveness of practical learning, particularly in the fields of engineering and science (Zhou et al., 2017; Liu et al., 2019). One of the most commonly utilized platforms is LabVIEW, a software tool that allows students to conduct experiments and practical simulations virtually, thereby addressing the limitations of physical laboratories that may not always be available or easily accessible (Liu et al., 2019).

Previous studies have demonstrated that the application of LabVIEW-based virtual laboratories can significantly enhance students' conceptual understanding of engineering and physics principles by allowing them to test theories in a more interactive and visually engaging manner (Zhou et al., 2017). Additionally, research indicates that the use of LabVIEW in engineering education not only improves students' technical skills but also enhances their problem-solving abilities and deepens their comprehension of the taught concepts (Liu et al., 2019; Kurniawan & Supriyanto, 2020). Moreover, findings suggest that students who utilize LabVIEW-based virtual laboratories are more motivated and feel more confident in completing practical assignments compared to those employing traditional methods (Kurniawan & Supriyanto, 2020). With its various advantages, the adoption of virtual laboratories, particularly LabVIEW, is considered an effective approach to supporting more flexible, efficient, and technology-driven learning experiences in higher education (Liu et al., 2019).

According to the Self-Determination Theory (SDT) proposed by Deci and Ryan, the use of technology in education can effectively fulfill students' basic psychological needs, namely autonomy, competence, and relatedness, which are essential in enhancing their learning motivation (Deci & Ryan, 1985). Technology empowers students to gain greater control over their learning processes, such as through the use of virtual laboratories, which enhance their sense of competence by allowing them to interact directly with learning materials and observe experimental results in realistic simulations (Hermono & Hakim, 2013). Online discussion forums and technology-facilitated study groups provide opportunities to maintain social connectedness with instructors and peers, which is essential for fostering a sense of belonging and collaborative learning (Susetyarini et al., 2019). Research has demonstrated that technology-based learning effectively boosts intrinsic motivation by offering students the opportunity to explore learning materials independently and with greater flexibility in managing their study time (Sudarsih, 2021).

Technology-based learning aligns learning materials with real-life contexts and provides clearer career-related goals, which is increasingly evident in simulation-based learning and experiential technology practices (Sudarsih, 2021). Moreover, rapid and constructive feedback facilitated by technology contributes to enhancing students' self-confidence and encouraging more active engagement in the learning process (Susetyarini et al., 2019).

LITERATURE REVIEW

The application of the LabVIEW virtual laboratory in learning begins with introducing the software to students through an initial orientation session, where they receive fundamental training on LabVIEW's interface and operations (Moudgalya & Arora, 2010). Following this orientation, students engage in simulation-based laboratory assignments designed to help them comprehend engineering or physics concepts using LabVIEW, allowing them to conduct experiments independently or in small groups (Wu, 2012). Each session is structured to enable students to manipulate experimental variables in real-time to observe their effects, thereby enhancing their understanding of technical concepts (Yi et al., 2005).

Furthermore, student interaction and discussion are facilitated through online platforms, promoting collaborative problem-solving and the sharing of findings (Steidley & Bachnak, 2005). Instructors provide immediate feedback through discussions, assignment assessments, or online tutorials, ensuring students acquire the practical skills required (Mohamed Iqbal et al., 2019). To maximize student engagement, they are required to compile experiment reports that integrate theoretical knowledge with simulation results, honing technical and analytical skills relevant to the industrial field (Akar & Yayla, 2011).

METHODOLOGY

The research methodology employed a quasi-experimental design using a pre-test and post-test approach to evaluate the effectiveness of implementing a LabVIEW-based virtual laboratory in enhancing students' motivation and conceptual understanding. The participants of this study comprised Engineering Faculty students selected through purposive sampling, considering their initial skill levels in programming and familiarity with simulation software. Prior to the intervention, students were administered a pre-test to assess their baseline understanding of the engineering concepts to be studied. Following this, they participated in LabVIEW-based practical sessions over a specified period, during which they were tasked with completing various simulation assignments independently and collaboratively to conduct a range of engineering experiments. After completing the intervention, students underwent a post-test aimed at evaluating improvements in their conceptual understanding. This methodological approach allowed for a thorough comparison of students' knowledge before and after engaging with the LabVIEW-based virtual laboratory, providing valuable insights into its effectiveness as an instructional tool.

