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Comparison among sophomore and undergraduate students about electric circuits understading

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A R T I C L E I N F O

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A B S T R A C T

We present an analysis on students' comprehension regarding electric circuits with three engineering groups (Electronic Engineering, EE, at Instituto Tecnológico Superior de Comalcalo; and two Petroleum Engineering groups, PE, at Universidad Politécnica del Golfo de México) and we used DIRECT as a test to detect some common misconceptions; EE students were undergraduate (4th year) and PE students were sophomore students (1st year), with PE we worked with a control group and an experimental group. The concentration factor indicates there is not a meaningful difference between the control group and EE group, therefore it is deduced that if professors uses traditional instruction the learning gains will be very low even if students are enrolled in several courses related to electric circuits. On the other hand, the experimental group worked with the Investigative Science Learning Environment ISLE system allowing them to work collaboratively and develop several scientific abilities focusing on lab experiments. Our results revealed that ISLE promotes meaningful learning on electric circuits comprehension; the experimental group achieved 28% in HH zone and 38% in MM zone; compared with other groups which achieved 3% in HH zone and 31% in MM zone. As we observed, there are improved results using ISLE.

Se presenta un análisis del nivel de comprensión de circuitos eléctricos c.c con tres grupos de estudiantes de ingenierías (Ingeniería electrónica, IE, del Instituto Tecnológico Superior de Comalcalco; Ingeniería Petrolera, IP, de la Universidad Politécnica del Golfo de México). Se aplicó el test DIRECT a los tres grupos de estudio, los estudiantes de IE se encontraban cursando el cuarto año de su carrera y los estudiantes de IP cursaban el primer año, con este último grupo se trabajó con un grupo de control y un grupo experimental. El factor de concentración indica que no hay diferencias significativas entre el grupo de control y el grupo de IE, por lo que se deduce que si la enseñanza es tipo tradicional la ganancia en el aprendizaje será muy pequeña incluso si los estudiantes llevan varios cursos relacionados con el tema. Por otro lado, el grupo experimental trabajó con la metodología ISLE permitiendo trabajo colaborativo y el desarrollo de diversas habilidades científicas dando prioridad al desarrollo de diversos experimentos. Los datos revelan que esta metodología provoca mejoras significativas en el aprendizaje de circuitos c.c obteniendo un 28% de ítems en la zona HH y un 38% en la zona MM, muy por arriba de los grupos de comparación, los cuales alcanzan solo un 3% en la zona HH y un 31% en la zona MM. Como se puede ver, hay mejores resultados con ISLE.

I. INTRODUCTION

Several years ago teaching by competence was introduced in México changing our educative system, a lot of professor reject this model because is very difficult (for them) to applied in classroom (Hernandez, 2013; Beneitone, 2007; Tobon, 2006). This proccess move education system from focusing on *what professor believes students need* to what *students have to know and how solve complex problems*. Up to now we are working with professors and students in order to accept that model because they cannot see good results in student´s performance along their career in some universities, principally in subjects as Math and Physics. However, there are several methodologies to teach physics which could help or support competence model like as Peer Instruction (Crounch & Mazur, 2001), Interactive Lecture Demonstration (Thornton & Sokoloff, 2004), Physics by Inquiry (McDermott *et al*, 2001), and others. In this work we use the Investigative Science Learning Environment ISLE system in order to improve student´s learning and develop some scientifics abilities, which are very important for their worklife. According to Etkina & Van Heuvelen (2006) (ISLE) curriculum focuses explicity on helping students to develop abilities used in the practice of science. Students could develop abilities as representing knowledge in multiple ways, designing an experiment to investigate a phenomenon, test a hypotesis, solve complex problems, collect and analyze data, etc. The cycle starts each conceptual unit analyzing patterns in experimental data or using a video format. Students use different representations and try to explain the phenomenon, then they built ideas using hypothetic-deductive reasoning and, very important, they work in groups discussing and sharing their knowledges. With ISLE, students have to learn to describe a phenomenon, collect and analyze data, find patterns, give and test explanation of the patterns, represent data in multiple ways. Students recived a rubric (Etkina *et al*, 2006) that allow them improve their explanation and lab report, those rubrics were made in order to develop certian scientific abilities in students. Rubrics are a very important aspect of any evaluation process because students and professor can asses their work and incorporate feedback among them, this is a kind of formative assessment which is defined by Black and William (1998) as “those activities undertaken by instructor and their students in assessing themselve, which provide information to be used as feedback to modify the teaching and learning activities in which they are engage”. For this reason, students need to understand what abilities they are expected to acquire and criterias for their worklife. Rubrics fulfil these functions. Why we have worry for developing different abilities in our students? A posible answer comes from ThinkWise Inc (2007), they consider “The competency-based approach is widely used today by many succesfull orgaization- and for good reason, it works”.

