An Analysis in Student Learning Achievement in Electrical Concepts Using a Guided Curriculum

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Abstract*– This study explored the effect of using a guiding curriculum with a customized learning management system (LMS) as a teaching delivery method on students' learning achievements in electrical and electricity concepts. A quasi-experimental with a post-test design was used to conduct the research. Sixty tenth-graders from a private high school in the Dominican Republic voluntarily participated in the study. Students from different classes were divided into two instructional modules: traditional classroom instruction, and guided-LMS instructions. Students in each of the two experimental groups receive instructions in electrical and electricity concepts in weekly sessions by a class teacher. A test was developed to measure students' understanding of basic concepts of electricity. The educational experiment was completed within 6 months. The results showed that a guided curriculum was an effective learning tool to support students in developing electrical engineering knowledge ($t = 2.688$, $df = 58$, $p = .009$).

Keywords—K-12, Engineering, LMS, STEM, Achievement.

I. Introduction

The training of individuals with theoretical and practical knowledge in the areas of engineering is one of the main goals of developed countries and of those interested in being part of the new 4.0 revolution that has already begun [1]. This training takes even more relevance when occurring at early ages, especially for those who aspire to pursue advanced studies in these branches of science, as for those individuals who soon will be part of the productive apparatus of those technologically advanced societies. Individuals could make more rational, responsible, and efficient use of technologies that concern them if they are more knowledgeable about them. One strategy that might help is focusing on early exposure to engineering and science in n K-12 education.

Teachers are the vehicle, the designer, and the primary point source of information in K-12 education. It is important for them to have some guidance especially when they start as teachers, to learn, evolve, and develop a sense of understanding to adapt materials into their curriculum [2]. A guided curriculum can help organize science and engineering content to better help both students and teachers. A better organization of the curriculum can be appealing to a broader audience and increase interest and students' learning achievement [3].

In this paper, we intend to study the influence of a guiding curriculum embedded in a customized (Learning Management System (LMS) within the electrical and electricity concepts for grade 10 in a private high school in the Dominican republic. This study is part of a broader work based on initial findings while integrating hardware and simulation software to teach microcontrollers [4]. Furthermore, we developed an educational system that incorporated both a customized LMS and hardware being used as a workstation [5]. Both, the hardware and software incorporate all the necessary equipment to conduct experiments in basic electrical engineering (Fig. 1).

The LMS communicates with the station, allowing the station equipment to be viewed on the computer like real instruments on screen. The LMS is designed in a way that instruction is carried step-by-step, tutorials are provided to conduct real practices using the station and the application.

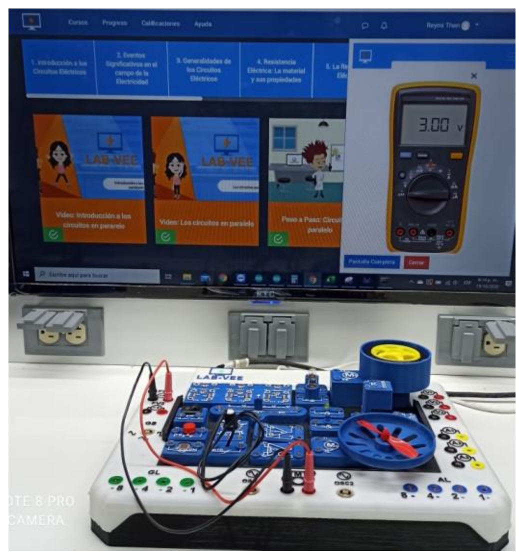

Fig. 1 Hardware and software ecosystem to teach electrical and electricity concept

The customized LMS is organized in a way that instructions are set to be delivered in weekly sessions. Each week or session has a set of questionnaires for student's reflection and grading. Each of the physical practices has instructional videos explaining what is, and how to use each element of the ecosystem besides relevant literature that provides an alternative to the student to learn the concept progressively. However, despite having this educational ecosystem, due to the pandemic of COVID-19, we have been able to only test the LMS/software and the content concerning the theoretical concepts. The modality of instruction switched to distance/virtual modality for the beginning of the 2020 school year. Although no real

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physical hardware has been used with the LMS our research team needs to measure if there is any improvement in the learning achievement in electrical and electricity concepts in students while using this LMS.