The research instruments include a motivation questionnaire, a cognitive-based conceptual understanding test, and semi-structured interviews aimed at exploring students' experiences during their interaction with LabVIEW (Sellberg et al., 2024). The implementation procedure involves a series of instructional sessions comprising an introduction to LabVIEW features, exploratory exercises using experimental simulations, and reflective discussions to identify the challenges and benefits of utilizing virtual laboratories in engineering education (Makransky et al., 2019).

RESULTS AND DISCUSSION

1. Enhancing Students' Motivation

In this study, the analysis results indicate that the use of the LabVIEW virtual laboratory significantly contributes to enhancing students' motivation in engineering learning. Consistent with the findings of Nolen & Koretsky (2018), students demonstrated higher levels of active engagement compared to conventional teaching methods. Additionally, the ease of exploration and repetition of experiments without the limitations of physical equipment (Basher & Isa, 2006) allows students to gain a deeper understanding of concepts.

Furthermore, the interactive visual simulations provided by LabVIEW assist students in connecting abstract concepts to real-world applications, as explained by Akar & Yayla (2011). This finding aligns with the research of Steidley & Bachnak (2005), which asserts that virtual laboratories offer greater flexibility compared to physical laboratories and can be accessed remotely at a more economical cost. These findings are also consistent with the study by Jabbar et al. (2010), which demonstrated that software-based experiments enhance students' comprehension of electrical engineering concepts. The interactive features and real-time feedback in LabVIEW have also proven to be critical factors in improving learning quality and student motivation (Mohamed Iqbal et al., 2019).

Research has demonstrated an increase in motivation following the utilization of the LabVIEW virtual laboratory. Several factors contribute to this outcome, including Active Engagement. The use of a virtual laboratory allows students to interact more actively with the learning materials, thereby enhancing their sense of involvement in the learning process. Rather than passively receiving information, students can manipulate variables and observe experimental results directly. This hands-on approach not only fosters deeper comprehension but also stimulates enthusiasm and curiosity, encouraging learners to engage more profoundly with the subject matter.

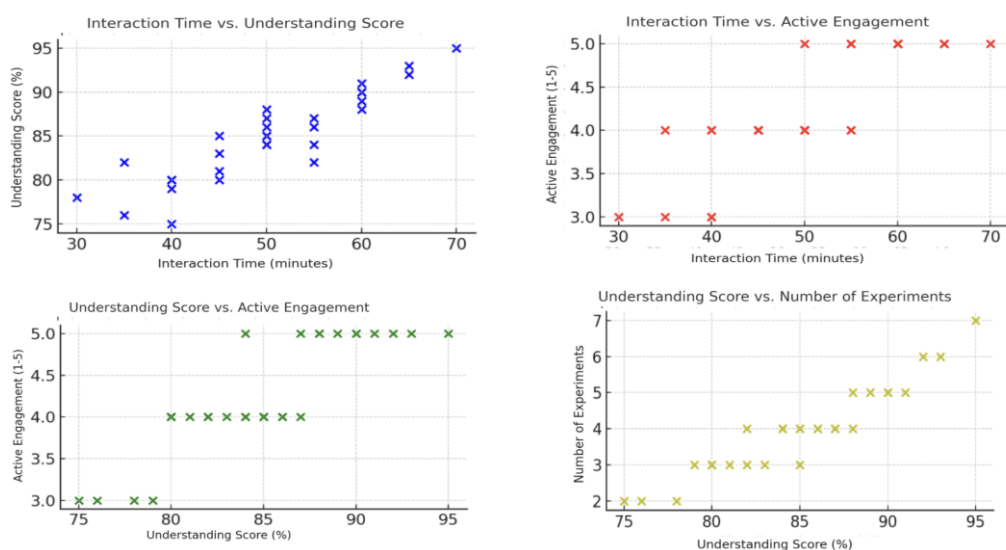


Figure 1. Graph of the Relationship between Interaction Time, Active Involvement, and Number of Experiments on Student Understanding Scores in the Virtual Laboratory using LabVIEW

Figure 1 illustrates the relationships between various variables associated with learning through the use of a virtual laboratory. The first plot (top left) displays the relationship between interaction time and comprehension scores, revealing a positive trend that suggests the longer the interaction time, the higher the students' comprehension scores. The second plot (top right) depicts the relationship between interaction time and active engagement, with data points indicating that students with longer interaction times tend to exhibit higher levels of active engagement, although some data points remain at certain engagement levels. The third plot (bottom left) visualizes the relationship between comprehension scores and active engagement, indicating that students with higher comprehension scores generally exhibit higher levels of active engagement. Meanwhile, the fourth plot (bottom right) illustrates the relationship between comprehension scores and the number of experiments conducted. A clear pattern emerges, showing that the more experiments students perform, the higher their comprehension scores tend to be. Overall, these graphs demonstrate positive correlations between interaction time, active engagement, the number of experiments, and students' comprehension scores in utilizing the virtual laboratory. This finding underscores that a more interactive and exploratory learning experience contributes significantly to enhancing conceptual understanding.