On the other hand, students’ patterns response of questions about electric circuits exhibit several misconception related to electric current, differential voltage, series and paralell circuits, Ohm´s law and others (Hewitt, 2007). The Determining and Interpreting Resistive Electric Circuit Concept Test (DIRECT) was developed to evaluate student´s understanding of a variety of direct current (DC) resistive electric circuits concepts and it could be used it with college/university students (Engelhardt & Beichner, 2004). Acording with Hewitt (2007) is it erroneous to say that current is “use up” in an electric circuit, this is a commun misconception detected in university students (Arnold & Millar, 1987). The quantity that is consumed in an electric circuit is not current, but energy; students think that a battery is a source of constant current (Licht & Thijs, 1990) and use different concept like voltaje, current energy or power interchangeably (Von Rhöneck & Völker, 1984). Psillos *et al* (1987) found that a group of 14-15 year old Greek students believed that an ammeter would consume current so that it functionated like a bulb (an ammeter does not consume current and has a negligible effect on the circuit). Engelhart & Bichner (2004) found that students assign the properties of energy to current, and then assign these properties to voltaje and resistance. DIRECT can detect several misconceptions about DC electric circuits concepts and has four mainly objectives: a) Physical aspect of DC electric circutis, b) Energy, c) Current, d) Potential difference. We will discuss the first objective later.

II. METHODOLOGY

We followed most of criterias of ISLE cycle in order to carry out this research. We apply DIRECT test to sophomore and undergraduate students, which are enrrolled in two different carrers and different universities. Sophomore students are from Universidad Politécnica del Golfo de México of Petroleum Engineering carrer and we took a control group (whom were instructed using traditional teaching) and an experimental group (whom were instructed using ISLE); udergraduate students are from Instituto Tecnologico Superior de Comalcalco of Electronic Engineering (traditional teaching). With an experimental group we started each unit analysing a video or performing an experiment, they work in teams (just three students) in order to promote socio-constructivism. They had to analyze the experiment, describe the phenomenon, use multiple representation such as picture, diagram of circuits, graphics, etc, in this way students chat together to share their knowledge and improve their reasoning. Finally they had to make a Lab report using rubrics in order to promote feedback and self- assessment. Instructor use these rubrics to assess students Lab report and then he/she point out (during class) progress and difficulties found it and how they could improve their reports. This sequence was used during all cuatrimester (four months). DIRECT was applied to 23 undergraduate students, 44 sophomore students (21 on experimental group and 23 on control group). In order to clasify student´s mental models we use concentration factor tool (Bao & Redich, 2001) as follow (considering 5- multiple choice test):

$$CF = \frac{\sqrt{5}}{\sqrt{5}-1}\left(\frac{\sum_{i=1}^{5}\sqrt{a_i^2}}{N} - \frac{1}{\sqrt{5}}\right). \qquad (1)$$

Where N represents the total number of students, a_i is options chosen by estudents. In order to quantify those mental models a three level code was neccesary, see Table 1.

TABLE 1. Three level code for score and concentration factor.