The curriculum layout in the LMS, for teaching Electrical concepts, is set in a way that students receive their lecture in the same way through the delivery of the curriculum. Every subject, or chapter, consists of a series of modules. Each module has three types of activities, and within those activities, each is linked to a specific resource, see table I.

Activities types are the introduction, module presentation, and a lab or practice. The introduction video appears only in the first module of the chapter or when an introduction to the subject for that chapter is necessary. The main presentation, where the theoretical background is introduced, is made of three subsections as resources. One explanatory video for the module or subject, Links and other documents to support further reading, and a short survey to assess module learning.

The last activity, and one of the most important due to its practical nature, is the implementation of a real lab. When the LMS is paired with the hardware station, students can measure electric variables, such as voltage and current across passive components, such as resistors. The lab or practice consists of three main components: a step-by-step tutorial, instructional videos (explaining each resource from the ecosystem and uses), and lastly a short survey to assess student learning.

TABLE I

Modules and Subjects Structure in the LMS

Subject	**Module**	**Activities**	**Resource**
Subject	Module	Introduction (Only at the beginning of module)	Introductory video
		Module lecture Presentation (all theory concepts are introduced)	Explanatory Videos
			Links and support resources
			Short Surveys
		Implementation (students perform real practice)	Tutorial PAP
			Instructional Videos (explaining each resource from the ecosystem and their uses)
			Physical or real Practice
			Short Survey

The guided curriculum in Electrical concepts used in this study had eight subjects, or chapters, and sixteen modules. Each of the modules accompanied by its correspondent activities as indicated in Table I. The main subjects or chapters of the LMS are listed below:

1. Electrical circuits Introduction
2. The electrical resistance
3. Voltage
4. Electrical Current
5. Series Circuits
6. Parallel Circuits
7. Electrical signals
8. Electrical circuits and their applications

The structure of the LMS's navigation has been carefully structured so it is easy for the students to change between subjects or modules. Module's titles are shown on the top bar, and its associated clickable thumbnail for that specific resource is also shown for easy identification and access (Fig. 2).

Fig. 2 Screenshot of LMS's navigation

Two characters were created and included in all interactive and customized videos, Toby and Molly. Toby and Molly interact with each other by having conversations and discussions about electrical concepts related to the student's chosen subject. Each conversation between Toby and Molly also is accompanied by its corresponding captions on the right sidebar. At the moment, all conversations and captions are only available in Spanish, but they can easily be audio-translated to English or any other language (Fig. 3).

Fig. 3 Screenshot of LMS's customized video

These self-explanatory videos are the main resources for teaching or learning theoretical concepts in each module. They can be found in each of the three main categories into which the LMS is organized. Each video is designed in a way that the information is transmitted to the students so they won't need to make any extra or special effort to understand. The videos are animated, the characters' voices are proper for their age range, and the conversations between toby and Molly use technological examples in engineering subjects, making them more engageable.

Although the hardware capability was not used in this experiment, the station is fully integrated with the LMS. The LMS integrates real instruments on screen such as power supplies, oscilloscope, sinewave generator, voltmeter, and amperemeter. The idea behind this is that students can follow the theoretical part of the guided curriculum, and when the student gets to the step-by-step lab they can assemble and test their real circuits without the need to include external measurement equipment. All instruments have dockable and moveable access and a physical port in the station (Fig. 4).

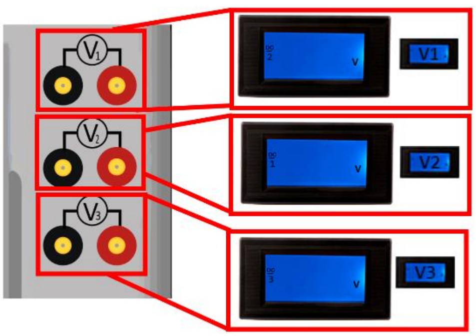

Fig. 4 Screenshot of the Voltmeter, Hardware station on left and LMS view on the right

The goal of the short surveys the student are faced with, within the navigation of any chosen subject, are meant to focus the students on the more relevant information from lectures and videos. They are made of a series of questions and evolving exercises throughout the curriculum which at the same time allows assessing student performance.

