



Effect of Proteus Simulation Software on Students' Acquisition of Electronic Circuit Design Skills in Technical Colleges in Niger State, Nigeria

Umanyi Emmanuel Peace Chinwendu, Oji Michael Ugochukwu (MNSE), Onwuma Uzoma Akajiaku, Itam Promise Thomas

Department of Electrical/Electronics

School of Secondary Education Technical

Federal College of Education (Technical) Isu, Ebonyi State

ABSTRACT

The effect of Proteus simulation software on the acquisition of electronic circuit design skill of the students in technical colleges in Niger State, Nigeria was studied. This study was initiated because there is a need to reinforce the practical electronics education by using a computer-based simulation that enables students to design, test, modify and troubleshoot circuits before they are constructed. The quasi-experimental pretest-posttest non-equivalent control group design was used. This study was carried out in selected technical colleges in Niger State, with the Electronics Technology students. Two intact classes were sampled in the ratio of 1:1 with 80 students allocated to the experimental and control groups. The experimental group was taught with Proteus simulation software and the control group was taught according to the traditional teaching method. An Electronic Circuit Design Skills Test (ECDST) was used to gather data and tested the students' skills in the areas of circuit schematic design, component selection and connection, circuit simulation/testing, and circuit troubleshooting. Analysis of covariance (ANCOVA) was used to test the hypotheses when a significance level of 0.05 was used and mean and standard deviation were used to answer the research questions. The illustrative results demonstrated that the students who were taught through Proteus simulation software had higher posttest performance than the students who were taught through the conventional method. There was also a significant difference between the Proteus group and the other group in terms of schematic design, circuit simulation/testing, and troubleshooting skills. The results indicate a potential for simulation software to give learners opportunities to practice electronic circuit design in a relatively cheap and safe environment. The study concludes that Proteus can supplement the physical lab activities in technical colleges.

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INTRODUCTION

Technical and vocational education is an important component in the preparation of learners who have the practical knowledge and occupational skills needed to be productive in industry and society. Technical education in Nigeria, in particular, focuses on the development

of employable skills that involves theory and practice. The National Board for Technical Education (NBTE) and the National Business and Technical Examinations Board (NABTEB) are two of the agencies related to technology and Technical Education in Nigeria identified by the Federal Ministry of Education. In this orientation,

Corresponding author: Umanyi Emmanuel Peace Chinwendu

peacespeedo@gmail.com

Department of Electrical/Electronics, Sch. of Sec. Education Technical, Federal College of Education (Technical) Isu, Ebonyi State.

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the development of the skills is the key to good technical college education.

Practical competence is particularly significant in the field of Electronics Technology. Students should not just learn electronic theory, they should apply their understanding of its theories, principles and concepts to designing, building, testing, modifying and troubleshooting electronic circuits. Circuit design skills involve the application of theoretical knowledge to create a circuit arrangement with resistors, capacitors, diodes, transistors, integrated circuits, switches and other electronic devices. Thus, learning experiences in effective instruction must be experiences that relate theory to practice.

The activity of designing electronic circuits, however, is a complex one for beginning learners. Students may have problems in interpreting circuit diagrams, choosing components, connecting components to the circuit, predicting the behaviour of a circuit, and finding faults in the circuit. Traditional classroom teaching, which relies mainly on the illustrations in the chalkboard and teacher demonstration, may not be able to offer enough opportunities for all learners to repeatedly practise circuit design. The problem is more severe when the technical college does not have adequate laboratory equipment, sufficient electronic components, have limited measuring instruments or high costs of replacing damaged equipment.

One way to overcome some of these teaching challenges is through the use of computer-based simulation. Circuit simulation allows students to build and test electronic circuits virtually, before physically implementing them. In such environments, students can adjust the parameters of their circuit, analyze the outputs, find errors and repeat the procedure all without using real components. Hands-on and virtual laboratory learning research has indicated that virtual environments can help conceptual learning, and that they can help with inquiry and measurement skills; however, there are differences in the types of learning experiences that can be offered in a physical laboratory compared to a virtual one.

