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Effects of The Application of Logic Gate Simulator Media in Improving The Results and Learning Activities of XI Grade Vocational High School Students

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Abstract: This literature review evaluates 12 previous studies on the use of simulation software in learning digital electronics and logic gates, with the aim of analysing its impact on student learning outcomes and activities. Various simulation software such as Proteus, Logisim, Circuit Wizard, and others are used to improve students' understanding of complex concepts, practical skills, and motivation in the subjects of electronics and digital logic. The results show that simulation software effectively improves student learning outcomes, engagement, and motivation by providing practical and interactive experiences without the need for expensive physical components. However, challenges such as limited access to the required hardware and the need for proper teacher training were also highlighted. Despite these challenges, this study shows that simulation software is a promising tool for improving the quality of electronics and digital logic learning if it is properly implemented and supported by adequate infrastructure.

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Introduction

Vocational high school is an educational pathway that focuses on developing practical skills and knowledge in various fields of expertise so that students are ready to enter the world of work. As Rojaki et al. (2021) said that Vocational High Schools have a very important role in preparing a skilled and ready-to-use workforce. One important aspect of vocational education is technical skills that are relevant to industry needs, one of which is skills in electronics and computers. Understanding the basics of electronics, such as digital logic and logic gate circuits, is an important knowledge for vocational students. Learning about digital logic is very important because it is the basis of electronic devices and computers used in everyday life (Harahap et al., 2024). Therefore, in preparing basic competencies in the field of electronics, especially digital circuits, there is a need for innovation in facing increasingly complex learning challenges and obstacles.

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As learning in general, there must be various obstacles. In practical learning, for example in vocational schools, many are faced with limited practical facilities and infrastructure. The obstacle that is often faced in the practical learning process is the limited facilities and adequate practicum tools. Many schools have difficulty providing complete physical devices for students to practice the theory learned (Qirom et al., 2024). The use of computer simulation-based learning media is a solution such as the Logic Gate Simulator which can be an effective alternative. Simulation media allows students to experiment and practice with logic circuits without the need for physical devices that are expensive and limited in number. Simulation in learning can be a great tool to visualise difficult concepts. Students can learn to design and test logic circuits in a safe and controlled environment. This provides an opportunity for students to understand the material in depth, identify errors, and improve their designs without the risk of tool damage or high costs. The use of simulation media also reduces the time needed to complete practical tasks, giving students more time to learn more in-depth theories and concepts.

Based on research conducted by Suparlan (2019), the use of technological media such as video tutorials and simulation software has been shown to improve student learning outcomes in subjects related to electrical engineering and electronics. Video tutorials and simulations offer students an easier and more interesting understanding, which leads to increased motivation and learning outcomes (Pratika, 2021). In addition, the use of Proteus in electronics practicums also shows that students who use simulations in learning practicums have a better level of understanding and can follow lessons better even though they do not have direct access to physical equipment (Syahminan & Hidayat, 2021). This proves that the use of media such as simulation software has an effect on improving various aspects of both the process and the results of learning and education.

In line with this research, Circuit Wizard in electronics learning also found that the use of simulation software in basic electronics learning increases students' motivation and learning outcomes (Makiyah et al., 2022). The results showed that students who studied using Circuit Wizard were more motivated and more successful in achieving better learning outcomes. These results show that simulation media not only help students understand difficult concepts, but also increase their interest and involvement in learning. In addition to the benefits gained in terms of material understanding and learning motivation, the use of simulation media also provides direct experience in experiments that previously could not be carried out physically. This is very important, considering the many limitations faced by schools in providing laboratory equipment that is in line with curriculum requirements. Therefore, simulation media can be an effective solution to overcome these problems while enriching students‘ learning experiences.

The use of this software helps students understand physical phenomena that are difficult to explain only through theory, while increasing their motivation to learn (Rasam et al., 2018). The use of similar simulations in digital logic learning can have the same impact, namely increasing students’ understanding of the concepts of electronics and digital logic.

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The importance of applying simulation media such as the Logic Gate Simulator in learning at vocational high schools is increasingly relevant to the demands of the industrial world, which wants a workforce that not only has theoretical knowledge, but also strong practical skills. Given that the skills in designing and analysing logic circuits are the basis of many jobs in the field of electronics, the use of simulation media that allows students to master these skills effectively is very important. Students are better prepared to face the challenges in the industrial world, where they are expected to have good practical skills. The application of the Logic Gate Simulator in digital logic learning in vocational high schools can provide great benefits in improving student learning outcomes and activities.

This is very important, considering that effective learning relevant to industrial needs is the key to creating competent and ready-to-use vocational high school graduates. Therefore, the use of simulation media in electronics learning allows students to gain better experience. This study aims to further examine the effect of applying the Logic Gate Simulator on improving student learning outcomes and activities in vocational schools. It is hoped that the results of this study can contribute to the development of learning methods that are more effective, efficient, and in accordance with the needs of students and the industrial world.