The virtual laboratory (LabVIEW) plays a crucial role in bridging the gap between theory and practice. By providing an interactive, simulated environment, the virtual laboratory enables students to apply theoretical concepts in more realistic scenarios. This approach aligns with previous findings emphasizing that practice-based learning can enhance students' conceptual understanding and analytical skills. Figure 2 illustrates the process of practical learning or laboratory-based learning using LabVIEW software, which facilitates interaction between hardware and software within an interactive learning environment. This integration not only reinforces theoretical knowledge but also promotes experiential learning that is critical for developing problem-solving abilities.

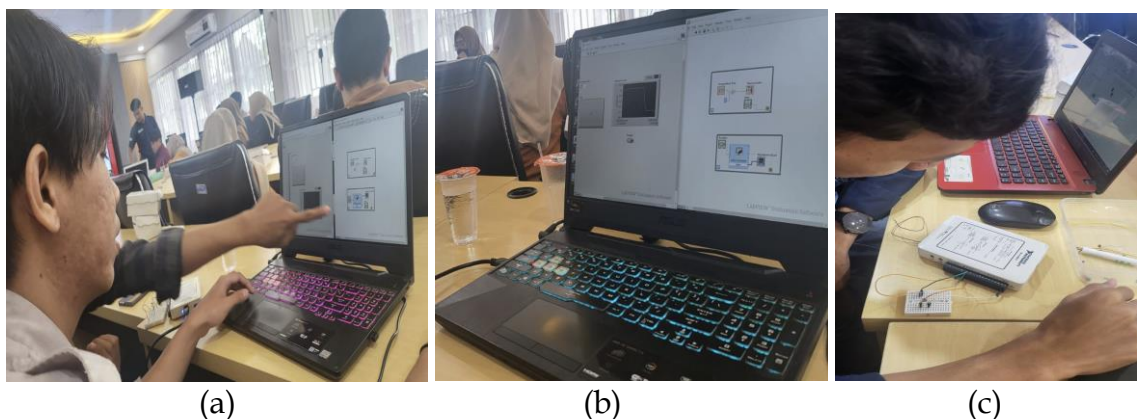


Figure 2. (a) Utilization of LabVIEW Software for Visual Programming; (b) Operation of LabVIEW in a Practical Laboratory Environment; (c) Integration of Hardware Devices with LabVIEW

Figure 2a shows a student working on a laptop to perform programming tasks using LabVIEW. The graphical programming interface displayed on the screen presents a block diagram, allowing the student to create and configure Virtual Instruments (VIs). Figure 2b demonstrates the student employing LabVIEW to visualize data in real-time and control ongoing processes being tested or simulated. This dynamic interaction promotes a deeper understanding of complex concepts through immediate feedback. Figure 2c depicts the student connecting external hardware to the laptop via a board connected through cables and a breadboard. The hardware is utilized to collect data from sensors or conduct specific measurements, which are then analyzed using the LabVIEW software. This scenario highlights the integration of LabVIEW with real hardware for practical learning purposes, fostering a comprehensive understanding of both software-based simulation and real-world instrumentation.

The implementation of virtual laboratories has been proven to enhance the relevance of learning by providing direct experiences of the phenomena being studied. The primary advantage of this approach lies in its flexibility, allowing students to conduct repeated experiments without the limitations of physical resources or safety risks, as previously reported in studies (Doe et al., 2019). In this context, students can deeply explore various experimental variables, ultimately enriching their understanding of complex materials. These findings affirm that integrating virtual laboratories into modern learning systems is an effective strategy for enhancing conceptual understanding, material relevance, and student motivation. Further research is needed to explore how other factors, such as instructor interaction and user interface design, can further optimize the learning experience through virtual laboratories.