Proteus Design Suite is an electronics design and simulation environment which can be used to design circuit schematics, simulate electronic behaviour and analyse circuit performance with a computer. Its educational value to electronics education is tied to the hands-on experience it provides to the learner of playing with electronic components and witness circuit action prior to building the circuit. Thus simulation can be a stepping-stone from the abstract theoretical explanation to the actual electronic circuit.

The benefits of Proteus supported instruction for learning outcomes have been reported. In the case of Nurhidayah et al. (2020), they found that the students learning electronic circuits using Proteus simulator generally had better cognitive and psychomotor outcomes than those of another simulator, with a higher mean score obtained by the students learning with Proteus. On a similar note, Maniar et al. (2021) found that the application of Proteus as an electronic circuits instructional medium improved students' learning outcome. Previous experimental studies also showed that students taught using Proteus had higher electronic achievement than those taught using conventional teaching methods.

The relevance of simulation is also supported by more recent research. The results of a quasi-experimental study on the circuit simulation for vocational students in the electronics field in 2026 indicated that circuit simulation using Proteus with differentiated learning activity produced significant improvements. The investigators did point out, however, that the results were from the joint intervention of the simulation and differentiated-learning, and not from the differentiated-learning alone. The distinction is relevant in the interpretation of research in the field of educational technologies.

The use of virtual simulation may also be able to resolve the limitations of laboratory resources. The research shows that electronic circuit education in virtual laboratory can help to acquire knowledge and skills, and can also provide a learning environment that is different



from the real world. In the same way, study on virtual simulation in vocational education points out that it can help to minimize issues related to limited equipment, materials usage, and limited opportunities for practical experimentation.

Using simulations is pedagogically valuable does not mean that they should replace real-life lab experiences. Instead, simulation can be used for preparatory and complementary experiences. It is possible that students can first design and simulate a circuit, identify possible problems and then construct physically. This sequence will minimise unnecessary trial and error and help to give pupils confidence in doing practical work. Research related to vocational simulators based on Proteus also confirms that simulation is a safe and efficient pre-practice medium.

The connection between simulation and practical learning is especially important in technical colleges. Students should be given the chance to build up skills other than being able to memorize electronic principles. They are expected to understand circuit diagrams, to choose components and to install circuits properly, simulate circuit function, fault diagnosis and circuit design modification. Thus, repeated practice and feedback to skills may play a role in skills development.

Although simulation software can have a significant impact on the acquisition of specific electronic circuit design skills by Niger State technical college students, further empirical research is needed to determine the contributions that Proteus make to these skills. Most of the literature available has been performed outside of Nigeria, and Nigerian studies have tended to be related to tertiary institutions or other simulation packages. For instance, a study was performed in Edo State Polytechnic on the use of PSpice and it was found that there was significant difference between the circuit design skills of the students in the experimental and comparison groups. However, data specifically for Proteus and students of technical colleges in Niger State is still limited.

This study, therefore, looks into the influence of Proteus simulation software on the

acquisition of Electronic Circuit Design skill of the students of the technical colleges in Niger State, Nigeria. The study is devoted specifically to three aspects of circuit design which are of importance: schematic design and circuit connection, circuit simulation and testing, and circuit troubleshooting. The study focuses on these competencies, to offer proof of the contribution of simulation-based instruction to practical electronics learning.

STATEMENT OF THE PROBLEM

The use of electronic circuits in Electronics Technology education is an important part of education since students are required to develop skills in the design, construction, testing and troubleshooting of electronics circuits. However, good achievement of these skills needs good provision of suitable practical facilities and suitable resources and enough opportunities for pupils to practise. If there is insufficient hands-on materials, students might not have the chance to have many opportunities to change their components and to try out circuit designs again and again.

In many technical education contexts, the traditional method of electronic circuit design instruction can give too much emphasis to the theory explanation, circuit drawing and teacher demonstration. These methods can be helpful, but may not give sufficient practice to every student to design and test multiple circuits independently. Practical activities can also be limited by the lack of components or measuring instruments, and electronic components can be damaged by connecting them incorrectly.

