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Simulation App: Improving the Procedural Knowledge of Electronics Technology Students in Electric Circuits

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Abstract The study of electric circuits, which requires some technical skill, appears to be difficult and challenging during a pandemic not just for electronics technology students but also to the instructors handling such course. Having observed this problem in modular learning, the researchers decided to conduct a study which involves the use of mobile simulation application – the EveryCircuit. This study focuses on the effect of using the simulation application on the procedural knowledge of students. An experimental research using the single group pretest-posttest design was utilized in this study. The first activity was the administration of the 40-item pretest, crafted and evaluated by skilled and experienced Electric Circuit instructors/engineers. At the end of the intervention, the posttest was administered, and grades were recorded. Data collected were analyzed using One-Way ANOVA, run through MS Excel - Data Analysis. Results of the study showed that there is a significant difference between the pretest and posttest scores of the students in favor of the posttest [P-value = 0.02121, $\alpha < 0.05$]. The pretest mean score of 0.25 which has increased as shown in the mean posttest score (1.45) of the students implies that the use of mobile simulation application may have played a significant role in enhancing students' procedural knowledge. Hence, the researcher recommends the use of any other simulation applications not only in electric circuits but also to other topics or even to the other disciplines, when applicable.

Keywords: *simulation application, procedural knowledge, EveryCircuit, electric circuits, electronics technology*

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1. Introduction

1.1. Background of the Study

"*We integrate simulation applications into undergraduate engineering courses to prepare students for their future careers*." – IEEE Spectrum, University of Hartford

The striking words above have partly triggered the researchers to commence this study. As known, the unexpected advent of Covid 19 has tremendously affected the country and its elements. One that is undeniably challenged is the education sector. Almost all universities and colleges suspended face-to-face academic activities, implementing alternative ways of teaching. There is then a significant shift from traditional, face-to-face teaching into distance education or the online teaching approach. Tagoloan Community College (TCC) is not exempted from this significant adjustment. Its College of Engineering Technology (CET) has found it a struggling process on how to deliver hands-on and technical subjects – one of which is Circuits courses. Eventually, this problem has given birth to this action research.

As pointed out by Jaudinez [1], technical-laboratory sectors such as chemistry, physics, *engineering*, biology, computing, psychology, languages, nursing, medicine, and other allied professions, program outcomes stress the importance of forming theoretical (content) and practical (processes) aspects. When developing the practical aspects, unique emphasis is given to the activities that allow students to explore experimental methods, how to synthesize observations, a range of lifelong and communication skills and laboratory practices. With the advancement of online learning during the first decade of the 21st century, online approaches have become more widely used in many educational setting [2]. For example, web-based activities are used extensively in distance education courses, whereas blended approaches are used to support teaching and learning activities in campus-based courses. Dantas and Kemm [3] discuss a blended learning approach in which web-based e-learning tools are used to undertake hypothesis testing and predictions prior to the practical class, interpret the results and review the submitted predictions after the class. However, operating under a distance learning mode denies valuable hands-on exposure to such facilities and to appreciate the subtleties of being immersed in such an environment. Therefore, it is important to review how universities and colleges are currently introducing lab-based practical experiments and technical-based courses to students, how they were introduced through online delivery in the pre-COVID-19 period, and what approaches must be taken in the post-COVID-19 period, especially to achieve learning outcomes whilst maintaining a high-quality educational experience.

Nevertheless, creative interventions and supplementary actions should be reflected as an adjustment at this new setting of education. Hence, the TCC-College of Engineering faculty of Electronics Technology had found an idea in addressing students' dismays in Circuits course like how to connect electric circuits the right way, how to determine if connected circuits function correctly, how to visualize the movement of electricity, and how to put into practice the theories presented.

In this research, the researchers first discuss simulation application and procedural knowledge, while summarizing examples from published literature. This is followed by presenting the transformation from traditional face-to-face delivery to online delivery, in which we examine technologies used for online delivery, including associated challenges and impacts on assessment practices implemented as a result of COVID-19. There follows a discussion on student experience, highlighting the impacts on their learning experience as well as on their wellbeing. Finally, consideration is made of the policies implemented by educational and other agencies to support universities to uphold quality assurance procedures during online delivery of teaching.

With curricula moving online during these challenging times, teaching laboratory and technical subjects becomes a challenge on the part of both students and teachers. Notable existing simulation applications have been produced by programmers and engineers to support the way educators attacked the contents of technical courses. These applications are working, reliable, and efficient, but some applications are not practically usable for students who are not privilege in life as they require high amount of data and strong internet connection. Thus, the researchers have decided to intelligently select a better simulation application that can be used by students in rural areas even offline. This research shall focus only on the use of "EveryCircuit", which can be downloaded through Google Chrome, Firefox, Microsoft Edge, Application Store, or Play Store. This application can be accessed using both iPhone Operating System (iOS) and Android phones.

