Utilization of Automation Studio Software to Enhance the Ability to Design Ladder Diagrams for 3-Phase Motor Control Systems

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ABSTRACT

This study investigated the effectiveness of Automation Studio software in enhancing electrical engineering students' ability to design ladder diagrams for three-phase motor control systems. Using a quasi-experimental pretest-posttest design, 30 students participated in a four-week training program. Data were collected through competency assessments focusing on basic knowledge, component analysis, problem-solving, and system design. The results revealed significant improvements across all areas: average scores increased from 54 to 92 in basic knowledge (70%), 52 to 78 in component analysis (51%), 52 to 80 in problem-solving (54%), and 33 to 80 in system design (143%). These findings demonstrate the software's capacity to bridge the gap between theoretical knowledge and practical application, fostering critical thinking and technical proficiency. This research highlights the potential of simulation-based learning tools like Automation Studio to enhance engineering education, equipping students with industry-relevant skills and preparing them for complex technological challenges.

Keywords: Ladder diagram, Three-phase motor, Automation Studio, Control system, Engineering education

INTRODUCTION

The increasing demand for efficient and reliable motor control systems in industrial automation underscores the importance of equipping students with relevant technical skills (Wang, 2021). Ladder diagrams, as a foundational programming tool for programmable logic controllers (PLCs), play a critical role in this context owing to their intuitive and graphical representation of control processes. However, traditional teaching methods often fail to effectively convey these concepts, leaving students unprepared for the complexities of real-world applications. To address this gap, this study explored the potential of Automation Studio, an interactive simulation software, to enhance students' ability to design ladder diagrams for three-phase motor control systems.

This graphical programming method is particularly advantageous in industrial automation because it allows engineers to effectively visualize control processes. The popularity of ladder diagrams can be attributed to their ease of understanding, which facilitates communication between engineers and technicians, especially those with an electrical background (Aurachman, 2021). Three-phase motor control has emerged as a significant field in the electrical engineering curriculum, wherein students are expected to design and implement reliable control systems. To enhance students' capacity to design ladder diagrams for three-phase motor control systems, the utilization of automation software such as Automation Studio has become increasingly pertinent (Jamadar et al., 2018). However, many students struggle to comprehend and design such control systems. This often results from the limited efficacy of conventional teaching methodologies (Sariman, 2019). Research indicates that more interactive and visual learning approaches can facilitate improved student understanding of concepts and technical skills (Putra, 2024). Consequently, the application of software such as Automation Studio has become highly relevant in this context.

Automation Studio is a simulation tool designed to support motor control system learning through a visual and interactive approach. The interactive features of the software, such as the ability to trace programs and monitor input and output statuses, can significantly enhance the learning process of technicians who are novices in ladder diagram programming (Aurachman, 2021). The utilization of this software has demonstrated effectiveness in enhancing students' comprehension of electrical engineering concepts, including the design of ladder diagrams for three-phase motor control systems (Muslimin, 2023). Previous research indicates that students who employ Automation Studio exhibit significant improvement in designing and understanding control systems compared to those who solely utilize traditional learning methods (Joelianto & Dananjaya, 2020). This evidence suggests that the integration of technology into education can provide practical solutions to enhance students' competencies.

Given the increasing demand for proficiency in designing motor control systems, this study aimed to evaluate the effectiveness of Automation Studio in improving students' ability to design ladder diagrams. To understand the background and relevance of this tool in engineering education, we first examined the existing literature. By adopting technology-based learning methods, it is anticipated that students will experience improved comprehension and application of the concepts being taught (Gianto 2021). Additionally, this research is expected to contribute to the development of more innovative and effective learning methods in electrical engineering education, thereby preparing students to address industrial challenges (Saputra 2023).

Thus, the utilization of Automation Studio in the learning of three-phase motor control systems not only enhances students' technical skills but also prepares them to contribute effectively in the increasingly complex and technology-driven industrial environment (Pratama & Hendini, 2019). This study is expected to provide new insights into the development of more effective and relevant learning methods in the current digital era. This study underscores the importance of equipping students with tools such as Automation Studio to meet the demands of modern engineering education. To contextualize the relevance of this approach, we first explore the existing literature on the role of simulation software in enhancing learning outcomes.

