Effect of ICTs in the learning of Basic Electronics in students of Electronic Engineering and Telecommunications

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***Abstract*– This work evaluates to what extent the application of ICTs allows improving learning in Basic Electronics in students of the Electronic Engineering and Telecommunications career. For this, two working groups were formed, to which a first evaluation was carried out, after which the use of ICTs was applied in one of the groups, to finally evaluate and compare the results based on statistical parameters.**

***Keywords*– Basic electronics, control group, experimental group, ICT, intact group.**

I. INTRODUCTION

A permanent concern within the university system is to improve the transfer of knowledge to the student. To meet this objective, it is necessary to establish novel alternative procedures and techniques; also, validate their effectiveness.

This research sought to know the level of learning development of Basic Electronics in a group of students of Electronic Engineering and Telecommunications and its relationship with the application of Information and Communication Technologies (ICTs), for this two working groups were formed: Experimental Group (EG) and Control Group (CG), to which an initial evaluation was submitted, after which the teaching process was implemented, applying ICTs only in the EG and routinely in the CG; Finally, based on statistical parameters, the results were evaluated and compared.

The objectives set in the work were:

- Deduce the confirmation or not of our working hypothesis and infer conclusions leading to the viability of our research.
- Determine the achievement of the objectives in terms of the level of learning of basic electronics in both groups, in order to make valid proposals.

II. DESIGN OF THE RESEARCH

A. Variable system

Table I shows the conceptual and operational definition of the variables used in this work.

TABLE I. DEFINITION OF VARIABLES

Independent Variable: Application of ICTs
Conceptual definition: ICTs, a set of technologies that allow the acquisition, production, storage, treatment, communication, recording and presentation of information, in the form of voice, images and data, contained in acoustic and optical signals.
Operational definition: • The objectives of the modular work are stated. • The contents are presented. • Knowledge is fixed.
Dependent Variable: Learning Basic Electronics
Conceptual definition: It is a learning process about basic electronics, using engineering techniques.
Operational definition: • Modular work is proposed. • The presented module is explained.

B. Operationalization of variables

Table II operationalizes the variables involved in the process, both in dimension and indicator.

TABLE II. OPERATIONALIZATION OF VARIABLES

VARIABLE	DIMENSION	INDICATOR
VI:ATICs	Planning and preparation of the theme.	* Poses modular work. * Organize the contents. *Learning Assessment.
	Presentation of the contents.	* Organization of activities. *Group and individual study. *Self-learning and self-assessment.
	Fixation of knowledge.	* Poses fixation exercises. * Reinforcement activities. *Use the results to reinforce.
VD:AEB	Electrical circuits	*Responses to contingencies. *Multiplication of alternatives. * Ability to perceive.
	Electronic circuits	* Organization of events. *Opening and confrontation * Ease of adaptation.
	Instrumentation	*Innovation capacity *Novelty and imagination. * Recognizes and uses instruments.
	Digital circuits	*Development of the ideas produced. *Search for improvement. *Will and resolution.

We define:
VI:ATICs = Independent Variable: Application of ICTs
VD:AEB = Dependent Variable: Learning Basic Electronics

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C. Research instruments

The techniques and instruments that have been used for the collection of information have been developed according to the characteristics and needs required for each variable, that is; for the independent variable, ICT application and the dependent variable, Learning Basic Electronics.

It is convenient to mention that the didactic unit developed for the present investigation corresponded to the topic of Basic Electronics Workshop, which has been developed according to the structure of the theme raised.

D. Research method

The following *empirical methods* were applied:

Direct measurement method: It allowed obtaining quantitative information regarding the properties or indicators of the variables raised.

Scientific observation method: Through the direct and programmed sensory perception of the processes, it was possible to know qualitative information of the variables.

Hypothetical-deductive: Proposed a hypothesis, then inferences were generated on the set of available empirical data, whose cause-effect relationship was induced from those.

Inductive: Based on the sample evaluations, generalizations were established for the entire population.

E. Type of research

Quasi-experimental, pre-test, post-test with intact groups.

Quasi-experimental: The subjects that are part of the CG and EG are not randomly assigned, nor are they matched, these work groups are already formed [1].

Design with pre-test, post-test: Both groups are evaluated at the beginning in the dependent variable, then the experimental treatment is applied to one of them and the other continues with the tasks or routine activities [2].