Score	Level	Concetration Factor	Level
0-0.4	L	0-0.2	L
0.41-0.7	M	0.21-0.5	M
0.71-1	H	0.51-1	H

We can obtain different pattern responses and using Table 1 is easy to clasify them as: a) LL model represent a radom zone and indicates that students no matter the test or items, b) LM model indicates there are two incorrect models, c) MM model indicates there are one correct model and one incorrect model, d) HH model indicates students could mastered some items and represent one correct model.

III. ANALYSIS AND RESULTS

A. ELECTRONIC ENGINEERING STUDENTS

In this section we will refer to student´s pattern responses by our groups of study. We started this discution with EE students. Figure 1 shows Electronic Engineering student´s pattern responses using Concentration Factor; they coursed some subject such as Electricity & Magnetism, Electric Circuits I, Electric Circuits II, Basic Electronics and others. We observed, there are just three items (HH zone) mastered by this group (3% of the test), this result is not adeceate because EE students are undergraduate and, for that reason we expected a better performance by this group; seven items fall in two model zone (MM) this is just a 31% of the test, so there are one correct model and one incorrect model. Twelve items (41%) appear in LM zone, here there are two incorrect models so most of students have several strong misconceptions on conceptual comprehension of DC circuits. Finally, seven items (25%) fall in LL zone, this is a random zone i.e students choose an item without reasoning.

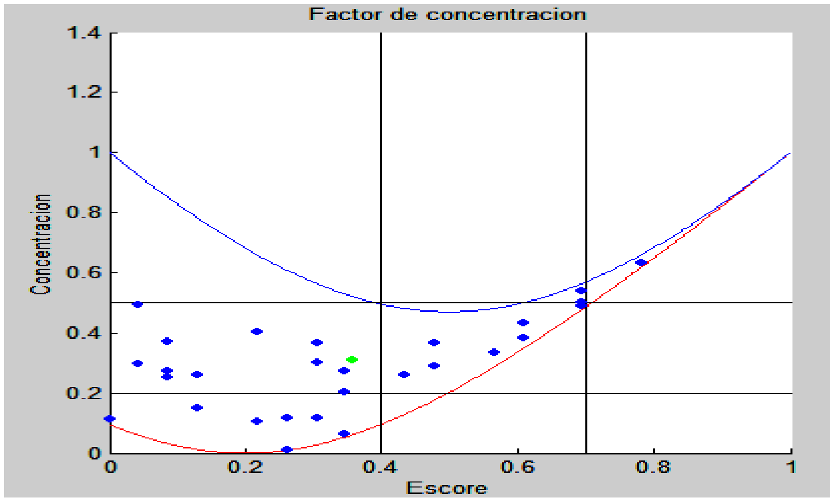

FIGURE 1. EE student´s pattern responses.

Data indicates EE students did not adquired adecuate abilities to understand DC electric circuits in spite of they are enrrolled in a career focused on electric and electronic circuit analysis. In fact, score and concentration factor (green diamond) fall in LM zone indicating that this group has (in general) two incorrect models on these topics. As we can see traditional teaching does not promote meaninfull learning and, it seems, no matter how many subject they already enrrolled the gains in learning will be tiny.