A. *Purpose of the study*

Based on the abovementioned information, the current study aimed to investigate if differences exist in learning achievements in electrical and electricity concepts for students receiving teaching instruction with a guided curriculum through a customized LMS. We hypothesize that those students receiving instruction through this guided curriculum with the customized LMS should reflect a considerable increase in their learning in electrical and electricity concepts. Also, we hypothesize that those students receiving this type of instruction (guided curriculum) should reflect a larger learning achievement in electrical and electricity concepts than those receiving traditional instruction delivery. An educational experiment was conducted in two tenth-grade classes where 60 student participants received weekly instruction in electrical and electricity concepts with two different modalities of teaching instruction (traditional vs. LMS guided curriculum). One major research question was as follows:

- Did significant differences exist in learning achievements in electrical and electricity concepts for students receiving different types of teaching instruction modalities?

According to the research question, the research null hypothesis of the study was:

- There was no significant difference in learning achievements in electrical and electricity concepts for students receiving different types of teaching instruction modalities

II. Research Method

A. *Research design*

In the study, a quasi-experimental with a post-test design was adopted to explore the effect of using a guided curriculum through a customized LMS on students' learning performances. The independent variable was the modality of instruction to teach Electrical and Electricity to students. The dependent variable was students' learning achievements in Electrical and Electricity concepts. A pre-test was also collected in the treatment group to study the within-group effect in learning achievement.

B. *Experimental control*

To minimize the threats to the internal validity of experimental research [6], several experimental controls were administered during the implementation of the study. Table II summarizes the experimental controls used in the study.

TABLE II

Experimental Controls

Potential	Threat Measure
Class instructor	The same instructor in all experimental groups
Class time	Students received the class at the same scheduled time
Learning contents	The same instructional materials were delivered to all groups.
Class setting	* In the same computer lab
Prior knowledge	Pre-test adopted in 10th graders virtual group

*The pre-test/post-test 10th grader's group due to COVID-19 restrictions received the instructions remotely.

C. *Research instruments*

We developed a simplified multichoice eight questions instrument to access student understanding of electrical and electricity concepts [7]. The questions were about basic resistance, voltage, and energy concepts. This instrument was provided as a pre-test and/or post-test where required (pre-test / post-test for Group A and post-test only for group B). Those questions provided a score for each student as a measurement of achievement on electrical engineering concepts. Five other questions were also included to explore students' interests in career choice and course interests.

D. *Research Participants*

Sixty students from a private high school in the Dominican Republic voluntarily participated in the study. Thirty of the students were from 10th grade for the year 2020 and thirty were from 10th grade for the year 2019. (Class A: 30; Class B: 30), Table III. Class A received instructions in electrical and electricity concepts using a customized LMS with a guided curriculum, and Class B received traditional instruction in a classroom setup.

TABLE III

PROFILE OF RESEARCH PARTICIPANTS

Class	Experiment	Number of students
Treatment A	Instrution through an LMS-guided Curriculum (distance/virtual)	30
Treament B	Instructions trought tradiotanl clasrromm means	30

E. *Data Analysis*

Two independent t-tests were used for data analysis to compare mean differences among experimental groups. The significance level was set to 0.05 in the study. One t-test was performed in group A between the pre-test and post-test and another among the post-test of group A and Group B.

III. RESEARCH RESULTS AND DISCUSSION

A. *Mean difference among experimental groups*

To test the efficacy of delivering instruction with a guided curriculum with an LMS, as a test of the hypothesis that significant differences exist in learning achievements in electrical and electricity concepts for students receiving teaching instruction with a guided curriculum LMS. We compared scores between the experimental and control group on the learning achievements variable, an independent sample t-test was conducted between each group's post-test (A and B). Also, another independent t-test was conducted between the pre-test and post-test of the treatment group to compare scores within-group learning achievement.