F. Description of the population and sample

Population: Students of the Basic Electronics Workshop course of the Electronic Engineering and Telecommunications Career.

Sample: 12 students were taken for the CG and 11 for the EG. Sampling is non-probabilistic, intentional. It supposes an informal selection procedure, where the selection does not depend on everyone having the same probability of being chosen, it rules the researcher's decision [3].

It was also intentional, given that the researcher selects the sample according to his criteria, without any mathematical or statistical rule, ensuring that it is representative, for this it is necessary that he objectively knows the characteristics of the population [4]

III. Implementation of the Research

A. Field work. Research Instruments

To measure the dependent variable (learning basic electronics), a knowledge test on basic electronics was developed.

Objective: This Basic Electronics Workshop test is part of a research project whose purpose is to obtain information about the level of Basic Electronics Learning in students of the Electronics and Telecommunications Engineering Career.

Structure: The dimensions evaluated by the knowledge test on learning basic electronics are the following: Theory of electric circuits, Fundamentals of diodes, Fundamentals of bipolar junction transistors, Basic concepts of instrumentation, and Theory of digital circuits.

Basic electronics learning module, a Basic Electronics Module was developed for use by teachers and students.

Objective: To measure the learning of Basic Electronics.

Application: Applied to the EG during fourteen class sessions, lasting four pedagogical hours each.

Structure: The dimensions, planning and preparation of the theme, presentation of the contents and fixation of the contents were evaluated. Table III shows the results in the qualification by the experts, both at the level of the Knowledge Test; as well as, for the Electronics Module.

TABLE III. LEVEL OF VALIDITY OF THE INSTRUMENTS APPLIED, ACCORDING TO THE JUDGMENT OF EXPERTS

EXPERTS	Electronics Learning		Electronics Module	
	Score	%	Score	%
1. Dr. Expert 01	720	80	783	87
2. Dr. Expert 02	765	85	765	85
3. Dr. Expert 03	765	85	765	85
4. Dr. Expert 04	810	90	810	90
5. Dr. Expert 05	765	85	765	85
Average Valuation	*765*	*85*	*777,6*	*86,4*

According to expert judgment, the test to measure the learning level of basic electronics obtained a value of 85.0%, the learning module in the students 86.4% we can deduce that the instruments have very good validity.

TABLE IV. VALUES OF VALIDITY LEVELS [5]

VALUES	VALIDITY LEVELS
91 – 100	Excellent
81 – 90	Very good
71 – 80	Okay
61 – 70	Regular
51 – 60	Deficient

B. Instrument reliability

Reliability by the method of two halves: In this case, the following steps were followed:

- To determine the degree of reliability of the knowledge test to measure the level of learning of basic electronics, as well as of the module; According to the perception of the students: First, a pilot sample of 21 people was determined. Subsequently, the instrument was applied to determine the degree of reliability.
- Then, the reliability coefficient was estimated for the knowledge test on learning basic electronics, by *The Two Half Method,* which consists of dividing the number of questions into two halves (odd and even).

- Subsequently, the level of correlation between the scores obtained in both halves was established. For which the Pearson correlation coefficient (r) was used.

  We have:

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{\left[n\sum X^2 - \left(\sum X\right)^2\right]\left[n\sum Y^2 - \left(\sum Y\right)^2\right]}} \quad (1)$$

  Where:
  n = Number of interviewees in the pilot sample
  X = Score obtained in the even questions.
  Y = Score obtained in the odd questions.

- Finally, the adjustment is made through the Spearman-Brow coefficient, which allows us to determine the reliability of the complete test.

  So we have:

$$r_s = \frac{2\,rxy}{1 + rxy} \quad (2)$$

  Where:
  rs = Estimated reliability for the complete survey.
  rxy = Pearson's correlation between the two halves (r).

Table V shows the level of reliability of the surveys according to the method of halves.

TABLE V. LEVEL OF RELIABILITY OF THE SURVEYS, ACCORDING TO THE TWO-HALF METHODS

Knowledge Test	Reliability
Learning of Basic Electronics	0,93
Learning Module	0,91

C. *Application and analysis of the pre-test*

The results obtained were analyzed at the descriptive level and at the inferential level, according to the objectives and hypotheses formulated.

Descriptive level: Frequencies and percentages have been used to determine the predominant levels in learning basic electronics.

Inferential level: Parametric statistics have been used and as such the t-Student. Distribution was used for the mean difference.