Research Method

This study uses a literature review approach to examine various relevant studies on the application of the Logic Gate Simulator in digital logic learning at the vocational high school level. This literature review aims to explore and analyse the findings of previous studies related to the effect of using simulation tools on student learning outcomes and activities. The main focus of this study is to explore how this simulation medium can influence students' understanding of digital logic concepts, practical skills, and the level of student involvement and motivation in the learning process. The selected literature consists of journals, articles, theses, and previous research related to the topic of simulation-based learning in vocational education, especially in vocational high schools. The author selected research relevant to this topic, namely that which discusses the application of the Logic Gate Simulator or similar simulation media in digital logic learning for vocational high school students. The literature used must include studies conducted in the last five to ten years to ensure that the technology discussed is still relevant and in line with current educational developments. After collecting the literature, the author conducted a thematic analysis to identify the main themes that emerged from various sources, such as the influence of the use of simulation tools on the understanding of material, the impact on student motivation, and the effectiveness of simulation media in improving learning outcomes. A synthesis process was carried out to combine these findings into a comprehensive understanding of the effect of implementing the Logic Gate Simulator in vocational education.

Result and Discussion

This study evaluates 12 previous studies that examined the application of the Logic Gate Simulator in improving student learning outcomes and activities in digital logic subjects at the vocational high school level. These studies include various studies that focus on the

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application of simulation media in digital logic learning, with the aim of improving students' understanding of basic logic concepts, as well as the practical skills needed in electronics and computer engineering. Various perspectives are raised in this study, such as how the Logic Gate Simulator can help students understand logic operations, increase their involvement in learning, and motivate them to participate more actively in practicums. The main objective of this discussion is to explore the contribution of the Logic Gate Simulator in improving learning outcomes, developing students' practical skills, and assessing the effectiveness of the use of simulation media in creating more interesting and interactive learning experiences. The findings obtained are expected to provide insights into how the Logic Gate Simulator can play a role in making digital logic learning more efficient and enjoyable for vocational high school students. A summary of the results of the review of these studies can be seen in Table 1.

Table 1. Previous Research

No.	Researcher	Method	Research Objective	Research Results
1	(Betriami & Efrizon, 2022)	Classroom Action Research	Improve learning outcomes and student activities in the application of electronic circuits using simulation software	Student learning outcomes increased from an average of 76.37 (cycle 1) to 85.82 (cycle 2). Classical completeness increased from 65.52% to 89.66% in cycle 2. Student activity also increased by 10.55% from cycle 1 to cycle 2
2	(Prasetyaningsih, 2017)	Classroom Action Research	Applying the Discovery Learning model with the help of Cedar Logic Simulator software to improve student activity and learning outcomes in basic electronics.	Student activity increased from 63.5% (round I) to 85.9% (round III), and classical learning outcomes increased from 78.57% (round I) to 93.33% (round II).
3	(Zulkarnain et al., 2019)	Prototype Development & Survey	Developing Arduino-based digital logic exercises equipped with simulations and quiz modules to help evaluate students'	60% of respondents gave positive feedback on the e-Logic Trainer Kit in improving their understanding of combinatorial logic circuits.

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			understanding of logic gates.	
4	(Sumartini, 2021)	Classroom Action Research	Improving students' laboratory skills in logic gate material by using the Logic Circuit Designer (LCD) application.	The use of the LCD application is able to improve students' laboratory skills, as well as motivate them in understanding logic gate material in computer systems subjects. The results of the two cycles of action research show an improvement in skills and learning outcomes.
5	(Saputra, 2022)	Development of Learning & Simulation Media	Developing and simulating a garden light automation system using the Proteus application to aid technical understanding of electronic components.	The simulation successfully demonstrated how an LDR-based garden light automatic circuit works. The use of Proteus was effective in helping students understand the function of electronic components such as LDRs and timers in automatic circuits.
6	(Dewantara et al., 2024)	Descriptive Research	Evaluate the effectiveness of using the Logisim application for digital electronics practicums conducted online via WhatsApp video calls.	The results showed that digital electronics practicums using the Logisim application via WhatsApp were effective with positive responses from 50 students. This practicum successfully increased students' understanding and involvement in digital electronics material.
7	(Anggriany et al., 2023)	Quasi-Experimental Design	To determine the effect of using video tutorials and Proteus software on student learning outcomes in electrical engineering drawing subjects.	Video tutorials have a 28.4% effect on student learning outcomes, while Proteus has a 34% effect. There is a significant difference between the use of video tutorials and Proteus on student learning outcomes.
8	(Arif et al., 2024)	Descriptive Research	Improve cadets' understanding of electronics and	The use of Proteus software improves cadets' understanding, with 97% of