Learning achievement data were gathered from samples of 30 students from 10th grade in September 2020 and February 2021 (group A, pre-test, and post-test), with a pre-test sample mean of 66.25 (SD = 17.42) and a post-test sample mean of 77.08 (SD = 13.57), Table IV. A t-test was conducted for the pre-test and the post-test and significance was determined by a p-value under 0.05. A significant difference was found between the means for the learning achievement of the pre-test and the post-test ($t = 2.688$, $df = 58$, $p = .009$).

TABLE IV

LEARNING ACHIEVEMENT WITHIN GROUP A

	N	Mean	S.D.
Post-Test A	30	77.083	13.5679
Pre-Test A	30	66.250	17.4167

The effect size d (calculated using the pooled standard deviation) was 0.6939. Using Cohen's (1988) guidelines [8], this is interpreted as a medium effect. The results provide evidence to support that there is a significant
difference in students learning achievement, in electrical and electricity concepts, when receiving guided curriculum instructions via LMS. It was observed that students have higher learning achievements, on average, when comparing the end and beginning of treatment.

TABLE V

LEARNING ACHIEVEMENT BETWEEN GROUP A AND B

	N	Mean	S.D.
Post-Test A	30	77.083	13.5679
Post-Test B	30	73.75	16.8506

Post-test data gathered from treatment A was also compared with the post-test of another sample of 30 students from 10th grade who received traditional delivery classroom instructions from 2019-2020 (Treatment B). Treatment B has a post-test sample mean of 73.75 (SD = 16.85), Table V. Those students receiving the same instructions learning electrical and electricity concepts and using a guided curriculum via LMS showed a superior learning achievement on average than those taught using traditional methods (Fig 2).

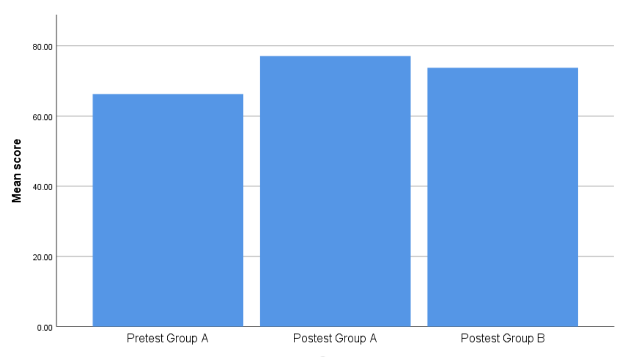

Fig. 5 Mean Scores vs Treatment group

A t-test was conducted for the post-test of treatment A, and the post-test of treatment B and significance was determined by a p-value under 0.05. No statistical significance was found between means of learning achievement for post-test treatment groups A and B ($t = 0.844$, $df = 58$, $p = .402$). The effect size d (calculated using the pooled standard deviation) was 0.2179.

Using Cohen's (1988) guidelines [8], this is interpreted as a small effect. Although not statically difference was found between students when they are taught with different teaching methods

B. *Discussion*

The data from the two t-tests performed suggest that the inclusion of a guided curriculum LMs into the teaching delivery increases the learning achievement compared with the traditional methodology of instruction. Interestingly, though, is that when compared within the treatment group, there is not enough evidence that the guided curriculum influenced the students learning (Fig. 5). Our group has discussed the influence the COVID-19 pandemic might have in our experiment as the class moved to remote instruction. We could not perform our experiment testing the full ecosystem hardware and software which would have made the instructions more engaging and iterative potentially providing a different outcome.

We took the data and performed a correlation analysis and Interestingly we observed a strong correlation between the courses the student likes the most in the school and the choice of career they want to pursue in the university ($r=0.212$, $p<.045$). We found that those that felt attracted to Spanish, orientation, and robotics were the only ones with an interest to study engineering-related careers in their future (Fig. 6).