LITERATURE REVIEW

The increasing use of simulation software and tools across engineering disciplines has led to the development of interactive and visually engaging learning approaches. This is particularly evident in education, where simulation tools such as Physics Education Technology (PhET) effectively enhance understanding of physics concepts through interactive and visual learning experiences (Mas'ud & Maemunah, 2022). The use of these simulations not only helps students understand complex material but also increases their engagement in the learning process (Mas'ud & Maemunah, 2022). In an engineering context, simulation software and tools play a vital role in enhancing learning effectiveness. For example, research conducted by Ilham shows how business game applications can be used in entrepreneurship learning, which emphasizes interaction and hands-on experiences for students (Ilham, 2023).

This approach is in line with the need to create a more dynamic and responsive learning environment to students' needs, especially in engineering fields that often involve abstract concepts that are difficult to understand without proper visualization. Furthermore, the use of information and communication technology (ICT) in education has significantly contributed to students' logical thinking skills (Kurniyawati & Prastowo, 2021). This includes the incorporation of ICT-based simulations. By utilizing simulation-based learning models, students can easily understand and apply the concepts taught, which in turn improves their learning outcomes (Munawir, 2023).

This shows that the integration of simulation software and tools into the engineering education curriculum not only increases student engagement but also improves overall academic outcomes. Overall, the increasing use of simulation software and tools in engineering education has created an urgent need for more interactive and visually engaging learning approaches. This is not only beneficial for students in understanding the material but is also important to prepare them for the challenges of an increasingly complex and technology-based professional world. While existing studies emphasize the broad benefits of simulation tools in education, this research specifically focuses on the role of Automation Studio in improving students' competencies in designing ladder diagrams for complex motor control systems. Building on these insights from existing research, the following section details the methodology employed to assess the impact of Automation Studio on students' learning outcomes. Building on these insights from existing research, the following section details the methodology employed to assess the impact of Automation Studio on students' learning outcomes. The literature highlights the value of simulation tools in fostering understanding and engagement in engineering education. Building on these insights, this study employed a quasi-experimental approach to assess the specific impact of Automation Studio on students' learning outcomes.

METHOD

This investigation employed a quasi-experimental methodology with a pre-test–post-test design. The research participants consisted of 30 students from the electrical engineering program, selected through purposive sampling. Competency assessment was used as the data collection instrument. This assessment evaluates basic knowledge, component analysis, problem-solving skills, and system design capabilities. The research protocol encompassed three phases: administering a pre-test to measure the students' initial competencies, conducting training using Automation Studio for four weeks, and implementing a post-test to quantify the improvement in abilities. The data were analyzed using descriptive statistics to calculate the mean, standard deviation, and percentage of improvement, as well as a t-test to examine the statistical significance of the difference between the pretest and posttest results. The subsequent section presents the results of the analysis, followed by a detailed discussion of their implications. The subsequent section presents the results of the analysis, followed by a detailed discussion of their implications.

RESULT AND DISCUSSION

The following section discusses the implications of these findings in detail. The following section discusses the implications of these findings in detail, highlighting their significance and potential applications in engineering education. High lighting their significance and potential applications in engineering education.

Result

Furthermore, the results of the paired samples test in Table I show a comparison of scores.

Table I Pretest And Posttest Results

Student	Pretest	Posttest
S1	55	90
S2	45	80
S3	40	85
S4	40	80
S5	65	80
S6	40	85
S7	40	85
S8	45	80
S9	40	75
S10	55	80
S11	40	85
S12	55	80
S13	50	80
S14	50	80

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Student	Pretest	Posttest
S15	35	70
S16	35	80
S17	40	90
S18	45	80
S19	45	80
S20	50	85
S21	55	80
S22	35	75
S23	65	85
S24	45	80
S25	60	85
S26	65	95
S27	55	85
S28	50	85
S29	40	90
S30	55	90

S1…30 = Student 1…30

Furthermore, the data in Table II were analyzed using SPSS software, providing insights into the statistical significance of the observed improvements. This analysis calculated the mean and standard deviation and conducted a t-test to assess the statistical significance of the differences between the pre-test and post-test results.