This action research aims to (1) determine the effectiveness of the simulation application in achieving procedural knowledge, (2) provide means for the students to perform their laboratory activities through the use of simulation, (3) aid the instructors in delivering the laboratory subjects, and (4) help the department in providing the best approach to achieve procedural knowledge.

1.1.1. The Simulation Application: EveryCircuit

Various types of games have been published in a smart phone game market. However, there are little serious simulation games among them. In this study, parking simulation game has been developed and published on the Apple application store and Android market, to analyze the usability and prospects of the smart phone based serious simulation game. Developed game was designed to give users realistic simulation experience with immersion in the smart phone environment. In case of Apple application store, more than 300 thousands download have been recorded. This means serious simulation games have much more potential for commercial value, even though there are constrains with small display and user interface.

Armed with this knowledge the researchers downloaded, evaluated, and read the reviews for as many circuit analysis applications as could be found on both devices. It must be noted that the researcher owns both types of devices and has for many years. Being familiar with how each one works, the researcher felt comfortable making these evaluations without other input. It was found that the best choice was an application called "EveryCircuit" that can be downloaded for Android and iOS devices. Hence, in this research, either the student is Android or iOS user, he or she can still access the "EveryCircuit" simulator.

The key feature of the "EveryCircuit" application is an ability to construct any type of circuit the student might encounter and then simulate the program to watch how the charge moves through the circuit. Animated dots are displayed in the circuit to show students the direction the current is distributing charge and how it is being split amongst the branches. To visually indicate how strong a current is in any particular branch of a circuit, the moving dots are bigger and brighter and move faster where the current is stronger and are dimmer and move slower where the current is not as strong. In each application the student can click on a branch to get real time values for voltage, current, and power for each component. As with any modeling software, values for circuit sources and components can be changed at any time with relative ease to see how different values will affect current and voltage values in the circuit. In DC circuits, students can follow the distribution of charge in one direction in a circuit as they are taught in the classroom and observe how that charge is split if it has any parallel branches. They can also see how in RC series circuits for instance the time constant works and that after five time constants the capacitor has the entire voltage of the source and there ceases to be any current flow, meaning the animated circuit current dots in the application become slower and less bright until they are not there anymore. They can see in RL series circuits how the circuit current builds over five time constants to where the inductor has an effective voltage of 0 V and acts like a short, meaning the circuit current dots in the application start off very dim and slow and get brighter and move faster until the circuit reaches steady-state. In AC circuits, students can visually see the current switch directions based on the frequency and voltage of the source. They can see how increasing the frequency of the source affects the current frequency. Real-time graphs for voltage and current can be shown at the same time. In purely resistive circuits it can be seen how the voltage and current are in phase with one another, but when you add a capacitor or inductor (or both) you can observe how the current either lags or leads the voltage. The helpfulness of this EveryCircuit application is in its relatively short learning curve for use, its portability and convenience, but most importantly, its ability to let students visualize exactly what it is they are studying. It brings another perspective to the table instead of just parroting an analysis technique and obtaining a result. It now makes that result meaningful because they can see what it is they are analyzing.

The thing here is that free version for the "EveryCircuit" application is available, but has only limited sandbox area, but it can still impress students. The software contains good circuit examples to refresh memory of basic principles and animations show quickly how things work. However, the small sandbox area can quickly annoy students on this free teaser version, meaning you can only use the smallest example circuits. But if you need a larger playground, a full version of EveryCircuit is available for some money. According to ePanorama, a blog which publishes news and articles on everything related to electronics, EveryCircuit is possibly the best circuit design and simulation application on the Android market at the moment.

Students can build and simulate circuits right on their phone or tablet, animate and understand how they work, check their homework, monitor their own progress, and test their designs. EveryCircuit allows the students to visualize, simulate, and interact. To visualize would mean that dynamic animations of voltages, currents and charges are displayed right on top of schematic. Detailed visualization gives insight into circuit operation like no equation does. To simulate is when you build an arbitrary circuit, EveryCircuit shows you how it works, even if you have just invented a new design. This is made possible by a custom-built circuit simulation engine under the hood. Lastly, students can interact by adjusting circuit parameters while simulation is running and seeing how that circuit responds — all is existing in real time. The amazing thing is that touchscreen interface makes it feel like you are building circuits with your own hands.