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			control system practicums using Proteus software and electronic components.	them successfully participating in the learning of electronics and control system practicums, which has a positive impact on learning outcomes.
9	(Ogungbenro et al., 2017)	Prototype Development	Designed a logic gate emulator to improve students' practical skills in the field of digital electronics.	The Atmel 8955 microcontroller-based logic gate emulator provides a cost-effective and efficient experimental platform, allowing students to conduct experiments without physical components and improving their understanding of logic circuits.
10	(Makiyah et al., 2022)	Quantitative Descriptive Research	Analysing the effect of using the Circuit Wizard application on students' motivation and learning outcomes in basic electronics courses.	The use of Circuit Wizard has a positive impact on motivation and learning outcomes. 45% of students have good motivation, 35% get an A, and 33% get a B in basic electronics courses.
11	(Syahminan & Hidayat, 2021)	Media Development & Simulation	Developing digital engineering learning using Proteus software and emulators to design and simulate electronic circuits.	The use of Proteus facilitates schematic design and circuit simulation as well as automatic conversion to PCB. This application helps beginners understand microcontroller programming and electronic simulation with complete components.
12	(Jacques et al., 2023)	Quantitative Descriptive Research	Analysing the impact of using the computer simulations ‘Circuit Wizard’ and ‘Interactive Physics’ in students‘ learning of electricity and mechanics.	The use of Circuit Wizard and Interactive Physics has a clear positive impact on students’ understanding of electrical and mechanical concepts, increasing their motivation and learning outcomes in these fields.

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These studies show that the use of simulation-based learning media such as Proteus, Logisim, and Cedar Logic Simulator can have a significant impact on increasing students' understanding and involvement in the material taught. The first study by Betriami & Efrizon (2022) used Classroom Action Research (CAR) to improve learning outcomes and student activity in the application of electronic circuits through simulation software. Student learning outcomes increased significantly, with classical completeness rising from 65.52% to 89.66%. This increase shows that simulation software facilitates students' understanding of abstract electronic concepts in a more digestible way. The advantage of using this software lies in its ability to visualise circuits, which allows students to understand the relationship between components without being limited by physical laboratory equipment. The long-term effect of using this simulation on further conceptual understanding has not been tested.

Prasetyaningsih (2017) used the Discovery Learning model with the help of Cedar Logic Simulator software. This study shows that student activity increased from 63.5% to 85.9%, while classical learning outcomes increased from 78.57% to 93.33%. This software allows students to explore basic concepts of electronics independently and actively. The advantage of this approach is the application of a learning model that prioritises self-discovery, which provides a more in-depth learning experience for students. However, a limitation of this study is the absence of further evaluation of the difficulties students face in using the software.

Zulkarnain et al. (2019) developed an Arduino-based digital logic exercise kit equipped with simulations and quiz modules. 60% of respondents gave positive feedback on this kit in improving their understanding of logic gates. The advantage of this prototype is its ability to offer an economical hands-on experimental experience, allowing students to learn digital logic without the need for expensive physical components. In addition, the use of Arduino, which is widely known as a learning tool, also supports the integration of theory and practice. The disadvantage is the limited evaluation of the long-term use of this kit.

Sumartini (2021) applied the Logic Circuit Designer (LCD) application to improve students‘ laboratory skills in logic gate material. The results showed an improvement in students’ skills and understanding in designing logic circuits. The LCD application allows students to design and test circuits directly, providing practical experience that is essential for understanding the material. The advantage of using this application is the visualisation it offers, which helps students understand complex concepts. However, the limitation is the dependence on software that may not always be compatible with the devices that students have.

Saputra (2022) developed and simulated a garden light automation system using the Proteus application. This research successfully demonstrated how an LDR-based garden light automatic circuit works, and showed that the use of Proteus is effective in helping students understand electronic components. The advantage of using Proteus is its ability to accurately simulate electronic systems without the need for physical components. However, the obstacle

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that may arise is the difficulty students have in understanding this software if they are not given adequate tutorials or guidance.

Dewantara et al. (2024) evaluated the effectiveness of using the Logisim application in digital electronics practicums conducted online via WhatsApp. This practicum showed positive results with increased student understanding and engagement, which shows that online learning can be effective even with media limitations. The advantage of using Logisim is its ability to simulate digital circuits with a user-friendly interface, while WhatsApp provides wider access for students to communicate and discuss. The weakness of this study is the limited actual practicum interaction due to the use of an online platform.

Research by Anggriany et al. (2023) used a quasi-experimental design to determine the effect of video tutorials and Proteus software on student learning outcomes in electrical engineering drawing subjects. The results showed that Proteus had a greater effect on student learning outcomes than video tutorials. The use of Proteus offers more realistic visual simulations, which greatly support the understanding of electrical engineering concepts. However, a shortcoming of this study is the lack of in-depth evaluation of the factors that influence the effectiveness of the video tutorial.

