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USE OF SIMULATION SOFTWARE IN ENHANCING CIRCUIT DESIGN SKILLS IN TERTIARY INSTITUTIONS IN IMO STATE

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Abstract
This study investigated the effectiveness of simulation software in enhancing circuit design skills among electrical/electronic engineering students in Federal University of Technology Owerri, Imo State. The study adopted quasi-experimental pre-test post-test control design. A sample size of 140 final year students out of a population of 958 students of Electrical/Electronic Engineering Department, Federal University of Technology Owerri (FUTO) was purposively sampled for the study. Two research questions and two hypotheses guided the study. The instrument used for the study is pre-test and post-tests mean scores of students which was validated and its reliability coefficient of 0.87 was obtained using Kuder-Richardson formula. Mean was used to analyze data for the two research questions while t-test was used to test the two null hypotheses at 0.05 level of significance. Findings show significant improvements in design accuracy, reduced prototyping costs, and enhanced collaboration among participants using simulation software. Based on the finding, it was recommended amongst others that electrical/electronic engineering lecturers and instructors should always use simulation software such as MATLAB/Simulink in teaching circuit design as this will lead to overall improvement in students' skills in electronic circuit design. Furthermore, instructors should encourage students to use simulation software to analyze electronic circuits workability before embarking on fabrication to reduce costs, enhance accuracy and boost the development of collaboration skills.
Keywords: *Simulation software, circuit design, electrical/electronic engineering, university, students*

Introduction
Circuit design is a critical aspect of electronic engineering, requiring expertise in designing, testing, and optimizing electronic circuits. Circuit design involves creating electronic circuits for various applications, from simple amplifiers to complex systems. Circuit design forms the backbone of electronic engineering and related fields, as it enables students to comprehend the structure and function of complex systems (Ali & Kumar, 2022). Mastery of circuit design is crucial because it underlies the operational understanding of devices like mobile phones, computers, and communication systems, making it foundational for all engineering work in electronics and electrical engineering. Circuit design fosters critical thinking, analytical, and problem-solving skills which are very essential for

innovation in technology. When students understand circuit design, they are better able to approach challenges and devise creative solutions, which are crucial in a field where rapid advancements demand adaptable skills (Santos et al., 2021). Circuit design is a crucial aspect of electronic engineering, involving the creation of electronic circuits for various applications (Katz, 2020). Circuit design involves the creation of electronic circuits using various components, such as resistors, capacitors, and transistors (Katz, 2020). The design process typically involves simulation, prototyping, and testing (Bamidele, 2019).

Effective circuit design requires consideration of several principles such as Kirchhoff's laws (Smith, 2019), Ohm's law (Johnson, 2020), and signal processing and filtering (Wang, 2020). Using a simulation software to enhance circuit design skills in students will enable them to analyze complex circuits to ascertain its workability before fabrication. This saves costs and time as well remove prototyping errors. Simulation software has revolutionized the field by providing a virtual platform for designers to test and refine their designs. Simulation software thus, enhances the design skills of circuit designers including electrical/electronic engineering students. Simulation software enables designers to model, analyze, and optimize circuit behavior before physical prototyping (Katz, 2020). This virtual approach reduces design time, cost, and errors.

Using simulation software in teaching circuit design encourages students to work collaboratively with one another even as they learn from each other and construct their own learning. The use of simulation software boosts active learning among students through quality collaboration. Collaborative learning has been a subject of interest to researchers for the past decades (Aziz & Hossain, 2010). There is a substantial body of literature supporting the idea that students can attain higher achievement, through working together in groups. Thus, using simulation software in teaching makes the class student-centered, giving room for quality interactions among the students which aid their academic achievements.

On the other hand, the lecture method, which is a traditional method of teaching in which the teacher stands before the students and teach them theoretically failed to yield more successes in technical and engineering courses including circuit design. Conventional teaching method constitutes a loss both for the teachers who apply it in teaching technical courses and the students (Felder & Brent, 1994). Thus, the use of simulation software is preferable alternative to traditional instructional method when considering a practical course such as electronic circuit design.

Statement of the Problem

Traditionally, instructors use lectures to convey theories and principles of circuit design, and this method is often supported by slides or chalkboard illustrations. This traditional method of teaching however was found to lack interactivity, which is essential for a subject as practical as circuit design. This is because the teacher in this context is seen as someone having a monopoly of knowledge without the students engaging in any form of active learning. As a result, students often struggle to visualize circuit behavior without hands-on experience making it difficult to develop core design skills. Furthermore, lectures alone do not facilitate critical thinking or active engagement, both of which are crucial in engineering and technical education (Afolayan & Adeyemo, 2022).

Based on this observed deficiency in the usage of lecture method for teaching practical course like circuit design, there is a great need to seek for an instructional method that will enable students develop relevant circuit design skills as well as other relevant skills like critical thinking, analytical and problem-solving skills which are very essential in the world of work especially in industrial technological fields. This missing link forms the basis of this study which investigated the use of simulation software in enhancing circuit design skills in tertiary institutions in Imo State, Nigeria.