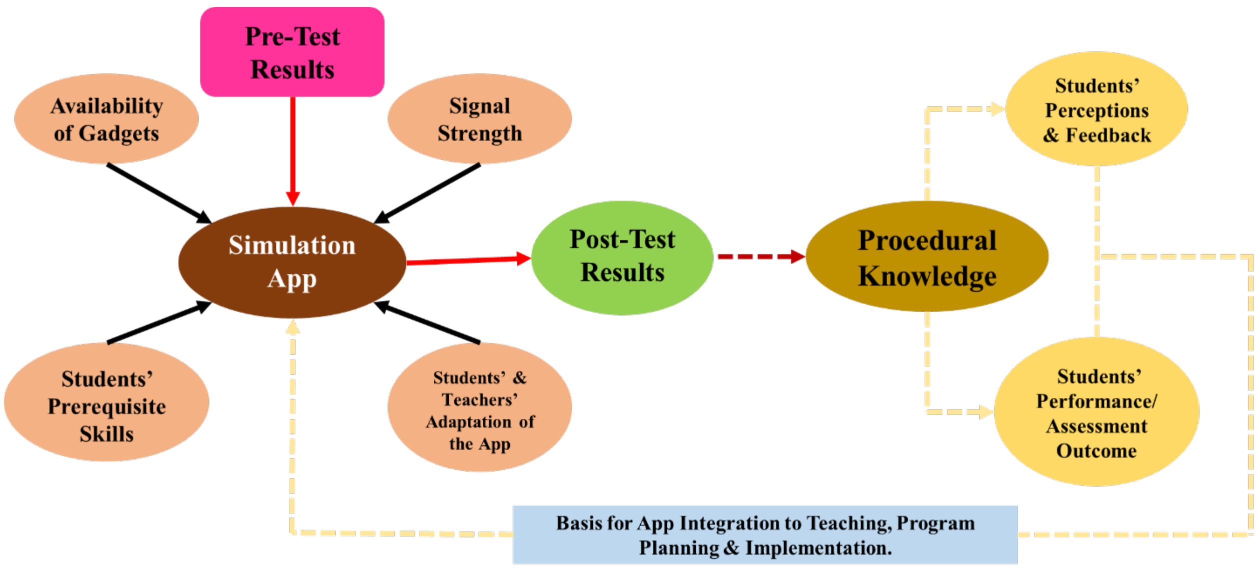
1.1.2. Procedural Knowledge

Procedural knowledge, also known as imperative knowledge, is the type of knowledge exercised in the performance of a task. It is basically "how" you know to do something. The classic example of procedural knowledge is riding a bicycle. When someone was teaching you how to ride a bicycle, no matter what they said, you probably struggled to grasp it until you would actually done it a few times. Once you figured it out, it quickly became implicit knowledge. That is, the type of knowledge that is hard to explain as it is subconsciously stored in your mind; ('muscle memory' is another phrase used to describe implicit knowledge.

Star [4] elaborated on the idea that procedures can be known deeply, flexibly, and with critical judgment-positive learning outcomes that are exclusively about students' knowledge of procedures and not necessarily a result of connections to conceptual knowledge. However, improving students' procedural knowledge is greatly questioned in the quality of learning at this new normal. The possibility of attaining this kind of knowledge is lower compared to face-to-face classes. For instance, it teaching simple electric circuits, procedural knowledge is at stake since students can not come to school to perform hands-on demonstration of my to connect and illustrate circuits. With this concern, this research is developed in order to verify the effectiveness of simulation application, in the use of EveryCircuit application, towards the improvement of procedural knowledge.

1.2. The Conceptual Framework

The following diagram shows the inter-relationship of variables to consider which might interrupt or hinder in the conduct of the study. It must be in the knowledge of all that signal strength, available of gadgets, students' prerequisite skills, and students' & teachers' adaptation of the application are the covariate variables that means that these variables need to be assumed and must be taken as not-contributing factors to the possible analysis of the resulting data of the treatment. The pre-test scores were then recorded which later on were compared against the post-test scores. When the post-test mean is significantly higher that the pre-test mean, this would then tells that the use of simulation application is effective. The effectiveness of the intervention would relate to the achievement of procedural knowledge. Once proven to be effective, recommendation on program enhancement and teaching intervention across disciplines may then be crafted out.



1.3. Statement of the Problem

This research aimed to evaluate the effect of the simulation application on the student's performance and procedural knowledge in learning electric circuits. Specifically, this research sought to answer the following questions:

- What is the percentage for the students who are using Android phones and iOS phones?
- Is there a significance difference between the post-test mean and the pre-test mean of the two groups – the Modular Learning Approach and the Simulation Application Integrated Learning Approach?
- Which is more effective in achieving procedural knowledge among Electronics Technology students – the Modular Learning Approach or the Simulation Application Integrated Learning Approach?
- What are the students' perceptions towards the use of simulation application in learning?

1.4. Significance of the Study

The intent of this research was to find how to improve student' procedural knowledge of circuit analysis using circuit simulation tools on smartphones such as EveryCircuit. Furthermore, this study would lead to benefit the students, the teacher, the school, and the society,

The results of this research would give students the proper and appropriate avenue to practice the theories on electric circuits they have learned into meaningful applications. In as much, they will be able to track their own progress as the simulation application allows the users to detect the errors committed as they run the program they created using the application. This further motivates students to at least explore the connections and complexities of how electric circuits work, enabling them to solve certain problems.