Arif et al. (2024) showed that the use of Proteus software in electronics and control system practicums is very effective in improving cadets' understanding, with 97% of them successfully completing the practicum. The advantage of using Proteus is its ability to simulate various circuits with complete components, which provides a more comprehensive learning experience. However, this application requires sufficiently powerful hardware, which can be an obstacle for some users with inferior devices.

Ogungbenro et al. (2017) developed a logic gate emulator based on the Atmel 8955 microcontroller to improve students' practical skills in digital electronics. This emulator provides a cost-effective experimental platform, allowing students to conduct experiments without the need for physical components. The advantage is lower cost, which allows more students to access and utilise this technology. However, the main obstacle is the limitation in terms of features and capacity of experiments that can be done with this microcontroller.

Makiyah et al. (2022) analysed the effect of using the Circuit Wizard application on students‘ motivation and learning outcomes in basic electronics courses. The use of Circuit Wizard showed a positive impact on students’ motivation and learning outcomes, with most students showing good motivation and adequate results. The advantage of Circuit Wizard is its ability to simulate various electronic circuits in an easy-to-understand way. However, the disadvantage of this application is its dependence on a specific platform, which may not always be compatible with the devices used by students.

Syahminan & Hidayat (2021) developed digital engineering learning using Proteus software and emulators to design and simulate electronic circuits. The results showed that Proteus is very helpful in schematic design and circuit simulation, as well as converting it into PCB format. The advantage of using this software is the ability to visualise circuits in

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detail and perform realistic simulations. However, limited access to supporting hardware can hinder the efficient use of this software in some schools or institutions.

Jacques et al. (2023) analysed the impact of using the computer simulations 'Circuit Wizard' and 'Interactive Physics' in students' learning of electricity and mechanics. The study showed a clear positive impact on students' understanding, as well as an increase in their motivation and learning outcomes. The advantage is that these two applications help students understand the concepts of electricity and mechanics in a more interactive and visual way. However, the use of two different applications can cause confusion if not properly guided.

The use of simulation software in learning has great potential to improve students' understanding of complex material, such as electronics and digital logic. The successful use of various simulation applications shows that simulations can provide practical experience that not only helps students understand theory, but also hones their technical skills. This shows that simulations can be an effective tool in an educational context that is increasingly moving towards technology-based learning. In addition, the use of digital media allows for more flexible learning, reducing dependence on expensive physical equipment that is difficult for some schools to access.

The use of simulation applications also allows students to conduct experiments virtually, developing their creativity and problem-solving skills without the limitations of physical laboratory equipment. On the other hand, the use of online platforms, such as WhatsApp in the research of Dewantara et al. (2024), shows that even in a remote learning situation, students can still be actively involved and gain a good understanding through online media and simulation software. This implies the importance of integration between technology and education in facing the challenges of learning in the digital age. However, the results of the study also show limitations, such as dependence on hardware that supports the software, as well as the possibility of technical difficulties faced by students in understanding or using simulation applications, as seen in several studies involving complex software such as Proteus and Circuit Wizard. Therefore, the main implication of the results of this analysis is the need for training for teachers and students in making maximum use of this technology and increasing access to better hardware.

The success of various studies provides a strong justification for the wider adoption of simulation software in the learning of electronics and digital logic. Simulation software, through its ability to visualise and simulate experiments that would normally require physical laboratory equipment, provides a more efficient and cost-effective way of teaching complex concepts. Another justification is the ability of simulation to increase student engagement in learning, by giving them the opportunity to learn through exploration and experimentation on their own, in accordance with the principle of constructivist learning. This justification is reinforced by research results that show that students who use simulation software show a significant improvement in learning outcomes.

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In addition, the use of applications such as Proteus, Logisim, and Circuit Wizard also provides a more interactive and accessible platform, which is in line with the tendency of the digital generation who prefer technology-based learning. Nevertheless, the justification for the adoption of this technology still requires attention to the technical and cost limitations associated with the hardware needed to run the application, as well as the need for further development in training methods for teachers and students in order to optimise the potential of this technology. Overall, simulation software in electronics and digital logic learning is increasingly strong given the potential to improve students' laboratory skills and a better understanding of the material.

Conclusion

Based on an analysis of 12 previous studies on the use of simulation software in learning electronics and digital logic, it can be concluded that simulation technology has a significant positive impact on learning outcomes and student engagement. The use of software has been proven to improve students' understanding of complex concepts, strengthen laboratory skills, and increase learning motivation. The ability to simulate experiments and circuits without the need for physical laboratory equipment, simulation software also offers an efficient and cost-effective alternative for teaching materials that require expensive and difficult-to-reach equipment.

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