Aim and objectives of the Study

The purpose of the study is to investigate the use of simulation software in enhancing circuit design skills in tertiary institutions in Imo State, Nigeria. Specifically, the study was conducted to:

1. Determine if a mean gain difference exists in student's circuit design skills when taught using simulation software and when taught using lecture method in Federal University of Technology, Owerri.
2. Determine if a mean gain difference exists in the pre-test and post-test mean scores of students with the use of simulation software in Federal University of Technology, Owerri.

Research Questions

The following research questions were posed to guide the study:

1. What is the mean gain difference in student's circuit design skills when taught with simulation software and lecture method in Federal University of Technology, Owerri?
2. What is the mean gain difference in the pre-test and post-test mean scores of students taught with simulation software in Federal University of Technology, Owerri?

Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance in the study:

1. There is no significant difference in the mean gain of students when taught circuit design skills with simulation software and lecture method in Federal University of Technology, Owerri.

2. There is no significant difference in the pre-test and post-test mean scores of students taught with simulation software in Federal University of Technology, Owerri.

Literature Review

Benefits of Circuit Design Skills in Engineering and Technical Education

1. Circuit design forms the backbone of electronic engineering and related fields, as it enables students to comprehend the structure and function of complex systems (Ali & Kumar, 2022). Mastery of circuit design is crucial because it underlies the operational understanding of devices like mobile phones, computers, and communication systems, making it foundational for all engineering work in electronics and electrical engineering.

2. Circuit design fosters critical thinking, analytical, and problem-solving skills which are very essential for innovation in technology. When students understand circuit design, they are better able to approach challenges and devise creative solutions, which are crucial in a field where rapid advancements demand adaptable skills (Santos et al., 2021).

3. Proficiency in circuit design aligns with the skills demanded by industries such as telecommunications, power generation, and consumer electronics. Employers seek engineers who can not only design circuits but also troubleshoot and optimize them, making these skills vital for career success (Dhar & Saha, 2023).

4. With the rapid evolution of technologies, such as the Internet of Things (IoT) and robotics, circuit design skills enable engineers to understand and leverage new components and design methods that emerge. Engineers with these skills are better equipped to contribute to cutting-edge projects, as they can adapt to and incorporate new technologies effectively (Owens et al., 2023).

5. Circuit design knowledge is applicable across various disciplines. For instance, biomedical engineering relies on circuit design in medical devices, while environmental engineering uses sensor circuits in monitoring systems. Therefore, circuit design skills are valuable not only within traditional electrical engineering but also in interdisciplinary areas (Lee & Chen, 2022).

Circuit Design Methodologies and Applications

Circuit design methodologies include the following analog circuit design, digital circuit design, mixed-signal circuit design. Similarly, circuit design finds applications in power electronics, communication systems, medical devices.

Recent Advancements in Circuit Design

Notable advancements in circuit design include: Artificial intelligence-based design optimization (AI-DO), Internet of Things (IoT) integration, 3D printing-based circuit fabrication.

Challenges and Future Directions in Circuit Design

Circuit design faces several challenges in the areas of energy efficiency, scalability and security.

Benefits of Simulation Software

1. Improved design accuracy: Simulation software ensures precise calculations and analysis.
2. Reduced prototyping costs: Virtual testing minimizes physical prototype iterations.
3. Enhanced collaboration: Shared simulation models facilitate teamwork.
4. Faster design optimization: Simulation software accelerates parameter tuning.

Types of Simulation Software

1. Simulation Program with Integrated Circuit Emphasis (SPICE): This software serves as industry-standard for analog and mixed-signal simulation.
2. Verilog/A VHDL: Hardware description languages for digital circuit simulation.
3. MATLAB/Simulink: High-level programming for system-level simulation.

Applications of Simulation Software

Simulation software derived applications in the following areas: Logic circuits, power electronics, communication systems: Simulation software models transmission and reception (Zhang, 2020).

Methodology

The study used quasi-experimental pre-test post-test control design. The population of the study comprised 140 final year students of electrical/electronic engineering at Federal University of Technology, Owerri, Imo State, who were divided into two groups: The experimental group which used MATLAB/Simulink simulation software (n=70) and the control group which comprised of non-users of the software (n=70). Thus, the participants were distributed equally into the control and experimental groups of 70 students each respectively. The students in both the experimental and control groups were first examined to assess their knowledge in electronic circuit design by asking them to design and electronic amplifier and filter circuits and they were duly graded in the process by the researcher. This record forms their pre-test scores. Then, the experimental group received treatment in the form of simulation software leading to the administration of a post test on the group after which their scores were recorded as post-test scores. These students in the experimental group completed learning and circuit design activities in small groups.

Those in the control group were however taught using conventional teaching method (lecture) and thereafter their knowledge was tested and their scores recorded as post-test scores. The mean scores of both categories of students were collated to ascertain the differences. Participants completed circuit design tasks on electronic amplifier circuits, filter circuits, power conversion and power supply circuits, and these circuits were tested to ascertain functionality. The instructional material was validated by two experts in electronic engineering from the department of Electrical/Electronic Engineering, Federal University of Technology, Owerri, and its reliability was ascertained at correlation coefficient of 0.87 using Kuder-Richardson formula. The entire exercise lasted for a period of two weeks. The

data obtained were statistically analyzed using mean for the two research questions while the t-test statistics was used to test the two null hypotheses at 0.05 level of significance.