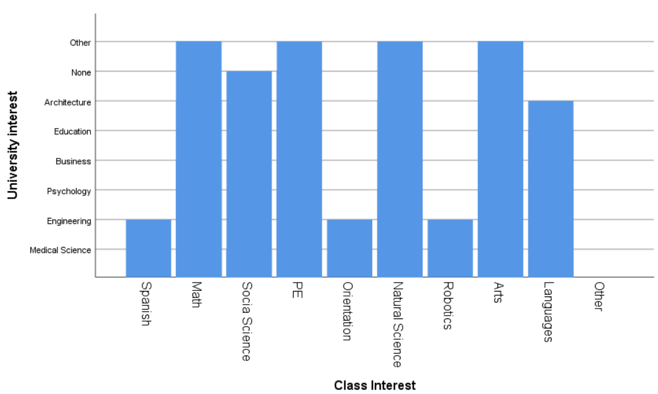

Fig. 6 Class Interest vs University Interests Pre-test Group A

When we run the same analysis to the postest for treatment A there was a shift in the career choice and the courses they like the most (Fig. 7). Now robotics ended being one of the most favorites and could not match any interest in engineering although the correlation supports it.

This information opens the possibility to further explore, in future research, how a guided curriculum can shift, or not, the preference in career choice or if it is the content that creates the shift and not the delivery methodology.

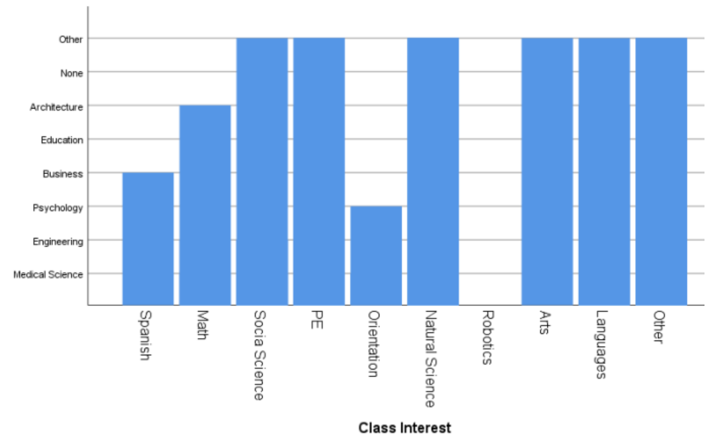

Fig. 7 Class Interest vs University Interests Post-test Group A

IV. Conclusions and Future Work

This study explored the effect of using a guiding curriculum with a customized learning management system (LMS) as a teaching delivery method on students' learning achievements in electrical and electricity concepts. Based on the statistical results identified above, the research null hypothesis was rejected. A significant difference in students' learning achievements was found among the two experimental groups. Compared to two of the control group which received traditional delivery instructions in the classroom, students in the treatment group receiving instructions with a guided curriculum achieved a better learning outcome. Moreover, a small to medium effect size was identified between groups. Therefore, using a guided LMS curriculum can potentially be an effective learning tool to support students in developing electrical and electricity engineering skills.

Although we did not pretend the findings in this study to be generalizable we understand that having a larger sample size will help to control power and effect size. Also, this study only took place in one private school. In future works, we hope to expand the scope of our study to other schools including public ones. The COVID-19 Pandemic changed our design as instructions changed to be remote. Once the pandemic is overcome we hope to be able to test our ecosystem hardware and software.

Future works should include a full working hardware-software ecosystem to test the students learning achievement; a pre-test / post-test design and for both treatment groups; the same location for instruction (not a remote delivery) at school. Also, future works will benefit by exploring other subjects like math, digital circuits, or basic electronics. Exploring student shift in the career choice of preference due to either the delivery methodology or the nature of engineering content been delivered should be the subject of further exploration.

Although this study took place in a K-12 learning environment it still might provide implications for engineering educators at higher educational institutions. In engineering colleges, when given an opportunity, the instructor chooses traditional delivery methods although using technologies for remote instruction (ex: Zoom, Skype, Webex, etc.). From the results of our study, a guided LMS showed its benefits in engineering learning. While using other traditional methods the instructors spend time designing their content more traditionally while using the guided curriculum through an LMS might result in more engageable activities lifting student performance while developing their knowledge in Electrical Circuits and any other Science related subjects.

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