B. PETROLEUM ENGEENERING. CONTROL GROUP

Now we are going to discuss student´s pattern responses by control group. Fiure 2 shows pattern responses, this group was taught using traditional instruction i.e, professor and students resolve many textbooks problems (Serway *et al*, 2010; Serrano, 2001), without concept reasoning activities nor lab experiments. These students were enrrolled to electromagnetism course for first time, this subject include topics such as Coulomb´s law, Electric field, Electric potential, DC electric circuit, Ohm´s law, Kirchhoff´s law and Faraday´s law. Instruction session was 6 hours per week during 14 weeks. Blue diamonds represent pre test results and magenta diamonds represent pos test results (see Figure 2). As we can see there is no meaninfull difference (more details in next section) between pre and pos test, i.e., student´s reasoning no change after this instruction. Observe that pos test means (red diamond) is lower than pre test means (green diamond), this data reveals that traditional instruction could provoke regression and confusion among students, this result is agree with other research but in electrostatic, Sandoval & Mora (2009) found that students become confused to translate Coulomb´s law and Electric field concept correctly when instructor use traditional teaching. We can see there are thirteen items falling in random zone (LL) this is a high percentage (45%) and reveals a low interest by students in this topics; pre and pos test means (green and red diamond) fall in LM zone which represents two incorrect models; remember EE students also have similar results, in fact among both control group and EE students there are no meaningfull difference. In this case, we found that both sophomore and undergraduate students have and keep having similar misconception about DC electric circuits and, of course, that state could remain for long time when this metodology is used.

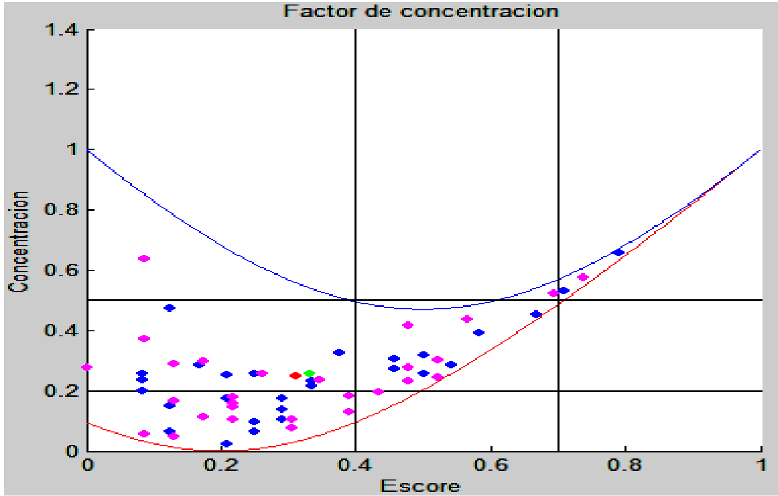

FIGURE 2. Student´s pattern response of control group.

C. PETROLEUM ENGEENERING. EXPERIMENTAL GROUP

In this section we show student´s pattern responses of experimental group. With this group we use ISLE metodology in order to improve DC electric circuits learning. ISLE engages students to conduct several lab experiments in order to acquire and develop some scientifics abilities practicing similar to how a scientist would. Teaching processes was as following: oral lecture, 2 hrs per week solving two or three conceptual activities and some texbook problems (Serway et al, 2010; Hewitt, 2007; Etkina & Van Heuvelen, 2006); laboratory, 4 hours per weeks where students conducted some experiments (Etkina & Vanheuleven, 2006) chosen carefully by instructor, there was one assistent to sopport students in the laboratory. Lab intructions were to analyze circuits, perform the experiment, decribe the phenomenon, find uncertaintity sources, identify patterns and make a conclusion. Students have to hand out a lab report and they could use rubrics to self-assessment (Karelina & Etkina, 2007).

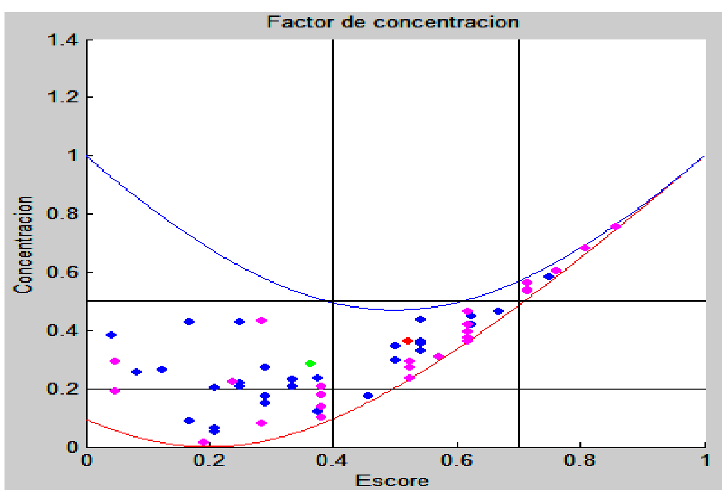

FIGURE 3. Student´s pattern responses of experimental group.