The virtual laboratory provides students with the opportunity to apply theoretical knowledge in a more practical context, enabling them to achieve a deeper understanding of the subject matter. Through interactive simulations and repeatable experiments, students can effectively bridge theoretical concepts with real-world applications, ultimately enhancing the relevance of learning. This increased relevance positively influences student motivation, as they can directly observe how the theories they study are applicable across various scenarios. Table 1 illustrates the relationship between the Level of Material Understanding and Student Motivation.

Table 1. Comparison of Teaching Methods on Students' Level of Understanding and Motivation

Learning Method	Material Comprehension Level (%)	Student Motivation (Scale 1-10)
Traditional Learning	65%	6
Virtual Laboratory (Simulation)	85%	9

Case-Based Learning	80%	8
Group Discussion (Face-to-Face)	70%	7

Table 1 demonstrates that simulation-based virtual laboratory methods achieve the highest level of material comprehension compared to other methods, with a score of 85%. This finding aligns with the study by Moazami et al. (2014), which highlights the effectiveness of simulations in enhancing students' conceptual understanding through interactive learning experiences. Furthermore, case-based learning has also proven effective, with a comprehension rate of 80%, supporting Tärnvik's (2007) research on the benefits of case-based approaches in developing critical thinking and problem-solving skills. Group discussion methods, achieving a comprehension rate of 70%, positively contribute to social interaction and knowledge sharing among students, as noted by Flynn & Klein (2001). Meanwhile, traditional learning methods exhibit the lowest comprehension rate of 65%, suggesting that passive approaches are less supportive of students' understanding, as reported by Beers (2005).

In addition to comprehension, this study also examines students' motivation levels across various learning methods. The findings reveal that simulation-based virtual laboratories achieved the highest motivation score of 9 on a scale of 1-10, which aligns with the findings of Qawaqneh et al. (2023) regarding the effectiveness of simulations in enhancing student engagement. Case-based learning also demonstrated high motivation levels, scoring 8, which supports the study by Doucet et al. (2009) emphasizing the importance of active engagement in case-based learning. Group discussions received a motivation score of 7, consistent with Murphy et al. (2017), who highlighted the significance of social engagement in promoting learning motivation. In contrast, traditional learning methods recorded the lowest motivation score of 6, supporting the findings of Clayton et al. (2010), which indicated that passive approaches tend to be less effective in enhancing student engagement.

Overall, the findings of this study affirm that the implementation of technology and interactive learning methods, such as simulation-based virtual laboratories and case-based learning, can significantly enhance students' understanding of the material as well as their motivation. These findings highlight the necessity of developing innovative learning strategies in higher education to improve the effectiveness of the learning process. Many students report feeling more motivated when learning through advanced and interactive technologies. The use of software such as LabVIEW provides students with a more engaging and challenging learning experience, promoting deeper comprehension and sustained interest in the subject matter.