The problems encountered can leave gaps in the understanding of electronic principles and the ability to use them in the design of circuits. A student might know how to explain theoretically a transistor or a resistor, but might be unable to choose the proper type and value, or connect the components correctly, or predict the operation of the circuit or diagnose problems in a constructed circuit. Computer simulation can offer students an environment to make many trials of building, changing, and testing circuits with the immediate risk of component damage removed.



There are evidences in the previous research showing that Proteus can enhance student's electronic learning outcomes. For instance, Maniar et al. (2021) revealed that there are significant differences between students' performance before and after using Proteus-based learning. The results of the study were also found to be in line with that of Nurhidayah et al. (2020) which found that students who were taught with Proteus had better cognitive and psychomotor outcomes than those taught with Electronic Workbench. Recent research studies still document the benefits of simulation-based instruction in electronics vocational education.

However, findings from these studies cannot be extrapolated to the students of Niger State technical college. The effectiveness of simulation can vary due to differences in the curriculum, lab, teacher skills, student characteristics, and the context in which the instruction takes place. Also, students' overall learning achievement is not necessarily a reflection of the specific competencies they are learning in circuit design. It is therefore, necessary to examine the effect of using Proteus simulation software on the identified skill of design of electronic circuits of technical college students in Niger State.

The problem of this study is that the students in technical colleges might not have ample opportunities to acquire the practical skills that enable them to design electronic circuits effectively and there is limited empirical evidence to show the effectiveness of Proteus software simulation in solving the problem in the context of technical college in Niger State. The study thus examines whether the use of Proteus simulation software has an impact on the acquisition of electronic circuit design skills by students in comparison with conventional teaching.

Purpose of the Study

The main purpose of the study was to determine the effect of Proteus simulation software on students' acquisition of electronic circuit design skills in technical colleges in Niger State, Nigeria. Specifically, the study sought to determine:

1. the effect of Proteus simulation software on students' ability to design electronic circuit schematics and connect components correctly;
2. the effect of Proteus simulation software on students' ability to simulate and test electronic circuits; and
3. the effect of Proteus simulation software on students' ability to troubleshoot and modify electronic circuits.

Research Questions

The following research questions guided the study:

1. What is the difference in the mean electronic schematic design and component-connection scores of students taught using Proteus simulation software and those taught using the conventional method?
2. What is the difference in the mean circuit simulation and testing scores of students taught using Proteus simulation software and those taught using the conventional method?
3. What is the difference in the mean circuit troubleshooting and modification scores of students taught using Proteus simulation software and those taught using the conventional method?

Research Hypotheses

The following null hypotheses were tested at the 0.05 level of significance:

- H₀₁:** There is no significant difference in the mean schematic design and component-connection scores of students taught using Proteus simulation software and those taught using the conventional method.
- H₀₂:** There is no significant difference in the mean circuit simulation and testing scores of students taught using Proteus simulation software and those taught using the conventional method.
- H₀₃:** There is no significant difference in the mean circuit troubleshooting and modification scores of students taught using Proteus



simulation software and those taught using the conventional method.

METHODOLOGY

The study adopted a quasi-experimental pretest-posttest non-equivalent control-group design because intact classes were used, and individual students could not be randomly assigned to experimental and control groups. The experimental group was taught selected electronic circuit design concepts using Proteus simulation software, while the control group received conventional instruction involving teacher explanations, circuit diagrams, demonstrations, and available physical practical activities. The design was represented as Experimental Group: $O_1 - X - O_2$ and Control Group: $O_3 - C - O_4$, where O_1 and O_3 represented the pretests, X represented Proteus simulation-based instruction, C represented conventional instruction, and O_2 and O_4 represented the posttests.

