Introducing Spice Software In Electrical Engineering: Implication For Developing Circuit Design Skills

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Abstract

The present study examined the SPICE as a powerful open-source analog electronic circuit simulator that can enhance the circuit design skills of electrical engineering students in Edo State. The participants were 73 students enrolled in the electrical engineering department at the Edo State Polytechnic Usen, Edo State, Edo State. Their ages ranged from 19 to 30 years, with a mean age of *9.14 (M)* and a standard deviation of *1.24 (SD)*. The participants were divided into two groups: Group A (Experimental Condition): Students who used SPICE simulation software in their coursework. Group B (Control Condition): Students who did not use SPICE and followed the traditional curriculum. A t-test analysis was conducted to address the research question: Would students in Edo State be better able to design circuits if they participated in a simulation program focused on integrated circuits? The results revealed a significant difference in circuit design skills between the experimental and control groups. Specifically, the experimental group demonstrated an average improvement of *m=8.97* in their skills. The t-value was *6.212*, indicating a strong effect. The p-value was *.000*, confirming statistical significance. In conclusion, the findings support using SPICE simulation software as an effective tool for enhancing circuit design skills among electrical engineering students. This study sheds light on the practical benefits of integrating SPICE into engineering education, emphasizing its role in bridging theory and practice.

Keywords: Simulation software, SPICE, circuit design skill, electronic

Introduction

The tremendous advantages of circuit simulators have led to advancements in electrical circuit design and optimization in recent years. It has been acknowledged that computer simulations, which incorporate visual components to mimic real-world systems or phenomena, are an effective teaching and training tool for the scientific disciplines (Duangngoen & Srisawasdi, 2016). Simulators for virtual reality are becoming indispensable in today's classrooms (Roy et al., 2017). These developments have led to the creation of numerous computer programs to address both common and unique problems. These programs use the computer's increased computational power to assist in planning, developing, and managing complex systems. A new teaching medium known as virtual simulation technology has started to appear in education and teaching, along with various new teaching methods (Yu & Chen, 2022). Virtual simulation technology is a massive benefit to students' spatial cognitive learning to help them better understand the landscape in front of them (Zhang & Ma, 2022). In many educational and training contexts, virtual learning simulations are used in addition to conventional teaching methods (Badowski & Wells-Beede, 2022; Behmadi et al., 2022; de Vries & May 2019; Foronda et al., 2020; Garmaise-Yee et al., 2022; McGarr, 2020; Moscato & Altschuller, 2019; Nassar & Tekian, 2020; Padilha et al., 2019; Perez et al., 2022; Qiao et al., 2021). Likewise, prior studies have highlighted its educational advantages (Dyrberg et al., 2017; Khan et al., 2018; Soraya et al., 2022; Wertz, 2022).

There is a contention that students' comprehension of scientific ideas and concepts is contingent upon their active participation in engineering and scientific practices (Papakonstantinou & Skoumios, 2021). Computer simulations provide students with the ability to immediately interact with authentic situations that may be unattainable in the real world on account of their peril or scarcity (Wang et al., 2014). Existing literature indicates that virtual learning simulations allow students to observe ostensibly imperceptible phenomena, alleviate the temporal burden of physically conducting lengthy experiments, and furnish online and dynamic guidance (De Jong et al., 2013). By supporting students in developing an understanding of concepts and processes via inquiry-based learning and participation in realistic investigations with continuous feedback, virtual learning simulations can facilitate learning in an unprecedented way (Bonde et al., 2014; Furtak et al., 2012). Circuit simulators are advanced technological instruments that enable designers and engineers to replicate the operation of electrical circuits across various conditions, obviating the need for physical prototypes. This facilitates comprehensive testing and analysis, conserving resources, and time throughout the design phase. These simulators facilitate efficient and effective troubleshooting by accurately predicting the performance of circuits and offering crucial insights into their behavior.

One of the main benefits of circuit simulators is their ability to identify design flaws and enhance circuit performance. By simulating various scenarios, engineers can quickly identify potential issues and make iterative modifications to the circuit design. This iterative process helps to maintain practical functionality, optimize circuit performance, and reduce the chance of failure. Several simulation modules based on virtual laboratories assist with fundamental electronic practices. For instance, a virtual laboratory on fundamental electronics subjects has been used in multiple studies using the software Proteus (Waluyo et al., 2021), Multisim (Djalal & HR, 2019), MATLAB (Benotsmane et al., 2020), LabView (Korgin et al., 2019), and PSPICE (Muchlas & Budiastuti, 2020). The current study aimed to introduce SPICE simulation as software that could enhance circuit design skills.