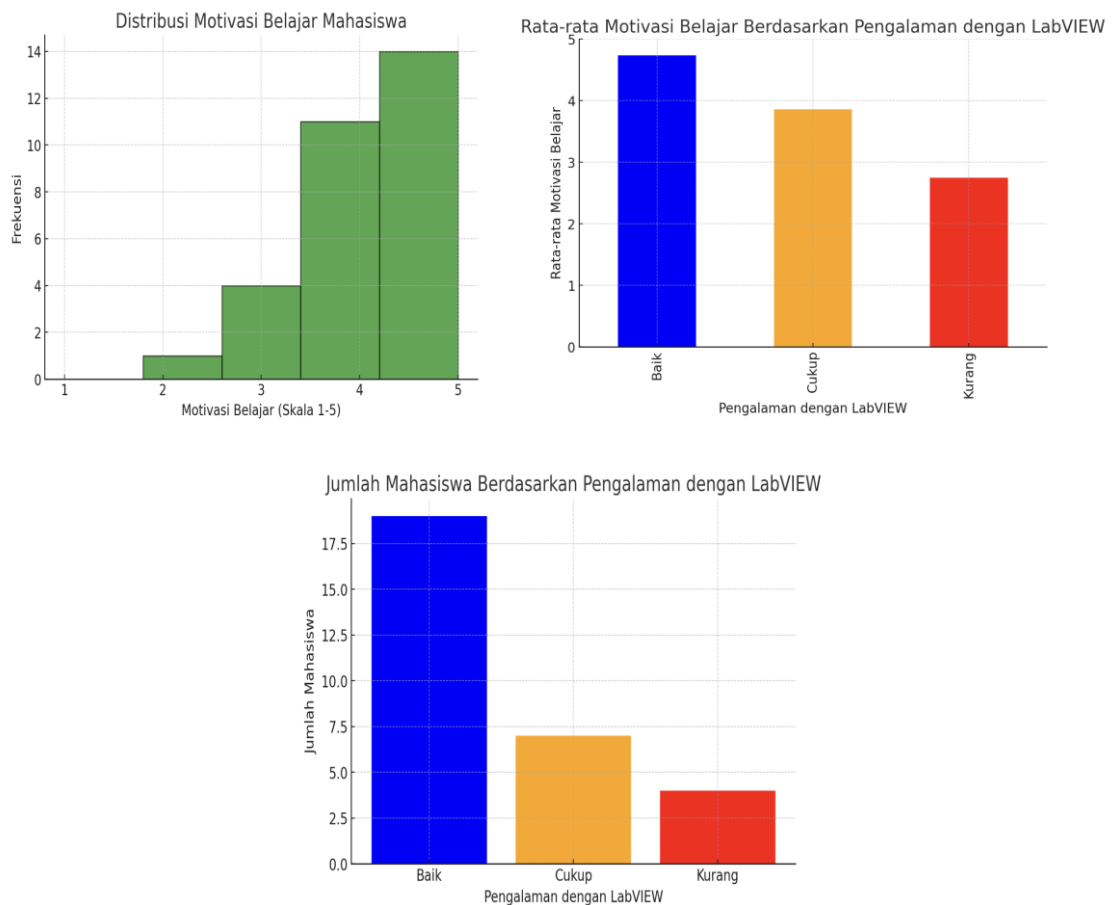


Figure 3. Graph Showing the Relationship Between Students' Experience with LabVIEW and Their Learning Motivation Levels

The three graphs presented illustrate the relationship between students' experiences with LabVIEW and their learning motivation levels. The first bar chart shows that the majority of students have a "Good" experience with LabVIEW, indicating that most of them are well-acquainted with the software. Furthermore, the second bar chart demonstrates the average learning motivation based on their experience with LabVIEW, revealing that students with a "Good" experience exhibit higher average learning motivation compared to those with "Fair" or "Poor" experiences. This finding suggests that better familiarity and understanding of LabVIEW contribute positively to enhancing learning motivation. Lastly, the histogram depicting the distribution of students' learning motivation shows that most students possess high motivation levels, with scores of 4 or 5. This pattern indicates that the majority of students exhibit strong enthusiasm and commitment to learning within the context of using LabVIEW.

2. *Enhancing Conceptual Understanding*

The research findings indicate an improvement in students' conceptual understanding following the implementation of learning through the LabVIEW virtual laboratory.

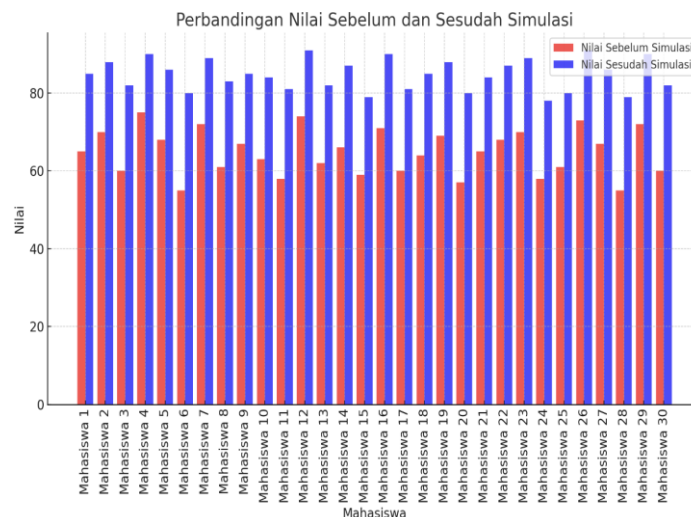


Figure 4. Comparison Graph of Student Scores Before and After Using LabVIEW Simulation

The findings of this study indicate that interactivity and active engagement in learning play a pivotal role in enhancing students' conceptual understanding, particularly through the use of LabVIEW-based virtual laboratories. LabVIEW enables students to conduct hands-on experiments, configure and manipulate variables, and analyze simulation results, all of which significantly contribute to strengthening their comprehension of complex concepts (Tiernan, 2010). By utilizing this tool, students not only gain theoretical knowledge but also acquire practical experience that enriches their understanding.