The teachers, on the other hand, will also benefit from this research. If teachers are guided very well, they can also create meaningful problems dealing with electric circuit applications. By using the simulation application, real-time feedbacking is also possible. This also gives teachers the assurance that at least their students were able to apply the theories they presented in the learning modules by allowing their students to simulate electric circuits using the application.

The school may be guided in creating seminars/trainings/workshops on how to properly execute the applications. It may also decide to upgrade the version of the simulation application. By doing so, this gives better impact to the users of the simulation application – the students and the teachers.

The community will also indirectly take the advantage of the outcomes of this simulation application to the extent that the students will soon be giving their services back to the community they live in.

1.5. Scope and Limitation of the Study

This research involves forty (40) First Year students as research participants which are randomly selected out of the 121 first year students. These students are currently enrolled in the second semester of Academic Year 2020-2021 at Tagoloan Community College (TCC), Baluarte, Tagoloan, Misamis Oriental. They are taking the same course which is Bachelor of Science in Engineering Technology Major in Electronics Technology (BSET-ET).

The forty (40) students will be equally divided into two (2) groups. The first group, consists of 20 students, will be treated as the Control Group who will be receiving the pure modular learning approach. The other twenty (20) students belong to the second group, treated as the Experimental/Treatment Group who will experience the treatment or alternative way (using the Simulation Application Approach) of teaching the subject matter. The experimental group are asked to download EveryCircuit software in their smartphones. Same subject matter will be taken into consideration which is on Electric Circuits. Based on the syllabus, this topic is good for one week. Specific topics on AC and DC circuits are covered. These topics are designed from simple to complex approach. Pre-requisites topics for Electric Circuits are also considered. Same qualified and experienced instructors will be teaching the subject matter.

To clearly clarify the procedure done, in the first day of the week the pretest was conducted for both groups. Then, students were instructed and oriented as to the proper use of the simulation application. The simulation application/software that will be employed is "EveryCircuit" for both Android users and iOS users, which can be downloaded through the Application Store, or Play Store. On the last day of the week, the post-test was then given to both groups.

1.6. Related Literatures

The significance of the preceding is crucial to the substance of the thesis. The related literatures and similar studies mentioned in this study is professed to substantiate the arguments that support the theories and assumptions therein. The relevant information gathered in this chapter provides convincing pieces of evidence on the authenticity of the study of interest and thus provides motivation to pursue the study on the development of circuit simulation software in electronic circuit course in the hope of providing guided tools for a successful transfer of technology to the students. The point of reference information herein reflects the various commendable works and scholarly studies conducted that are relevant to alternative.

As far as the effectiveness of integrating simulation application in teaching non-technical courses have been positively claimed by many researchers, the need to unlock the relevance and relationship of simulation application to teaching technical & hands-on subjects has brought the existence of this new research. TCC electronics technology students enrolled in technical courses have been greatly affected as to how they significantly gained the procedural knowledge of such courses, not just the declarative ones. Selected related literature and studies are scrupulously considered herewith.

1.6.1. A Historical Review of Circuit Simulation

The study of Pederson [5] on a Historical Review of Circuit Simulation gives an overview of the importance of Circuit Simulation. The author emphasized the developments 1950's using the earliest digital computers.

Initially, computer-aided circuit analysis of linear circuits was used in design optimization, design centering, and in determining the effects of parasitic on circuit performance. Although this use of computer-aided circuit analysis has continued, computer-aided design (CAD) and circuit design automation are now principally concerned with problems associated with the overall design and evaluation of very large circuits and systems.

The paper is a review of a major thread of CAD activity and remains of major interest. This thread involves computer-aided circuit analysis (circuit simulation) and its use in CAD systems. Fortunately, several excellent review papers have appeared within the past year or two to document well the technical milestones, as well as the problems of interest at the present time. It is possible then, in this paper, to concentrate on the developments in our present capability of circuit simulators, stressing the significant trends, noting some early developments which did not become major aspects, and observing the interchange between theory and practice.

1.6.2. Circuit Simulators: A Revolutionary E-Learning Platform

The works of Itagi and Deshpande [6] that ventured into the circuit simulators: a revolutionary e-learning platform. The study mainly deals with the communication tec6hnologies along with the basic electronic components, design of circuits and systems. This paper deals with a brief of various circuit simulators. Computer Circuit simulators are software's that help analyze an electronic circuit and determine much of its performance without physically constructing it using hardware components. It makes analysis of the system quite effectively with easy-to-use technology with speed and accuracy. Computer simulation which in simple words is a virtual way of emulating the behavior of a circuit, engages the students by integrating them into the learning experience. By replacing the monochrome class teaching of the working of a circuit, with its simulation, learning and practicals can be done simultaneously and students can grasp more knowledge about computer software and hardware simultaneously. The superlative growth of simulators has brought in a host of new technologies for e-learning and will provide massive support to engineers in the years to come. There paper has showcased two important points with regards to simulation: (1.) improving student understanding of basic research principles and analytic techniques, (2.) investigating the effects of problems that arise in the implementation of research. It gives an added advantage of predicting a myriad of situation that would take individual set-ups. Prototyping and simulation go hand-in-hand to contribute to the overall success of almost any circuit design.