In the realm of electrical engineering education, the integration of practical skills and theoretical knowledge is paramount. Aspiring engineers must not only grasp theoretical concepts but also develop the ability to apply them effectively in real-world scenarios. The Simulation Program with Integrated Circuit Emphasis (SPICE) is a powerful tool that bridges this gap. One of the most popular tools for circuit simulation is the Spice (Simulation Program with Integrated Circuit Emphasis) simulator. The SPICE language, a standardized format for describing electrical circuits, serves as their foundation. Spice-based simulators are especially helpful for designing analog and mixed-signal circuits because they offer precise transistor-level simulation. PSPICE is the MicroSim Company's version of the SPICE software. With a schematic and various problem-solving technique, users can construct a virtual circuit and assess the outcome through the software. There are five primary steps in simulating a circuit. Various components are first inserted from the directory, then the components are arranged, and wires are connected between the components to create a circuit. Next, modifications are made to the part attributes, values, and names. The schematic file is error-checked after saving. After that, the outputs are examined and evaluated.

With the help of circuit simulators, modifying the values of individual components to achieve optimal circuit performance is a breeze. Users can fine-tune circuit characteristics and meet specific design requirements by adjusting capacitors, resistors, etc. Designers can swiftly refine and improve their designs with the help of simulations because of the real-time feedback they give. Many concerns remain regarding the potential of circuit simulators, although they have demonstrated significant promise. For example, in the Nigerian setting, there is a lack of data regarding how effective circuit simulators are for enhancing circuit design skills. Consequently, this study addresses a knowledge vacuum by looking into circuit simulators and under-researched software programs that can potentially improve students' skills in circuit design.

Research question:

Would students in Edo State be better able to design circuits if they participated in a simulation program focused on integrated circuits?

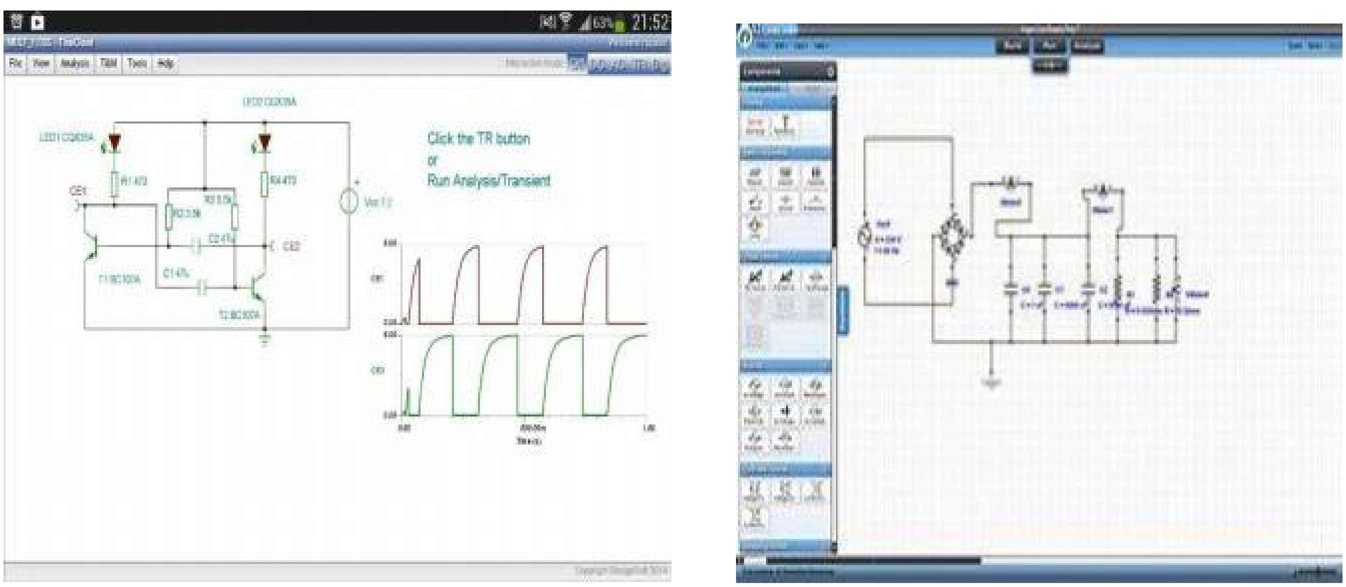
Method

The primary objective of this study is to assess the effectiveness of integrating SPICE simulation software in improving circuit design skills among electrical engineering students. A quasi-experimental design was employed, comparing two groups of students: one exposed to SPICE (experimental group) and the other following the traditional curriculum (control group). Participants (n=187) were drawn from the electrical engineering department at the Edo State Polytechnic Usen, Edo State, Edo State. A pre-test assessment was administered to both groups to assess their initial circuit design skills using a standardized circuit design task (designing an amplifier). The experimental group was exposed to SPICE simulation software (practice circuit simulations and design exercises), while the control group continued with regular coursework. After the intervention period, a post-test was administered to both groups to evaluate circuit design skills using tasks similar to the pre-test. A t-test was conducted to compare the mean scores of the experimental and control groups.