Table II Paired Sample Test

Aspect	Mean Difference	Std. Deviation	t-value	p-value	Improvement (%)
Basic Knowledge	-37.67	14.55	-14.18	0.000	70%
Component Analysis	-26.33	13.52	-10.67	0.000	51%
Problem Solving	-28.00	14.95	-10.26	0.000	54%
System Design	-47.33	13.11	-19.77	0.000	143%

All four aspects exhibited statistically significant differences between the pre-test and post-test scores ($p < .05$). The negative mean differences indicated reductions in scores from pre-to post-test across all aspects, demonstrating measurable changes in performance. The results of the paired samples test indicated significant improvements across all measured areas. To better understand the implications of these findings, we discuss how these improvements align with the research objectives and explore the potential impact of Automation Studio on students' learning outcomes.

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Table III Improving Students' Ability

Aspect	Average Value		Improvement (%)
	Pretest	Posttest	
Basic Knowledge	54	92	70
Component Analysis	52	78	51
Problem Solving	52	80	54
System Design	33	80	143
Learning Outcomes	48	83	73

Building on these findings, the mean percentage improvement in students' proficiency in utilizing Automation Studio was calculated using Equation 1, providing additional quantitative data regarding the effectiveness of the intervention.

$$\text{Percentage Increase} = \frac{\text{Posttest Mean} - \text{Pretest Mean}}{\text{Pretest Mean}} \times 100\% \qquad (1)$$

The following section discusses the implications of these findings in detail, emphasizing how the improvements align with the research objectives. The paired sample test revealed significant improvements in students' abilities across all measured aspects, as detailed in Table II. The mean differences between the pre-test and post-test scores indicate consistent positive trends, supported by statistically significant p-values ($p < 0.05$). For instance, basic knowledge scores increased by 70%, whereas system design skills showed an exceptional improvement of 143%. These findings, summarized in Table III, demonstrate the efficacy of the intervention in enhancing students' competencies.

Furthermore, the statistical analysis corroborates that these improvements are not attributable to random variation but indicate a consistent trend across all evaluated parameters. The findings of this investigation demonstrate statistically significant enhancements across all measured domains. The subsequent discussion elucidates these results, emphasizing their congruence with the research objectives and the broader implications for engineering education.

DISCUSSION

The significant improvements observed across all domains of basic knowledge, component analysis, problem solving, and system design underscore the transformative potential of Automation Studio in bridging the gap between theory and practice in engineering education.

Basic Knowledge

This study explores the effectiveness of Automation Studio software in teaching electric motor control concepts to students. The research methodology involved a pre-test and post-test design to assess the impact of the software on student learning outcomes. Before introducing the Automation Studio software, the students were administered a basic knowledge test to establish a baseline understanding of electric motor control concepts. The results of this initial assessment revealed an average score of 54 out of 100, indicating a moderate level of pre-existing knowledge among the participants.

Following the implementation of Automation Studio in the curriculum, students were given the opportunity to engage with the software and explore its various features for learning about electric motor control. After a period of instruction and hands-on experience with the software, the same knowledge test was administered to evaluate its impact on student understanding.

The post-test results demonstrated a remarkable improvement in student performance. The average score increased significantly to 92 out of 100, representing a substantial gain in knowledge and comprehension of electric motor control concepts. This dramatic increase in test scores, from 54 to 92, translates to a 70% improvement in overall performance. The considerable enhancement in test scores strongly suggests that Automation Studio is highly effective in facilitating students' learning of electric motor control principles. The software appears to provide a user-friendly and interactive platform that enables students to visualize and manipulate complex concepts, leading to a deeper understanding of the subject matter.