1.7. Foreign Studies

1.7.1. Relevant Studies on Circuit Simulation Software

The study conducted by Lin Haifeng [7] on "Application of Circuit Simulation Software in Electronic Technology Teaching" presented analysis of electronic circuits in simulation technology. There were two advantages, on the one hand it overcomes the limitations of laboratory components and instruments, and on the other hand it also broke the time and space constraint. Thus using the simulation software, will assist the electronic technology courses teaching, so that the theory be verified at any time. The study showed that simulation software is the effective tools to lay a solid foundation for electronic system analysis and design for future work.

Ratu and Erfan [8] ventured into the study on "The effect of every circuit simulation to enhance motivation and students' ability in analyzing electrical circuits" basic course. Their research used quasi-experimental research used matching pre-test – post-test control group design. The sample of their research were 35 students of physics education study program, faculty of teacher training, Samawa University which divided into two groups. The experiment group (17 students) used Every Circuit simulator, and control group (18 students) used conventional learning (oral). Instrument used in their research were learning motivation questionnaire and electric circuit's analysis test sheet. The data in their research were analyzed using independent t-test and normalized gain test. The result showed that student's motivation on experimental group is higher than control group. The Students ability in analyzing electric circuits of the experimental group is significantly better than control group. The researcher concluded that Every Circuit simulator is effective in improving motivation and student's ability in analyzing electrical circuits. Thus, the idea offers an overview on what will be the approach of the present student in using circuit simulation software.

Taher and Khan [9] also conducted a relevant study on the use of simulation software that allows instructor to determine the effectiveness of simulation versus hands-on laboratory based on a case study for teaching an electronics course. The research study aims to determine how effective is simulation-based teaching methodology in comparison to traditional hands-on activity-based labs. A mixed method research design was employed to identify the presence or absence of learning patterns using qualitative and quantitative modes of data evaluation viz a viz cognitive apprenticeship instructional methodology. The present case study was designed to analyze the potential impact that the use of computer simulation based instructional strategies has upon students' learning and problem-solving skills in a technology-based course. Thus, there study essentially proceeded with two qualitative research questions and one research question using the combination of qualitative and quantitative approaches. The paper also discusses the other aspects of findings which reveal that simulation by itself is not very effective in promoting student learning. Simulation becomes effective only when it is followed by hands-on activity. The paper presents the qualitative findings of the study, and the quantitative findings. Furthermore, the paper presents recommendations for improving student learning, vis-à-vis simulation-based and hands-on labs. Based on findings it is suggested that first students be exposed to theoretical knowledge in traditional lecture mode followed by simulation-based lab activities, and finally required to do hands-on lab experiments. The research mentioned above justifies the effectiveness of using simulation software.

The study conducted by Ozuag, Canturk and Ozyilmaz [14] promotes the augmented reality (AR) technology, that brings a new perspective to the simulation of electronic circuits and contributes to reducing the dependency on a physical environment and equipment. Electronic circuits are detected by mobile smartphones and their simulations are displayed on the smartphone screens. The study aims to increase the learning quality by simulating and transferring into the physical environment such invisible concepts as current, and voltage etc. which is more appropriate to the current situation. In the study, electronic circuits drawn originally on paper have been simulated through the augmented reality technology. Use of the augmented reality technology has brought a new perspective to the simulation of electronic circuits and contributed to decrease the dependency on a physical environment and equipment in electronic education.

1.8. Local Studies

The study conducted by Rio [15] on "The development and acceptability of training module in switching logic" is aimed to develop a simulation and Training Module in Switching Logic as instructional material in the teaching of students of Bachelor of Technology in subjects such as Industrial Design Process and Control, Industrial Electronics and Industrial Motor Control. The researchers used an adopted and modified questionnaire-checklist to determine the level of acceptability of the module with respect to its objectives, Contents, Pretest and post-test contents, Illustrations/photos and Usefulness. To determine the level of acceptability of the developed training module in switching logic as perceived by the evaluators in terms of objectives, contents, pre and post-test contents, illustrations/photos and usefulness, weighted mean was used. To test if there is significant difference on the level of acceptability of the developed training module in switching logic as perceived by the two groups of respondents', t-test was utilized.

Torculas, et. al. [10] ventured into the study on the development of a mechatronics work cell that employs simulation on a Programmable Logic Controller (PLC)-based instructional tool for the electro-mechanical technology students of Mindanao University of Science and Technology in Cagayan de Oro City, Philippines. The study's primary purpose was to enhance the skill set of the students by focusing into the significance of utilizing mechatronics training tool into the laboratory. The training tool consists of various input and output devices that performs pick and place based on a established control sequence which may be changed depending upon the problem set specified by the instructor. Input and output identification, interfacing, PLC programming, and troubleshooting were highlighted in the actual hands-on manipulation.