The above Figure shows that 20% of responses fall on LL zone (randome zone) pre test as well as pos test, so this indicates that those items, which cause a lot of confusion, remain the same way before and after instruction. On the other hands, 41% fall in LM zone (two incorrect models) in pre test. However in pos test this percentage decrease 13%, so this is a good trend in our sequence. In MM zone pattern responses were 26% in pre test, but we can see an important increase for pos test and reachs 39%, this way ISLE provoke favorable changes on conceptual reasoning and we consider as a very good result. In adition, in pre test just 3% of pattern responses reach HH zone, this result is very similar to undergraduate students, however ISLE promoted that experimental group improved their conceptual reasoning and, after instruction they obtain 28% of pattern responses in this zone indicanting that is an excellent tendency. We can see that there is a meaningfull difference between pre and pos test means (green and red diamonds). Observe red diamons fall in zone MM in pos test; this is the best results among three groups because EE students and control group fall in LM zone. We made a hypotesis test for two population and our hypotesis are shown in Table 2. H_0 and H_1represent null hyotesis and alternative hypotesis respectively, μ_{exp}, μ_c and μ_u are experimental group, control group and undergraduate students means respectively.

TABLE 2. Hypotesis for two populations.

Hypotesis	Description
H_o: $\mu_{exp}= \mu_c$ H_1: $\mu_{exp} > \mu_c$	There is no meaningfull difference between ISLE and traditional teaching. ISLE promotes larger results than traditional teaching.
H_o: $\mu_{exp}= \mu_u$ H_1: $\mu_{exp} > \mu_u$	There is no meaningfull difference between experimental group and undergraduate students. ISLE promote larger results in experimental group than undergraduate students
H_o: $\mu_u = \mu_c$ H_1: $\mu_u > \mu_c$	There are no meaningfull differences between undergraduate and sophomore students. Undergraduate students have larger result than sophomore students.

In order to determine if there is meningfull difference between ISLE and traditional instruction, we used *t*-student distribution with a 5% of significant level, freedom degrees of 42 and critic value of *t* equal to 1.684, we computed means difference standarization and results are shows in Table 3.

TABLE 3. Results of hypotesis test.

Comparison groups	Means difference standarization
Experimental group vs Control group	2.4653
Experimental group vs Undergradute students	1.9201
Control group vs undergraduate students	0.5580

Table 3 shown that comparising experimental group vs control group, and experimental group vs usdegraduate students, means difference standarization fall in non- accepted region, so we have to reject our null hypotesis and we have to accept alternative hypotesis. These results indicate there is meningfull difference between both traditional teaching and ISLE methodology and they are agree with concentration factor. On the other hand, comparising control group vs undergraduate students we have to accept null hypotesis so there are no meaningful differences between those groups.

C. BRIEF ANALYSIS ABOUT PHYSICAL ASPECTS OF DC ELECTRIC CIRCUITS

In this section we disscus about different mental models for each group of study analyzing one objective of DIRECT: Physical Aspects of DC Electric Circuits. TABLE 4 shows student´s mental models clasifying them acording to Ley Bao (2001), we can observe that control group had the lowest comprehension in this section, they just obtain 27% of MM models and remained 73% in a zone that indicate they chosen randomly any option for each item. Of course, this is not a good performance. EE students had 72% of items with MM model, this is a good result but we expected a better performance by those students because they finished their career earlier, so we can clasify this result as moderate. Observe there are no HH mental models, which indicate whether students mastered the concept studied. On the other hand, experimental group adquired the best mental models we can see there are 36% of items with HH mental models (control group and EE students did not reach any of these models); 18% reach MM model indicating a very well performance by these students. Observe, the percentage on LL model is very similar to EE students. We achieved similar results on the others objectives of DIRECT (energy, electric current and differential voltage), i.e better models were reached by experimental group than control and undergraduate students.