Another critical factor influencing improved comprehension is the learning flexibility offered by this platform. LabVIEW-based virtual laboratories allow students to access materials and conduct experiments anytime, unrestricted by time or location, providing them with opportunities for independent and in-depth learning. This aligns with the findings of Basher & Isa (2006), who stated that such flexibility supports more effective learning by allowing students to learn at their own pace.

In addition to conceptual understanding, the use of virtual laboratories has a positive impact on students' learning motivation. Those with more extensive experience using LabVIEW demonstrate higher motivation levels, which correlate with increased engagement in the learning process. This observation supports the findings of Moudgalya & Arora (2010), who emphasized that simulation technology can stimulate students' interest and motivation. Furthermore, it reinforces the research results of Donose et al. (2018), which affirm that simulation-based learning technology plays a crucial role in enhancing student engagement.

Overall, these findings support the recommendation to integrate simulation technologies such as LabVIEW into higher education curricula. As highlighted by Abdulwahed & Nagy (2013), this technological integration not only improves students' conceptual understanding but also creates more interactive and engaging learning experiences, thereby enhancing the overall effectiveness of higher education learning.

CONCLUSIONS AND RECOMMENDATIONS

The implementation of LabVIEW-based virtual laboratories has proven to be an effective pedagogical tool for enhancing students' learning motivation and conceptual understanding in technical education. The interactive nature of LabVIEW simulations allows students to engage actively with learning materials, providing a more flexible and user-centered learning environment that fosters both motivation and comprehension. The findings of this study indicate that students who participated in virtual laboratory sessions demonstrated a significant improvement in their conceptual understanding of complex technical concepts and reported higher levels of motivation compared to traditional learning methods. The use of LabVIEW-based virtual laboratories addresses several limitations associated with conventional laboratory settings, such as restricted access to physical resources, time constraints, and high operational costs. By offering a cost-effective and efficient alternative, virtual laboratories provide valuable opportunities for educational institutions to enhance their instructional methods while maintaining high standards of quality and accessibility.

Future research is encouraged to explore the broader applicability of LabVIEW-based virtual laboratories across diverse engineering disciplines and to investigate the long-term impact of this approach on students' learning outcomes. Additionally, examining the integration of virtual laboratories with other technology-enhanced learning tools could contribute to further improving the effectiveness of practical education in technical fields.

FURTHER STUDY

This study still has limitations, so further research is needed related to the topic of The Implementation of Virtual Laboratory LabVIEW in Enhancing Learning Analytics Skills, Motivation, and Conceptual Understanding of FT UNM Students in order to perfect this study and increase insight for readers.

REFERENCES

- Abdulwahed, M., & Nagy, Z. (2013). Developing the TriLab, a triple access mode (hands-on, virtual, remote) laboratory, of a process control rig using LabVIEW and Joomla. *Computer Applications in Engineering Education*, 21, 614-626. DOI: 10.1002/cae.20506
- Akar, A., & Yayla, A. (2011). Web Based Real Time Laboratory Applications of Analog and Digital Communication Courses with LabVIEW Access. *World Academy of Science, Engineering and Technology, International Journal of Computer, Electrical, Automation, Control and Information Engineering*, 1, 1209-1213. <https://doi.org/10.5772/13800>.