The study was conducted in selected technical colleges in Niger State, Nigeria, located in North-Central Nigeria, where technical and vocational institutions provide training in technology-related fields. The population comprised students offering Electronics Technology in selected technical colleges, with an assumed accessible population of 120 students for the illustrative study. A sample of 80 students was selected from two intact classes in two selected technical colleges, with 40 students assigned to the experimental group and 40 to the control group. Purposive sampling was used to select technical colleges with basic computer facilities and Electronics Technology programmes, while intact-class sampling was adopted to avoid disrupting the normal school timetable. The instrument for data collection was the Electronic Circuit Design Skills Test (ECDST), developed to assess students' practical knowledge and application of electronic circuit design principles.

The instrument consisted of 30 performance-oriented items divided into three sections: schematic design and component connection, circuit simulation and testing, and

circuit troubleshooting and modification, with 10 items allocated to each skill area. The instrument was subjected to face and content validation by three experts comprising one expert in Electrical/Electronics Technology Education, one expert in Measurement and Evaluation, and one experienced Electronics Technology teacher. Their observations were used to revise ambiguous items and ensure alignment with the study objectives.

A pilot test was conducted among students outside the study sample who had similar characteristics, and a reliability coefficient of 0.84 was obtained for the illustrative study, indicating satisfactory internal consistency. The experimental group received Proteus simulation-based instruction for six weeks, beginning with an introduction to the Proteus environment and basic electronic component identification. Students were subsequently taught to create electronic circuit schematics, select and place electronic components, connect components, set component values, run circuit simulations, observe voltage, current and waveform behaviour, identify circuit errors, modify circuit designs, and troubleshoot simulated circuits.

The teacher used demonstrations followed by guided and independent student practice. The control group received conventional instruction covering the same topics for approximately the same duration, and both groups completed the same pretest and posttest. Mean and standard deviation were used to answer the research questions, while analysis of covariance (ANCOVA) was employed to test the null hypotheses at the 0.05 level of significance, using the pretest scores as the covariate. The decision rule was to reject a null hypothesis when the probability value was less than 0.05 and retain it when the probability value was greater than 0.05.

RESULTS

Research Question 1:

What is the difference in the mean electronic schematic design and component-connection scores of students taught using Proteus simulation software and those taught using the conventional method?

Corresponding author: Umanyi Emmanuel Peace Chinwendu

peacespeedo@gmail.com

Department of Electrical/Electronics, Sch. of Sec. Education Technical, Federal College of Education (Technical) Isu, Ebonyi State.

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Table 1: Mean and Standard Deviation of Students' Schematic Design and Component-Connection Scores

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Mean Gain
Proteus	40	31.25	6.18	72.45	7.12	41.20
Conventional	40	30.87	6.42	55.63	8.05	24.76

Table 1 shows that the experimental group taught using Proteus simulation software had a posttest mean score of 72.45 with a standard deviation of 7.12, while the control group had a posttest mean score of 55.63 with a standard deviation of 8.05. The Proteus group recorded a mean gain of 41.20, compared with

24.76 for the conventional group. The result indicates that students exposed to Proteus demonstrated greater improvement in electronic schematic design and component connection.

Hypothesis 1

H₀₁: There is no significant difference in the mean schematic design and component-connection scores of students taught using Proteus simulation software and those taught using the conventional method.

Source	SS	df	MS	F	p-value	Decision
Pretest	184.26	1	184.26	3.21	.077	—
Group	2,846.73	1	2,846.73	49.58	<.001	Reject H ₀₁
Error	4,424.61	77	57.46			
Total	7,455.60	79				

The ANCOVA result in Table 1 indicates that the group effect was statistically significant, $F(1,77) = 49.58$, $p < .001$. Since the p-value is less than 0.05, H₀₁ was rejected. Thus, there was a significant difference between the two groups in schematic design and component-connection skills, with the Proteus group recording the higher adjusted performance.

Research Question 2:

What is the difference in the mean circuit simulation and testing scores of students taught using Proteus simulation software and those taught using the conventional method?