Alajar, et. al. [16] has undertaken into the development of a simulated PLC-based material sorting instructional trainer that employs sensors to detect metal and non-metal materials as part of mechatronics application in a miniaturized plant set-up. The simple PLC programming of the control sequence provided opportunities of the students to implement automation via PLC ladder programming. The students in that particular set-up gained skill set in input and output interfacing, programming, and plant conceptualizing.

1.9. Related Literature Synthesis

The preceding literatures cited above provided benchmark information that substantiates the technical content of the present study. The literatures cited complements the theories required to fortify the study. The relevant studies provided valuable inputs that support the conduct of the study.

The arguments that were considered were anchored on the issue of alternative learning strategies using simulation undertaken by various institutions in an effort to enhance learning retention of their respective clients. Alternative learning tools such simulation were tried and tested in some controlled environment through pre-test and post-test to effectively measure differences and thus mitigating intervention are appropriately undertaken. Henceforth, the aforementioned interventions are implemented in order to address the so-called industry-academe mismatch which is usually blamed at the school's failure to provide the right technical skill set for the human workforce. The arguments mentioned provided undeniable reason for this study to be conducted in an effort to supplement laboratory activities through simulation and keep abreast with the current demands.

2. Methodology

This section discusses how this study is done, what procedures have been undertaken, what method is employed, and how data are being analyzed. This action research uses the experimental pretest–posttest research design. Guided by this design, one experimental group is exposed to a treatment or intervention and then compared to one control group who did not receive the treatment. It should be noted however that despite the versatility of the pretest–posttest designs, in general, they still have limitations, including threats to internal and external validity. Dimitrov and Rumrill [11] had discussed the brief notes on internal and external validity of such design. Internal validity is the degree to which the experimental treatment makes a difference in (or causes change in) the specific experimental settings. External validity is the degree to which the treatment effect can be generalized across populations, settings, treatment variables, and measurement instruments.

At first, the whole population of the First Year electronics technology students were surveyed as to what smartphones they using – Android or iOS. The result of the survey was presented through a Pie Chart. After the survey, the participants of this research were randomly selected using the simple random sampling technique.

The first activity was the administration of the 40-item pretest, crafted and evaluated by skilled and experienced Electric Circuit instructors/engineers. At the end of the intervention, the posttest was administered, and grades were recorded. The pretest and post-test questionnaires were given to the students online via FB Messenger. The pretest and post-test scores and differences from both groups were presented through tabular representation. Data collected were analyzed using One-Way Analysis of Variance (ANOVA), later on, run through MS Excel - Data Analysis. Results of the study were then interpreted whether there is a significant difference between the pretest and posttest scores or not using the P-value with $\alpha < 0.05$. The two groups, control group and experimental group, were then compared using Tukey Pairwise Comparisons in order to verify which group performed well. It was further supported by the use of the Boxplot Graphical Representation run using the MiniTab 17 Statistical Software to see the significant difference of the means between the two groups. It is only then that the researchers can conclude if the intervention has an effect to procedural knowledge of the students.

Lastly, after doing the intervention, the students were asked to answer one question on what their perceptions and insights on the integration of simulation app in learning electric circuits. Their responses were then summarized and shown through table. These were transcribed and analyzed for clarity of their perceptions.

3. Results and Discussions

The researchers conducted a 40-item pretest to both groups. Those who are in the Control Group received exactly the same pre-test questions with those who are in the Experimental Group. After both groups had taken the pre-test, the test was graded, and scores were recorded. After taking the pre-test, those in the Control Group purely received the Modular Approach of Teaching while those in the Experimental Group received the treatment or intervention which is the Usage of Simulation Application (EveryCircuit) in Teaching. After giving the intervention, both groups have been given with exactly the same 40-item post-test. In the same manner, the post-test was graded, and scores were recorded.

After recording the scores for both groups, the differences between pre-test and post-test were calculated. All of these significant computations were reflected in Table 1: Control Group and Table 2: Experimental Group.

Table 1. Control Group

PRE-TEST	POST-TEST	DIFFERENCE
30	31	1
27	25	-2
17	17	0
24	24	0
20	19	-1
18	20	2
10	13	3
27	28	1
26	27	1
31	32	1
23	20	-3
19	17	-2
15	16	1
20	19	-1
20	22	2
17	17	0
19	20	1
27	25	-2
25	26	1
30	32	2
22.25	22.50	0.25

Table 2. Experimental Group

PRE-TEST	POST-TEST	DIFFERENCE
17	20	3
20	21	1
23	25	2
34	34	0
19	20	1
10	14	4
19	22	3
23	24	1
26	24	-2
17	18	1
29	27	-2
32	33	1
19	22	3
20	23	3
23	25	2
28	29	1
16	18	2
10	12	2
30	31	1
32	34	2
22.35	23.80	1.45

Question 1: What is the percentage for the students who are using Android phones and iOS phones?