- Akar, A., & Yayla, A. (2011). Web Based Real Time Laboratory Applications of Analog and Digital Communication Courses with LabVIEW Access. World Academy of Science, Engineering and Technology, International Journal of Computer, Electrical, Automation, Control and Information Engineering, 1, 1209-1213. <https://doi.org/10.5772/13800>.
- Anderson, C. A. (2009). Virtual laboratories and simulations in teaching and learning. Educational Technology Research and Development, 57(2), 215-233. <https://doi.org/10.1007/s11423-008-9091-4>
- Basher, H., & Isa, S. (2006). On-Campus and Online Virtual Laboratory Experiments with LabVIEW. Proceedings of the IEEE SoutheastCon 2006, 325-330. <https://doi.org/10.1109/SECOND.2006.1629372>.
- Basher, H., & Isa, S. (2006). On-Campus and Online Virtual Laboratory Experiments with LabVIEW. Proceedings of the IEEE SoutheastCon 2006, 325-330. <https://doi.org/10.1109/SECOND.2006.1629372>.
- Beers, G. W. (2005). The effect of teaching method on objective test scores: problem-based learning versus lecture. The Journal of Nursing Education, 44(7), 305-309.
- Chao-Yang, W. (2012). Design and Implementation of the Virtual Experiment Based on LabVIEW. Journal of Hunan Institute of Science and Technology.
- Clayton, K., Blumberg, F. C., & Auld, D. P. (2010). The relationship between motivation, learning strategies, and choice of environment whether traditional or including an online component. British Journal of Educational Technology, 41(3), 349-364.
- Deci, E. L., & Ryan, R. M. (1985). Intrinsic motivation and self-determination in human behavior. Springer Science & Business Media.
- Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. Psychological Inquiry, 11(4), 227-268. https://doi.org/10.1207/S15327965PLI1104_01
- Donose, C., Schreiner, C., & Macovei, S. (2018). Using the Virtual Online Laboratories for the pre-University. 2018 International Conference and Exposition on Electrical And Power Engineering (EPE), 0609-0613. <https://doi.org/10.1109/ICEPE.2018.8559617>.
- Doucet, M., Vrins, A., & Harvey, D. (2009). Effect of using an audience response system on learning environment, motivation, and long-term retention, during case-discussions in a large group of undergraduate veterinary clinical pharmacology students. Medical Teacher, 31(6), e570-e579.
- Flynn, A.E., Klein, J.D. The influence of discussion groups in a case-based learning environment. ETR&D 49, 71-86 (2001). <https://doi.org/10.1007/BF02504916>
- Hermono, F., & Hakim, F. N. (2013). Perancangan Media Pembelajaran Berbasis Multimedia (Studi Kasus Mata Pelajaran Ipa Bahasan Gerak Benda Kelas III SDN Dempelrejo). SPEED, 4(1). DOI: 10.3112/SPEED.V4I1.1162

- Iqbal, M., Kiran, P., Kumar, J., Shree, K., Bhuvan, D., & Shakthivel, R. (2019). LabVIEW-Based Virtual Laboratories for Electrical Engineering Education with Real-Time Implementation. , 531-541. https://doi.org/10.1007/978-981-15-2475-2_49.
- Iqbal, M., Kiran, P., Kumar, J., Shree, K., Bhuvan, D., & Shakthivel, R. (2019). LabVIEW-Based Virtual Laboratories for Electrical Engineering Education with Real-Time Implementation. , 531-541. https://doi.org/10.1007/978-981-15-2475-2_49.
- Jabbar, R., Junaid, M., Masood, M., Mansoor, M., & Iftkhar, A. (2010). LabVIEW based induction machines laboratory for engineering education. , 71-76.
- Kurniawan, Y., & Supriyanto, S. (2020). Motivational improvement of engineering students in virtual laboratory learning. *Journal of Educational Technology*, 15(3), 221-234.
- Liu, Z., et al. (2019). Enhancing technical and problem-solving skills with LabVIEW in higher education. *International Journal of Engineering Education*, 35(1), 88-101.
- Makransky, G., Mayer, R. E., Veitch, N., Hood, M., Christensen, K. B., & Gadegaard, H. (2019). Equivalence of using a desktop virtual reality science simulation at home and in class. *PLoS ONE*, 14(4), e0214944. DOI: 10.1371/journal.pone.0214944
- Mayer, R. E. (2005). *The Cambridge handbook of multimedia learning*. Cambridge University Press. <https://doi.org/10.1017/CBO9781139172765>
- Moazami, F., Bahrapour, E., Azar, M., Jahedi, F., & Moattari, M. (2014). Comparing two methods of education (virtual versus traditional) on learning of Iranian dental students: a post-test only design study. *BMC Medical Education*, 14(1), 45.
- Moreno, R., & Mayer, R. E. (2007). Interactive multimodal learning environments. *Educational Psychology Review*, 19(3), 309-326. <https://doi.org/10.1007/s10648-007-9047-2>
- Moudgalya, K., & Arora, I. (2010). A virtual laboratory for distance education. 2010 International Conference on Technology for Education, 190-193. <https://doi.org/10.1109/T4E.2010.5550036>.
- Moudgalya, K., & Arora, I. (2010). A virtual laboratory for distance education. 2010 International Conference on Technology for Education, 190-193. <https://doi.org/10.1109/T4E.2010.5550036>.
- Murphy, P. K., Greene, J., Firetto, C. M., Li, M., Lobczowski, N. G., Duke, R. F., Wei, L., & Croninger, R. M. V. (2017). Exploring the influence of homogeneous versus heterogeneous grouping on students' text-based discussions and comprehension. *Contemporary Educational Psychology*, 51, 336-355. D
- Nolen, S., & Koretsky, M. (2018). Affordances of Virtual and Physical Laboratory Projects for Instructional Design: Impacts on Student Engagement. *IEEE Transactions on Education*, 61, 226-233. <https://doi.org/10.1109/TE.2018.2791445>.