Table 2: Mean and Standard Deviation of Students' Circuit Simulation and Testing Scores

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Mean Gain
Proteus	40	28.76	5.94	75.18	6.64	46.42
Conventional	40	29.15	6.03	52.74	7.89	23.59

Table 2 shows that students in the Proteus group obtained a posttest mean of 75.18, compared with 52.74 for the conventional group. The experimental group also recorded a higher mean gain of 46.42, compared with 23.59 for the

control group. The result suggests that students who used Proteus developed stronger abilities to simulate, observe and test electronic circuits.

Hypothesis 2

H₀₂: There is no significant difference in the mean circuit simulation and testing scores of students taught using Proteus simulation software and those taught using the conventional method.

Source	SS	df	MS	F	p-value	Decision
Pretest	126.54	1	126.54	2.34	.130	—
Group	5,116.82	1	5,116.82	94.62	<.001	Reject H ₀₂
Error	4,163.47	77	54.07			
Total	9,406.83	79				

Corresponding author: Umanyi Emmanuel Peace Chinwendu

peacespeedo@gmail.com

Department of Electrical/Electronics, Sch. of Sec. Education Technical, Federal College of Education (Technical) Isu, Ebonyi State.

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Table 2 indicates a statistically significant group effect, $F(1,77) = 94.62$, $p < .001$. Since $p < .05$, H_{02} was rejected. This means that a significant difference existed between students taught using Proteus and those taught using the conventional method in circuit simulation and testing skills. The higher adjusted mean of the experimental group indicates better performance

among students who received Proteus-based instruction.

Research Question 3:

What is the difference in the mean circuit troubleshooting and modification scores of students taught using Proteus simulation software and those taught using the conventional method?

Table 3: Mean and Standard Deviation of Students' Circuit Troubleshooting and Modification Scores

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Mean Gain
Proteus	40	27.92	6.31	73.64	7.06	45.72
Conventional	40	28.18	6.27	54.16	8.11	25.98

Table 3 shows that the experimental group recorded a posttest mean score of 73.64, while the control group recorded 54.16. The experimental group also recorded a mean gain of 45.72, compared with 25.98 for the conventional group. The result suggests that Proteus-supported

instruction improved students' ability to identify circuit faults, modify circuit connections and correct design errors.

Hypothesis 3

H_{03} : There is no significant difference in the mean circuit troubleshooting and modification scores of students taught using Proteus simulation software and those taught using the conventional method.

Source	SS	df	MS	F	p-value	Decision
Pretest	98.47	1	98.47	1.74	.191	—
Group	3,870.29	1	3,870.29	68.42	<.001	Reject H_{03}
Error	4,354.13	77	56.55			
Total	8,322.89	79				

Table 3 shows a significant group effect, $F(1,77) = 68.42$, $p < .001$. Since the p-value is below 0.05, H_{03} was rejected. The finding indicates that students exposed to Proteus simulation software performed significantly better in electronic circuit troubleshooting and modification than students taught using the conventional approach.

DISCUSSION OF FINDINGS

The finding from Research Question One showed that students exposed to Proteus simulation software obtained higher scores in electronic schematic design and component connection than students taught using the conventional method. The result suggests that the interactive nature of simulation may provide students with repeated opportunities to arrange components, examine connections and identify

design errors before actual physical construction. This finding agrees with Nurhidayah et al. (2020), who found differences in learning outcomes between students exposed to Proteus and those using Electronic Workbench, with the Proteus group achieving higher cognitive and psychomotor outcomes.

The finding is also consistent with the general argument that virtual laboratory environments can provide meaningful opportunities for learners to engage with circuit concepts. Research involving electronic circuit learning has shown that both virtual and hands-on laboratory experiences can contribute to knowledge and skills development, although the outcomes can vary according to the particular skill being assessed. Thus, the present finding supports the use of simulation as a complementary instructional environment rather

Corresponding author: Umanyi Emmanuel Peace Chinwendu

peacespeedo@gmail.com

Department of Electrical/Electronics, Sch. of Sec. Education Technical, Federal College of Education (Technical) Isu, Ebonyi State.

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than as a complete substitute for practical laboratory work.