The 121 population of the first year electronics technology students enrolled during the second semester of academic year 2020-2021 was surveyed online though the use of Google Form. The result of the survey is presented below.

Type of Phone	Frequency	Percentage
Android Users	89	74%
iOS Users	32	26%

From the table above, it can be noted that majority is using Android phones having 89 who responded out of 121, which constitutes 74% of the first year students' population. On the other hand, there are 32 iOS phone users which is equivalent to 26% of the population. These data were obtained in order to determine if the type of smartphone used by the students differ in how quick the simulator respond and likely affect the accurate operation of the simulator.

Question 2: Is there a significance difference between the post-test mean and the pre-test mean of the two groups – the Modular Approach and the Simulation Application Approach?

In order to see if there is a significant difference between the post-test mean and the pre-test mean of the two groups, we need to make use of the calculated differences. The two sets of differences were then analyzed through One Way ANOVA using MS Excel – Data Analysis using a significance level of $\alpha=0.05$.

Table 3 shows that the p-value of 0.02121 is lesser than the alpha value which is 0.05. This simply means that there is indeed a significant difference between the two groups. The study of Ratu and Erfan [8] on the effect of every circuit simulation to enhance motivation and students' ability in analyzing electrical circuits has supported this claim.

Table 3. Anova: Single Factor (Control Group vs Experimental Group)

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Control Group	20	5	0.25	2.61842105
Experimental Group	20	29	1.45	2.36578947

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14.4	1	14.4	5.7782471	0.02121	4.098172
Within Groups	94.7	38	2.492105			
Total	109.1	39				

Table 4. Tukey Pairwise Comparisons of Control Group vs. Experimental Group

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95% Confidence

Factor	N	Mean	Grouping
EXPERIMENTAL GROUP DIFFERENCE	20	1.450	A
CONTROL GROUP DIFFERENCE	20	0.250	B

Means that do not share a letter are significantly different.

This claim is further supported when the Tukey Pairwise Comparisons is run using MiniTab 17 Statistical Software. Refer to Table 4.

Question 3: Which is more effective in achieving procedural knowledge among Electronics Technology students – the Modular Approach or the Simulation Application Approach?

To clearly give comparisons to the differences between the two groups, the data on score differences for both groups are illustrated using Boxplot Graph.

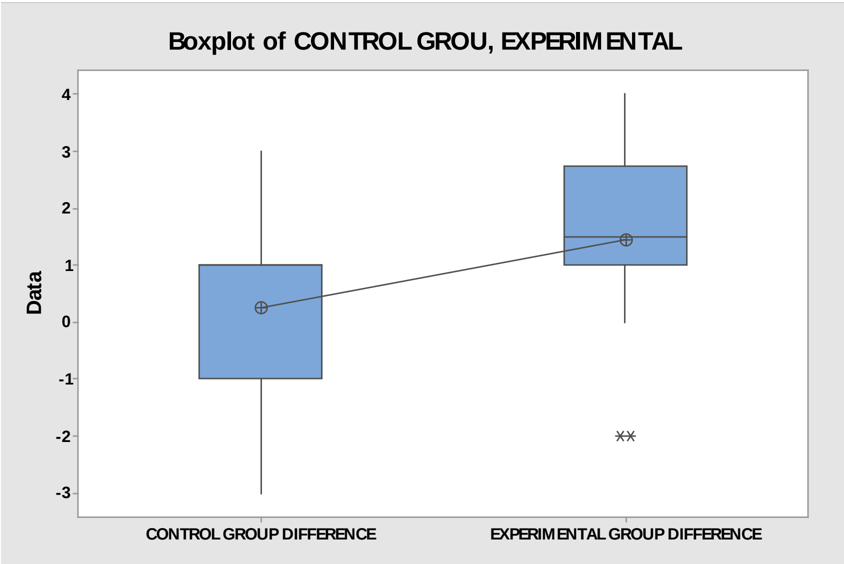


Figure 1. Boxplot of control Group and Experimental Group

Figure 1 shows that that those students in the experimental group have performed well – meaning to say, they initially developed their procedural knowledge. It can then be concluded that the intervention or treatment which is the use of the simulation application is found to be more effective than the pure modular learning approach. This result is supported by the study of Taher and Khan [9] on the use of simulation software that allows instructor to determine the effectiveness of simulation versus hands-on laboratory based on a case study for teaching an electronics course. Their study has concluded that simulation has contributed to the learning performance of the students.

Question 4: What are the students' perception towards the use of simulation application in learning?

After giving the intervention, those students who belong to the experimental group were asked to answer the question: How do you define the use of EveryCircuit in learning Electric Circuits? Their responses were transcribed to better understand the though given and were summarized using a table. Take note that since some students shared the same thoughts in their responses, the frequency (f) of the answers was also recorded. Refer to Table 5.