Results

The results were presented in relation to the research questions and hypotheses as follows:

Research Question 1: What is the mean gain difference in student's circuit design skills when taught with simulation software and lecture method in Federal University of Technology, Owerri?

Table 1: Mean Gain Scores of students' Achievement in Electronic Circuit Design

Groups	N	Pre-test Mean(M_1)	Post-test Mean (M_2)	Mean Gain
Experimental	70	5.8	8.9	3.1
Control	70	5.4	7.2	1.8

Table 1 revealed that the pre-test Mean score of the experimental group which used simulation software was 5.8 while that of the control group which used conventional method was 5.4. Furthermore, the post-test Mean scores for both the experimental and the control groups were recorded as 8.9 and 7.2 respectively.

Again, the mean gain on the basis of the differences between the pre-test scores and post-test scores of each group indicated 3.1 for the experimental group and 1.8 for the control group. This shows that the performance of students in circuit design was better with the use of simulation software.

Research Question 2: What is the mean gain difference in the pre-test and post-test mean scores of students taught with simulation software in Federal University of Technology, Owerri?

Table 2: **Pre-test and post-test mean scores of students taught with simulation software**

Group	N	Pre-test Mean (M_1)	Post-test Mean (M_2)	Mean Gain
Experimental	70	5.8	8.9	3.1

Table 2 above showed that the pre-test and post-test mean scores of students who used simulation software in circuit design were obtained as 5.8 and 8.9 respectively, giving a mean gain of 3.1. This revealed that there is an improvement in circuit design skills of students with simulation software.

Hypothesis 1: There is no significant difference in the mean gain of students when taught circuit design skills with simulation software and lecture method in Federal University of Technology, Owerri.

Table 3: t-test analysis on the post-test mean gain scores of the experimental and control groups

Groups	N	Mean	Mean Difference	df	t_{cal}	t_{crit}	Decision
Experimental	70	8.9	1.7	138	2.75	1.98	Reject
Control	70	7.2					

Table 3 revealed t-cal (2.75); t-crit (1.98) at degree of freedom of 138 and 0.05 level of significance. Post-test Mean of the experimental group yielded 8.9 and that of the control group 7.2. Therefore, the null hypothesis is rejected implying that with simulation software, there is a significant difference in the achievement of students taught circuit design in Federal University of Technology Owerri.

Hypothesis 2: There is no significant difference in the pre-test and post-test mean scores of students taught with simulation software in Federal University of Technology, Owerri.

Table 4: t-test analysis on the pre-test and post-test mean gain scores of the experimental group

Subject	Teaching method	n	Mean	SD	Level of Sig.	Df	t_{cal}	t_{crit}	Decision
Pre-test	Lecture	70	5.8	0.87	0.05	138	4.93	1.98	Reject
Post-test	Simulation software	70	8.9	1.12					

Table 4 showed the pre-test and post-test mean scores of students when taught with simulation software as 5.8 and 8.9 respectively. The results from the Table 4 further revealed t-cal as 4.93 and t-crit (1.98) at a degree of freedom of 138 and 0.05 level of significance. The null hypothesis is therefore rejected, revealing that there is significant improvement in performance of students when taught circuit design with simulation software.

Discussion

The study revealed that students of electrical/electronic engineering in Federal University of Technology Owerri experienced an improvement in their circuit design skills when taught using simulation software as seen from the results of the analysis. This finding was supported by Katz (2020) who posits that simulation software enables designers to model, analyze, and optimize circuit behavior before physical prototyping. Katz further stated that the use of simulation software reduces the circuit design time, cuts cost, and eliminates errors thereby raising the quality of the design.

Similarly, the study revealed that electrical/electronic engineering students work collaboratively with one another, learning from one another and constructing their own learning. This finding was corroborated by Aziz and Hossain (2010) who posit that the use of simulation software boosts in teaching circuit design inspires students to engage in active learning which increases learning outcomes among peers.

Conclusion

The study demonstrates the effectiveness of simulation software in enhancing circuit design skills among electrical/electronic engineering students in tertiary institutions in Imo State. The findings support the integration of simulation software into engineering education. This is very essential due to the fact that simulation software has transformed circuit design by enhancing accuracy, reducing costs, and fostering collaboration.

As electronic engineering continues to evolve, simulation software will remain an indispensable tool for circuit designers.

Recommendations

Based on the findings of the study, the following recommendations are suggested:

1. Government should adequately fund technology and engineering programmes in universities to enable management provide training facilities including simulation software for the training of students.
2. Electrical/Electronic Engineering lecturers should always use simulation software to teach design courses in universities.
3. Students should be encouraged to serve their internship where they will have access to hands-on experience on circuit design.
4. Lecturers and instructors should be trained on the use of simulation software for circuit analysis.

5. Collaborative learning, project-based learning, and other student-centered learning strategies should be adopted in training engineering students to boost their skills development.

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