These findings are consistent with broader research in engineering education, which has shown that simulation software can play a crucial role in improving students' grasp of fundamental engineering concepts. The visual and interactive nature of such software allows students to experiment with different scenarios and observe the outcomes in real time, reinforcing theoretical knowledge with practical applications.

The results of this study highlight the potential of Automation Studio as a valuable educational tool in the field of electric motor control. By providing a hands-on simulated environment, the software appears to bridge the gap between theoretical knowledge and practical applications, resulting in a more comprehensive understanding of the subject matter. Furthermore, the significant improvement in test scores suggests that Automation Studio may be particularly effective in addressing common misconceptions or difficulties that students typically encounter when learning about electric motor control. The software's ability to present complex concepts in a more accessible and engaging manner likely contributes to its success as a teaching aid.

In conclusion, this study provides compelling evidence for the efficacy of Automation Studio in enhancing student learning outcomes in the domain of electric motor control. The substantial increase in test scores, coupled with supporting evidence from related studies, underscores the potential of simulation software as a powerful tool in engineering education. As technology continues to evolve, the integration of innovative teaching methods may become increasingly important in preparing students for the challenges of the modern engineering landscape. To further support these findings, feedback from educators and students who have used Automation Studio provides additional insights into its practical applications and areas of improvement. In addition to enhancing basic knowledge, Automation Studio significantly improved students' ability to analyze system components.

Component Analysis

The improvements in component analysis, which increased by 51%, indicate that Automation Studio enables students to better comprehend the interplay between system components. This deeper understanding directly contributes to the overall ability to design efficient and reliable control systems. The improvements in component analysis, which rose by 51%, indicate that Automation Studio enables students to better comprehend the interplay between system components. This deeper understanding directly contributes to their overall ability to design efficient and reliable control systems. The significant improvement in students' component analysis skills, as evidenced by the increase from an average score of 52 to 78, underscores the effectiveness of Automation Studio in enhancing learning outcomes. This 51% improvement suggests that the software provides a powerful platform for students to visualize and comprehend the intricate relationships between various components in control systems. The substantial leap in performance indicates that Automation Studio not only facilitates better understanding but also enables students to apply their knowledge more effectively in practical scenarios.

Purba's research further supports this notion, demonstrating that Automation Studio enables students to conduct more thorough analyses of current and component interactions, particularly in the context of induction motor circuits (Dema Purba, 2022). This capability is crucial in developing a comprehensive understanding of complex electrical systems, as it allows students to observe and manipulate variables in a controlled virtual environment. The software's ability to simulate real-world conditions provides students with hands-on experience that is difficult or costly to replicate in physical laboratories.

The findings align with broader research in engineering education, which consistently highlights the benefits of simulation software in promoting a deeper understanding of complex systems. This correlation suggests that the use of such tools is not merely a trend but also a pedagogically sound approach to enhancing engineering education. The integration of simulation software such as Automation Studio represents a shift towards more interactive and engaging learning methodologies, moving away from traditional, purely theoretical approaches.

Dani and Erivianto's study (2023) corroborate this, indicating that such software tools can significantly enhance students' ability to grasp nuanced interactions between components in engineering systems. Their research emphasized the importance of providing students with tools that bridge the gap between theoretical knowledge and practical application. By allowing students to visualize and manipulate complex systems in a virtual environment, these tools foster a more intuitive understanding of engineering principles.

This suggests that the integration of Automation Studio and similar simulation tools into engineering curricula can lead to more effective learning experiences and better preparation of students for real-world applications where understanding component relationships is crucial. The practical skills developed through these simulations are directly transferable to industry settings, potentially reducing the learning curve of graduates entering the workforce. Furthermore, the use of such software encourages students to explore and experiment with different scenarios, thereby fostering creativity and innovation in problem-solving.

A substantial improvement in analytical skills also implies that students may be better equipped to tackle complex engineering problems and design more efficient control systems in their future professional endeavors. This enhanced capability is particularly valuable in an era in which engineering systems are becoming increasingly complex and interconnected. The ability to analyze and optimize component interactions is a critical skill in fields such as automation, robotics, and smart manufacturing.