Table 5. Students' Perceptions on the Use of Simulation Application in Teaching

Students' Sample Responses	*Category/Themes*
Despite that the use of the simulation application was new, students were able to learn better the electric circuits with the use of the software.	Better Learning in Circuits
Students evaluated the software as complicated and challenging, but had given them fun while learning the concepts.	Challenging Application
At first, students found it hard to navigate the application. Their worries were cleared out the moment that they were properly instructed and oriented as to how the software works.	Proper Orientation
Apart from the encouragement that the application has given the students, they positively acknowledged that the application gave them the proper avenue to put the theories and concepts on electric circuits into applications.	Application of the Theories
The students had stressed out that learning electric circuits is no longer a problem when using EveryCircuit application.	Better Learning in Circuits
The students had emphasized that though the software is available offline, they still wanted to access the online mode; however, it seemed hard to access the software because there was no stable signal in their respective places.	Signal Interference
The students suggested that if possible upgraded version will be provided to them so that more options and controls are available.	Upgraded Version of the App
Number of Students in the Experimental Group	20

Table 5 has summarized and transcribed the responses of the students, who belong in the Experimental Group, on what their perceptions and insights about the use of the EveryCircuit simulation application. As shown, five (5) students shared that despite that the use of the simulation application was new, students were able to learn better the electric circuits with the use of the software. This is also similar to the findings of Lin Haifeng [7] on Application of Circuit Simulation Software in Electronic Technology Teaching in which students had shown better learning.

Four (4) students evaluated the software as complicated and challenging, but still had given them fun while learning the concepts on electric circuits. Despite the struggle on the use of the app, three (3) students also responded that clear orientation must be given by the teacher before allowing them to use the software. If properly oriented, students will be able to properly navigate and manipulate the software.

Two (2) students expressed that the software gave them the encouragement and the proper avenue to put the theories and concepts on electric circuits into applications despite the new normal education. Two (2) students had stated that learning the concepts on electric circuits will no longer be hard for them if this simulation app is integrated in the discussion. Two (2) students had pointed out that when the simulator is used in online mode, that would be a problem because signal interference might affect the performance of the simulation application. Interestingly, two (2) students raised their suggestion that when feasible they will be given the upgraded version of the simulation application. When the software is upgraded, more controls and options will be available. When more controls are available, students can explore more about the complexities of electric circuits and other topics offered by the software.

4. Conclusions

Reiterating what Cohen et al. [12] say, "Action research starts small, by working through changes even a single person can try, and works towards extensive changes."

Based on the results obtained from the research the following conclusions can be derived.

- Majority (74%) of the students were using Android mobile phones.
- There is a significant difference between the two groups (p-value=0.02121). This supports the claim the use of simulation application in teaching electric circuits may have an impact to procedural knowledge and that simulation application integration is way better than pure modular learning.
- Students found it challenging on how to navigate and access the simulation application. But when clear instructions as to how to use the application are given by their teachers, they then learned how to manipulate the application.
- Students wanted to upgrade the version of the application so more controls and options will be unlocked.
- Students may have developed procedural knowledge when using the simulation application.

In conclusion, it is important for all students to succeed early in their academic careers. Unfortunately, in electronics technology foundation level courses, it is often a short window for students to produce academically. If students cannot comprehend both the theoretical and applied nature of complex electronics concepts, they have little chance of graduating. It is imperative for electronics technology faculty to use every tool at their disposal in an effort to serve students. It appears that recent developments in terms of access to technology and new software programs can provide the necessary clarity for students to succeed.

5. Recommendations

The following recommendations comprise the finalized action plan as an answer to the perceived deficits in student comprehension. Recommendations are all based on data gathering and analysis of this research.

- Recommendations include that Tagoloan Community College must make efforts to use cooperative learning strategy in alleviating students' learning difficulties in procedural knowledge using the simulation application. Seminars, trainings, or workshops on how to effectively use the simulation application should be given to the teachers teaching technical/hands-on subjects.

- The teachers must let students use the circuit analysis applications for their homework and general understanding of circuit concepts and let them use the complex number applications on homework, quizzes, and tests.
- Motivation to pursue the study on the development of circuit simulation software in electronic circuit course in the hope of providing guided tools for a successful transfer of technology to the students. Tootlkit or User's Manual on how to manipulate the selected chosen application should be crafted to better understand how such application be integrated into teaching the circuits. This manual would give the students the confidence and guidance on how the application works.
- For future studies it would be wise to monitor the amount of other operating system devices such as Windows or computer-based simulators being used by students and maybe seek out similar applications that are comparable. As of the date of this research, the overwhelming majority of students are using Android or iOS phones. It is clear that a high quality mixed methods research design could focus on combining quantitative survey data and feelings and perceptions from qualitative data gathered during focus groups to determine a deep understanding of issues related to this research.
- Whether the world is in the pandemic or not, whether the way of education is done online or physical, teachers may still integrate the use of the simulation application in their classes.

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