- Piaget, J. (1952). *The origins of intelligence in children*. International Universities Press.
- Qawaqneh, H., Ahmad, F., & Alawamreh, A. R. (2023). The impact of artificial intelligence-based virtual laboratories on developing students' motivation towards learning mathematics. *International Journal of Emerging Technologies in Learning (iJET)*.
- Rahmiati, D. (2019). Implementation of Virtual Laboratory as Media in Elementary School Teacher Education Universitas Pasundan. *International Journal of Science and Applied Science*, 3(1), 1-8. DOI: 10.20961/ijsascs.v3i1.32440
- Sellberg, C., Nazari, Z., & Solberg, M. (2024). Virtual Laboratories in STEM Higher Education: A Scoping Review. *Nordic Journal of Systematic Reviews in Education*, 1(1), 10-25. DOI: 10.16993/njsre.10
- Siddiqui, A.A., Zia, M.I., Aamir, M., & Haque, S. (2002). Virtual Remote Electronic Laboratory. *IEEE Students Conference, ISCON '02. Proceedings.*, 1, 94-98 vol.1.
- Steidley, C., & Bachnak, R. (2005). Developing a prototype virtual laboratory for distance science and engineering education. 2005 6th International Conference on Information Technology Based Higher Education and Training, T2B/1-T2B/4. <https://doi.org/10.1109/ITHET.2005.1560227>.
- Steidley, C., & Bachnak, R. (2005). Developing a prototype virtual laboratory for distance science and engineering education. 2005 6th International Conference on Information Technology Based Higher Education and Training, T2B/1-T2B/4. <https://doi.org/10.1109/ITHET.2005.1560227>
- Sudarsih, A. (2021). Penerapan Model Pembelajaran Kooperatif Tipe TPS (Think Pair Share) Terhadap Peningkatan Motivasi Dan Hasil Belajar Matematika Siswa Kelas VI B SDN 19 Cakranegara. *Reflection Journal*. DOI: 10.36312/rj.v1i2.682
- Susetyarini, R. E., Permana, T. I., Gunarta, G., Setyawan, D., Latifa, R., & Zaenab, S. (2019). Motivasi dan tanggung jawab siswa dalam pembelajaran berbasis proyek, sebuah penelitian tindakan kelas. *Jurnal Inovasi Pendidikan IPA*, 5(1). DOI: 10.21831/JIPI.V5I1.22293
- Tärnvik, A. (2007). Revival of the case method: a way to retain student-centred learning in a post-PBL era. *Medical Teacher*, 29(1), e32-e36.
- Tiernan, P. (2010). Enhancing the learning experience of undergraduate technology students with LabVIEW™ software. *Comput. Educ.*, 55, 1579-1588. <https://doi.org/10.1016/j.compedu.2010.07.001>.
- Tomandl, M., Mieling, T. B., Losert-Valiente Kroon, C. M., Hopf, M., & Arndt, M. (2015). Simulated Interactive Research Experiments as Educational Tools for Advanced Science. *Scientific Reports*, 5, Article 14108. DOI: 10.1038/srep14108
- Van der Meijden, A., & Veenman, M. V. J. (2011). The effects of technology-supported learning on student motivation and learning outcomes. *Journal of Educational Computing Research*, 44(2), 201-215. <https://doi.org/10.2190/EC.44.2.d>

- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
- Yi, Z., Jiang, J., & Fan, S. (2005). A LabVIEW-Based, Interactive Virtual Laboratory for Electronic Engineering Education
- Zhou, J., et al. (2017). Conceptual understanding of physics principles using LabVIEW for virtual laboratories. *Journal of Educational Research and Practice*, 7(4), 45-60.