Moreover, the use of simulation software such as Automation Studio can help develop critical thinking and analytical skills that extend beyond the specific content of the course. Students learn to approach problems systematically, consider multiple variables, and predict outcomes based on their analysis. These cognitive skills are valuable across various engineering disciplines and can contribute to more robust and innovative engineering solutions in the future.

The significant improvement in performance also suggests that Automation Studio may help address common challenges in engineering education, such as the difficulty in visualizing abstract concepts or the gap between theoretical knowledge and practical application. By providing a tangible, interactive platform for exploring engineering principles, the software may help reduce student frustration and increase engagement with the material. In addition to enhancing foundational knowledge and analytical skills, the use of Automation Studio also significantly improved students’ problem-solving capabilities, as evidenced by the post-test results.

Problem Solving

The implementation of Automation Studio in engineering education yielded significant improvements in students' problem-solving abilities, as evidenced by a substantial 54% increase in average scores from 52 to 80. This remarkable enhancement can be attributed to the software's capacity to facilitate solution exploration through direct simulation, which encourages the development of critical thinking skills. The interactive nature of Automation Studio allows students to experiment with various scenarios and observe the outcomes in real time, fostering a deeper understanding of complex engineering concepts.

Research in the field of engineering education has consistently demonstrated the positive impact of simulation-based learning on students' critical thinking abilities (Grecu, 2023). These studies highlight the importance of providing students with hands-on experience in a controlled virtual environment where they can apply theoretical knowledge to practical situations. By engaging in Automation Studio, students are exposed to a wide range of engineering challenges, enabling them to develop problem-solving strategies and hone their analytical skills.

The use of simulation software such as Automation Studio bridges the gap between theoretical knowledge and practical application, preparing students for the complexities of real-world engineering problems. As students interact with software, they learn to identify key variables, analyze system behavior, and propose innovative solutions. This process not only enhances their technical skills but also cultivates creativity and adaptability, which are crucial attributes for success in the engineering field.

Furthermore, the practical experience gained through Automation Studio equips students with the confidence and competence to effectively tackle real-world challenges (Alali, 2024) (Cheng et al., 2023). By simulating various engineering scenarios, students can develop a more comprehensive understanding of system dynamics, potential failure modes, and optimization strategies. This exposure to realistic problem-solving scenarios better prepares them to meet the demands of the professional engineering environment, where quick thinking and innovative solutions are highly valued.

The significant improvement in problem-solving abilities observed through the use of Automation Studio underscores the importance of integrating advanced simulation tools into engineering curricula. As technology continues to evolve, the ability to adapt and solve complex problems has become increasingly crucial for aspiring engineers. By providing students with access to cutting-edge simulation software, educational institutions can ensure that graduates are well equipped to meet the challenges of the rapidly changing engineering landscape and contribute meaningfully to technological advancements in their future careers. Moreover, the observed advancements in system design further highlight the tool's potential to prepare students for real-world challenges.

System Design

In the realm of system design, a remarkable improvement was observed, with a substantial increase of 143% in students' ability to design control systems. This significant progress is reflected in the average score, which increased impressively from 33 to 80. The implementation of Automation Studio played a crucial role in this advancement by providing students with a powerful platform for creating and rigorously testing ladder diagrams before moving on to physical implementation. This approach aligns seamlessly with contemporary research findings, which emphasize the effectiveness of simulation in aiding students in designing and thoroughly testing systems prior to their real-world implementation (Dani & Erivianto, 2023).

The integration of Automation Studio into the curriculum has proven to be a game changer in enhancing students' learning experiences and outcomes. By offering a virtual environment for experimentation and refinement, the software allows students to explore various design possibilities, identify potential issues, and optimize their control systems without the constraints and risks associated with immediate physical implementation. This iterative process of design, testing, and refinement in a simulated environment fosters a deeper understanding of system behavior and promotes critical thinking skills essential in the field of control systems engineering.