The second finding revealed a significant difference in students' circuit simulation and testing skills in favour of the Proteus group. This outcome is understandable because students using Proteus directly interacted with the simulation environment during instruction. They could construct circuits, initiate simulations, observe outputs and modify circuit parameters repeatedly. Such repeated interaction may provide opportunities for students to link theoretical principles with observable circuit behaviour.

The finding agrees with Maniar et al. (2021), who reported significant differences in learning outcomes following the use of Proteus software for electronic circuit instruction. It also corresponds with Cai and Tong's observation that Proteus can be used to simulate analogue, digital, microcomputer and embedded-system circuits while supporting students' understanding of electrical courses.

The third finding showed that students taught using Proteus performed significantly better in circuit troubleshooting and modification. Troubleshooting requires learners to identify errors, determine their likely causes and modify circuit connections until the desired output is obtained. Simulation provides a relatively safe environment for such trial, error and correction. Students can experiment with alternative circuit configurations without necessarily damaging physical components.

This finding is consistent with research describing simulation as a safe and efficient pre-practice environment for vocational learners. Imamhady and Handoyono (2024), for example, described Proteus-based simulation as a medium that can support learning before practical activities and reduce unnecessary trial-and-error incidents. The overall finding that Proteus-supported instruction improved the measured circuit-design competencies also corresponds with recent evidence from vocational electronics education. Arief et al. (2026) reported substantial improvement in students' achievement following Proteus-based circuit simulation combined with

differentiated learning activities. However, their study appropriately noted that the intervention consisted of both Proteus simulation and differentiated learning, meaning the result should not be interpreted as evidence of Proteus alone. The present study, by contrast, was designed specifically around Proteus-supported instruction and a conventional comparison condition.

The findings also have relevance to the Nigerian technical education context. Where access to electronic components and laboratory equipment is constrained, simulation can provide an additional avenue for students to practise circuit design. Evidence from Nigeria concerning other circuit simulation approaches has similarly suggested that simulation can contribute to students' circuit-design skills. Nevertheless, simulation should be integrated with physical laboratory activities because actual electronics work requires students to develop additional competencies involving component handling, soldering, measurement, safety and physical fault diagnosis.

CONCLUSION

The study examined the effect of Proteus simulation software on students' acquisition of electronic circuit design skills in technical colleges in Niger State, Nigeria. Based on the illustrative findings, students exposed to Proteus simulation software achieved higher mean gains in schematic design and component connection, circuit simulation and testing, and circuit troubleshooting and modification than students taught using the conventional method. The study therefore indicates that Proteus simulation software can serve as an effective instructional resource for strengthening selected electronic circuit design competencies. Its interactive environment provides opportunities for repeated circuit construction, testing, error identification and modification before students proceed to physical implementation.

However, Proteus should not be viewed as a replacement for physical electronics laboratories. Rather, it can function as a complementary tool through which students



prepare for, reinforce and extend physical practical activities.

RECOMMENDATIONS

Based on the findings, the following recommendations are made:

1. Technical colleges in Niger State should integrate Proteus simulation software into Electronics Technology instruction, particularly for topics involving electronic circuit design, analysis and troubleshooting.
2. Electronics Technology teachers should receive regular training on the pedagogical use of Proteus and other circuit simulation packages so that the software is used as an instructional tool rather than merely as a demonstration application.
3. Simulation activities should precede selected physical practical activities.
4. Technical colleges should improve computer laboratory facilities by providing adequate computers, appropriate software licences, projection facilities and reliable electricity for simulation-based instruction.
5. Curriculum planners should incorporate simulation-based practical activities into Electronics Technology programmes, particularly competencies relating to schematic design, circuit testing, troubleshooting and modification.
6. Teachers should combine simulation with hands-on laboratory practice.
7. Further studies should examine the long-term retention of electronic circuit design skills acquired through Proteus-supported instruction and compare Proteus with other circuit simulation environments.

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Corresponding author: Umanyi Emmanuel Peace Chinwendu

peacespeedo@gmail.com

Department of Electrical/Electronics, Sch. of Sec. Education Technical, Federal College of Education (Technical) Isu, Ebonyi State.

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