Ethical Considerations

Informed consent was obtained from the participants, and confidentiality and anonymity were ensured.

Fig 1: SPICE circuit design interface



Result

Table 1 shows the mean and standard deviation scores for the group.

		Pre-test		Post-test		
Group	N	Mean	Standard Deviation	Mean	Standard Deviation	Mean Gain
Experimental	36	40.19	10.54	49.16	13.81	8.97
Control	37	39.71	11.29	42.57	13.58	2.78
MD		0.48		6.59		

The pre-test mean difference is 0.48, as shown in Table 1, where the mean for experimental conditions is 40.19, and the mean for control conditions is 36.79. No statistically significant variation was observed in the participants' mean scores regarding their skill levels in circuit design. Conversely, the post-test analysis demonstrates that the control condition had a mean score of 42.57, while the experimental conditions had a mean score of 49.16, representing a mean difference of 8.59. The respective gain scores for the two conditions were 2.78 and 8.97. Therefore, the outcome demonstrates that the participants' exposure to the SPICE software enhanced their interest in circuit design under the experimental conditions.

Table 2 shows at-test comparison.

Source of variation	N	Mean	SD	df	*t*	Sig
Experimental	36	40.19	13.81			
Control	37	39.71	13.58	71	6.212	000

To determine whether the SPICE simulation software would spur students' skills in circuit design, a t-test analysis was conducted on the data. In circuit design, the analysis revealed a significant difference between the experimental and control conditions (MD = 6.59, t (71) = 6.212, p =.000). Thus, the result provided insights into how SPICE enhances students’ abilities in practical circuit design.

Discussion

This study examined the role of simulation programs with integrated circuit emphasis in increasing circuit design skills among Electrical Engineering Students at the National Institute of Construction Technology and Management, Uromi, Edo State, Nigeria. The result showed a significant difference between the students taught circuit design skills with the simulation software and those prepared with conventional methods. For the pre-test and the post-test study conducted, the mean and standard deviation scores showed that exposing the students to a simulation program with integrated circuit emphasis significantly influenced their circuit design skills in the post-test study (*M* = 49.16, *SD* = 13.81) compared to the control group (*M* = 42.57, *SD* = 13.58). This result might be attributed to SPICE allowing students to virtually create and simulate electronic circuits by observing voltage waveforms, current flows, and component behaviors. The software provides a platform for visual feedback, which helps bridge the gap between theoretical concepts and practical implementation and allows the students to recognize common problems (e.g., voltage spikes, oscillations) and rectify them virtually. In addition, the results add to the growing body of evidence showing the advantages of educational simulations in learning and support the present trend toward technology-heavy learning strategies (Cristol et al., 2015). Not only did this study back up previous findings on learning (e.g., Akselbo et al., 2020; Davis, 2019; Khan et al., 2019; Makransky & Petersen, 2019; McCoy et al., 2016; Scahill et al., 2021), it also uncovered some fascinating new ways of looking at learning.

The implication of the study

SPICE was the first computer program for undergraduate students to study integrated circuit design. It allowed students to simulate and analyze the performance of electronic circuits, providing hands-on experience. SPICE's educational impact lies in training students and fostering engineering talent, while its economic impact includes cost-effective circuit design and industry leadership.

Conclusion

The current study examined whether using SPICE simulation software can improve students' circuit design skills. This research method aims to provide empirical evidence regarding the impact of SPICE simulation software on circuit design skills, contributing to effective engineering education. The research established a positive difference between the two conditions on circuit design skills in the post-test study. The study concludes that students' proficiency in electronic circuit design could be enhanced by using the SPICE simulation software, a crucial technological tool. As a result, the study adds to the body of literature by confirming earlier findings that encourage using simulation software in the classroom. Nevertheless, external factors (e.g., student motivation, prior knowledge) might influenced the outcome, and the generalizability of the finding is limited to the specific student population and educational context. Future researchers should include more representative samples and explore other moderating variables that could broaden our understanding of this outcome. However, the study recommends fully integrating SPICE resources in the classroom and consistently training instructors in this direction, ultimately benefiting future engineers.

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