Moreover, the utilization of this advanced software goes beyond merely enhancing students' technical proficiency. It serves as a bridge between theoretical knowledge and practical applications, preparing students for the multifaceted challenges they are likely to encounter in an increasingly complex and technologically driven industry. By familiarizing themselves with industry-standard tools and practices, students develop a more holistic skill set that encompasses not only technical expertise but also problem-solving abilities, attention to detail, and understanding of system optimization. The significant improvement in system design capabilities also hints at the potential for long-term benefits to students' professional development. As they become more adept at using sophisticated design and simulation tools, students become better positioned to tackle complex projects, innovate in their field, and adapt to the rapidly evolving technological landscape of the industry. This enhanced preparedness is likely to translate into greater employability and career advancement opportunities for graduates entering the workforce.

Furthermore, the integration of such advanced software in educational settings reflects a broader trend towards more practical, industry-aligned teaching methodologies in engineering education. By bridging the gap between academic learning and industry requirements, institutions can ensure that their graduates are not only well-versed in theoretical concepts but also equipped with the practical skills and technological proficiency demanded by modern employers.

Learning Outcomes

In addition to these improvements, the average learning outcome showed a substantial increase of 73%, emphasizing the overall effectiveness of the training program. Table III demonstrates a notable increase in the average student learning outcomes from the pre-test stage to the post-test stage, with a substantial improvement of 73%. These data provide compelling evidence of the significant effectiveness of the implemented learning process. A detailed analysis of the results revealed several key points:

Average pre-test score (48): At the initial stage, prior to the commencement of the learning process, an average score of 48 indicates that students' initial understanding of the material was relatively low. This baseline score is typically attributed to a lack of mastery of fundamental concepts or insufficient prior exposure to the subject matter being tested. This serves as a crucial benchmark for measuring the subsequent impact of the learning intervention.

Average post-test score (83): Following the completion of the learning process, the average score increased dramatically to 83. This remarkable improvement of 35 points suggests that the teaching methods and strategies applied were highly effective in enhancing students' comprehension and retention of the material.

The post-test score reflects a significant leap in knowledge acquisition and understanding. Percentage Improvement: The 73% increase from the pre-test to the post-test scores is a clear indicator of the learning process's efficacy. This substantial improvement demonstrates that the educational intervention successfully bridged the knowledge gap identified in the pre-test stage.

Effectiveness of Teaching Methods: The considerable improvement in scores strongly suggests that the instructional techniques, curriculum design, and learning activities employed were well suited to the students' needs and learning styles. This effectiveness may be attributed to factors such as engaging in teaching methods, well-structured content delivery, or the use of innovative educational technologies. Student Engagement and Motivation: The significant increase in scores may also reflect high levels of student engagement and motivation throughout the learning process. When students are actively involved and motivated to learn, they tend to show greater improvement in their understanding and performance.

Potential Long-term Impact: While the post-test results demonstrate immediate improvement, they also suggest the potential for long-term retention of the learned material. This could have positive implications for students' future academic performance and the application of knowledge in related areas. Areas for Further Investigation: Despite the overall positive results, it would be beneficial to analyze individual student performance to identify any outliers or specific areas where improvement was less pronounced. This could inform targeted interventions or refinements of the teaching approach for future iterations.

Comparative Analysis: To further contextualize these results, it would be valuable to compare this 73% improvement with similar studies or previous implementations of the same learning process. This comparison can provide insights into the relative effectiveness of the current approach and potential areas for enhancement. In conclusion, the data presented in Table III clearly demonstrate the substantial positive impact of the learning process on student outcomes. The 73% increase in average scores from pre-test to post-test is a strong indicator of the effectiveness of the teaching methods employed and the students' capacity for knowledge acquisition and application.

The substantial improvements observed in students' competencies, as evidenced by the data, highlight the effectiveness of Automation Studio in bridging the theoretical and practical gaps in engineering education. To further contextualize these findings, feedback from educators and learners provides additional insights into the practical applications and perceived benefits of this tool, along with areas for potential enhancement.