TABLE 4. Student´s pattern responses for Physcal aspects of DC electric circuit.

	Electronic Engeenering students			**Control group. PE**			**Experimental group. PE**		
Item	**Score**	**FC**	**Model**	**Score**	**FC**	**Model**	**Score**	**FC**	**Model**
10	0.2609	0.1183	LL	0.1304	0.2893	LM	0.0476	0.2908	LM
19	0.6087	0.3812	**MM**	0.3913	0.1828	LL	0.7143	0.5393	**HH**
27	0.6957	0.4905	**MM**	0.4783	0.278	**MM**	0.7143	0.5338	**HH**
9	0.3043	0.3005	LM	0.3043	0.0774	LL	0.7133	0.5278	**HH**
18	0.4783	0.3655	**MM**	0.3913	0.1282	LL	0.2857	0.4304	LM
5	0.6957	0.5	**MM**	0.5217	0.3005	MM	0.381	0.2066	LL
14	0.3478	0.2723	**MM**	0.0870	0.3708	LM	0.619	0.3939	**MM**
23	0.5652	0.3335	**MM**	0.2174	0.1765	LL	0.6190	0.4214	**MM**
4	0.0435	0.4953	LM	0.2174	0.1446	LL	0.2381	0.2211	LM
13	0.4783	0.2893	**MM**	0.6957	0.5211	**MH**	0.7619	0.6038	**HH**
22	0.3478	0.2013	**MM**	0.2174	0.1575	LL	0.3810	0.0986	LL

IV. CONCLUSION

We found that traditional teaching does not engage students to think differently, work in better ways and not adquiere the proficiencies that students needs for their future work experience. Undergraduate students and control group (sophomore) have similar mental models in spite EE students having be in more subject (related to DC electric circuits) than control group and experimental group, those students (EE) just reach 3% of test like the HH model and 31% in MM zone, 66% obtain LL and LM models these results are very similar to control group. We expected a better performance by EE students because they are studiying to analyze electric and electronic circuits so this is not a good omen, it seems those students will finish their career with a lot of misconception and incorrect models about electric current, differential voltaje and electric energy; we can deduce that thier proficiencies were not developed correctly. Students control group, whom faced DC electric circuits by first time, obtain mental models too close to EE group, this results indicate that learning between sophomore and undergraduate students, adquiered and keeping similar misconception for long time and no matter how subjects they coursed, using traditional teaching. For experimental group we find good results in their learning on this topics using ISLE cycle, datas shows there is a big movement in their mental models because in pre test they had similar misconception to control group and EE students but after instructions this students changes their mentalities and enjoyed works in teams, we could observed they shared knowledges and helped thogeter, this provoke best performance and improve learning. Experimental group reached 28% and 39%, respectively, mental models that represent good tendency in instruction as we see is lager than control group and undergradute students. In addition, numbers of item falling in random zone is the lowest; 20% by experimental group, 45% by control group and 25% by EE students. Hypotesis test indicate there is meaningfull difference between ISLE methodology and traditional teaching (such as control group and undergraduate students), although we found there is no meaningful difference between sophomore and undergraduate students´ reasoning, on

DC electric circuits, if they were teaching using traditional eduaction but if we use an active methodology we could have good results on their performance. Althougth, rubrics were an adecuate instruments to induce feedback improving student´s performance and their labs report, in this way we can assess abilities developed for those students. We find that improvement was increasing step-by-step following the activities undertaken by instructor. Is very important to say that we need to improve our sequence because there is anothers important abilities that experimental group did not reach so, we will spend more time to select correctly activities and more time for feedback.

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