Feedback

To obtain a comprehensive assessment of Automation Studio's efficacy, feedback was solicited from educators

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specializing in pneumatic control, programmable logic controllers (PLCs), and automation systems. Their responses elucidated the software's effectiveness in facilitating student learning while also identifying potential areas for future enhancements. Table IV presents a summary of their insights, delineating both the strengths and areas for improvement.

Table IV Response From Educators

Educator Name	Expertise	Response
Educator_1	Pneumatic Control	Automation Studio is very helpful in providing in-depth visual simulation for pneumatic systems. Students can easily understand how actuators, valves, and pneumatic circuits work interactively. However, I suggest the addition of a troubleshooting module to train problem analysis skills.
Educator_2	Programmable Logic Controller (PLC)	With the ladder diagram programming feature, this software makes it easier to teach basic-to-advanced control logic. Students understand the relationship between logic and expected results more quickly. I appreciate the stability of the simulation, but integration with real PLC hardware could be further improved.
Educator_3	Automation System	In the context of automation, Automation Studio is highly supportive of learning integrated control systems. Students can simulate complex systems, such as automated production. The addition of the latest industrial component library will further increase the relevance of the software to industry needs.

While educators provided valuable insights into the instructional potential and areas for improvement of Automation Studio, it is equally important to consider the perspectives of students who engaged directly with the software. Table V presents responses from learners, elucidating their experiences, challenges, and perceived benefits of utilizing Automation Studio in their academic pursuits.

Table V Student Response

Learner Name	Response 1	Response 2	Response 3
Student_1	Automation Studio helps understand the concept of a three-phase control system with clear visuals	The simulation feature is very helpful in understanding the relationship between components in the system	I can make mistakes without worrying about damaging the physical tools, so learning is freer
Student_2	Ladder diagrams are easier to understand because I can see the results immediately.	The real-time simulation feature helps me solve technical problems faster	It encourages me to be more independent and creative in trying different control configurations.
Student_3	I feel more confident working in the laboratory after learning with this simulation.	The components provided are complete enough to construct a control system diagram.	Automation Studio helps me understand the application of theory in practice, so the concepts become more concrete

Collective feedback from educators and students substantiates the efficacy of Automation Studio as an educational tool. Educators emphasized its strengths in providing interactive simulations and facilitating experiential learning, while also identifying areas for potential improvement, such as the integration of physical hardware and expansion of the component library. Correspondingly, the students commended the software for enhancing their comprehension of control systems, fostering autonomous learning, and augmenting their confidence in applying theoretical concepts. Collectively, these perspectives corroborate the software's impact on bridging the gap between theory and practice, while also delineating avenues for future development to align more closely with industry requirements.

CONCLUSION

The research investigates the efficacy of Automation Studio software in teaching electric motor control concepts to students through a pre-test and post-test design. The results indicated significant improvements in student performance, with average scores increasing from 54 to 92 in basic knowledge (a 70% increase), from 52 to 78 in component analysis (51% improvement), and notable gains in problem-solving and system design skills. Statistical analysis using SPSS confirmed the significance of these improvements. The findings suggest that Automation Studio enhances students' comprehension by providing an interactive platform for visualizing complex concepts and bridging theoretical knowledge with practical application. This aligns with extant research indicating that simulation software is efficacious in engineering education, corroborating the potential of Automation Studio as a valuable pedagogical tool for enhancing learning outcomes in 3-Phase Motor Control Systems.

PRACTICAL RECOMMENDATIONS

Educational institutions should integrate simulation tools, such as Automation Studio, into their engineering curricula to enhance student engagement and learning outcomes. Training programs should emphasize hands-on learning using simulation software to build student confidence and proficiency in real-world applications.

Suggestions for Future Research

To investigate the long-term retention of skills gained through simulation-based learning to assess its sustainability. Explore the application of Automation Studio in other domains such as robotics and smart manufacturing to expand its utility. To examine the integration of Automation Studio with physical hardware to evaluate its effectiveness in bridging the transition from virtual systems to real-world systems. By addressing these recommendations, the use of simulation tools can be further optimized, ensuring that engineering education evolves in alignment with industrial advancements.

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