Descriptive level:

1) The *pre-test* was applied both to the EG of 12 students; as well as the CG of 11 students.
2) Subsequently, the EG was trained through the application of ICTs. In the CG it was routine.
3) Finally, the *post-test* was applied to both groups to verify the level of learning.

The use of the *quasi-experimental design* with pre-test was in order to determine the level of initial learning.

TABLE VI. RESULTS OBTAINED AT THE PRE-TEST LEVEL

Statisticians	EG-Y_1	CG-Y_2
n	12	11
Bigger number	8	8
Minor number	5	5
Rank	3	3
Average	6,42	6,55
Median	6	6
Variance	1,538	0,673
Standard deviation	1,240	0,820
Coefficient of variation	19%	13%

Table VI shows that, using the *mean difference point estimator*, a T= -0.291 was obtained. An acceptable T is observed with 21 degrees of freedom, and a significance level of 0.05 is 2.08, this allows us to observe that the calculated T is lower. Therefore, we can affirm that before the application of ICTs, the CG and EG students did not show significant differences.

D. *Application and analysis of the post-test*

It was carried out after the end of the academic year

TABLE VII. SCORES OBTAINED ACCORDING TO CHARACTERISTICS EVALUATED IN THE COMPARISON CAPACITY

Group	Electrical Circuits	Electronic Circuits	Instrumentation	Digital Circuits
EG	0.79	0.84	0.83	0.84
CG	0.52	0.51	0.55	0.53

Table VII shows that the learning level of basic electronics in the EG students managed to develop the desired characteristics in a higher percentage than the CG students. In the global results, EG solved with an effectiveness of 83%, while the CG solved 53% correctly. Better results were obtained, as summarized in table VIII.

TABLE VIII. RESULTS OBTAINED AT THE POST-TEST LEVEL

Statisticians	EG-Y_1	CG-Y_2
N	12	11
Bigger number	18	12
Minor number	16	10
Rank	2	2
Average	16,58	10,64
Median	16	10
Variance	0,629	0,455
Standard deviation	0,793	0,674
Coefficient of variation	0,05%	0,06%

It can be seen after the application of ICTs, the levels of capacity development at the level of similarities and differences, are better in the EG in relation to the CG.

E. *N Inferential level. Determination of normality*

For the analysis of the results obtained, it will be determined; initially, the type of distribution presented by the data, both at the CG and EG level; for this we used the Kolmogorov-Smirnov goodness-of-fit test [6].

Considering the value obtained in the distribution test, the use of parametric statistics, t-*Student* or non-parametric, *Wilcoxon test* [7] was determined.

Verification of the working hypothesis:

1) Propose null hypothesis (Ho) and alternative hypothesis (H1):

   Null Hypothesis (H0): There are no differences between the ideal distribution and the normal distribution of the data.

   Alternative Hypothesis (H1): There are significant differences between the ideal distribution and the normal distribution of the data.
2) Select the level of significance: For the purposes of the investigation, it has been determined that $\alpha = 0.05$.
3) Choose the test statistic: For the present hypothesis it is Kolmogorov-Smirnov. See table IX.

TABLE IX. KOLMOGOROV - SMIRNOV TEST FOR ONE

		pretest *EG*	postest *EG*	pretest *CG*	postest *CG*
N		12	12	11	11
PN (a, b)	***Half***	6.42	16.58	6.55	10.64
	DT	1,240	0.793	0.820	0.674
DME	***Absolute***	0.207	0.352	0.256	0.282
	Positive	0.207	0.352	0.202	0.282
	Negative	-0.181	-0.231	-0.256	-0.251
Z of Kolmogorov-Smirnov		0.716	1.221	0.848	0.935
Asymptotic Sig. (bilateral)		0.685	0.102	0.468	0.346

We define:

PN = Normal Parameters

DME = More Extreme Differences

DT = Typical deviation

4) We formulate the decision rule: A decision rule is a statement of the conditions under which the null hypothesis is accepted or rejected, for which it is essential to determine the critical value, which is a number that divides the acceptance region and the rejection region.

   Decision rule

   If alpha (Sig) > 0.05; The null hypothesis is accepted

   If alpha (Sig) < 0.05; The null hypothesis is rejected
5) Decision making: As the significance p value of the normality test statistic has the value of 0.685, 0.102, 0.468, 0.346; then for values Sig. > 0.05; the null hypothesis is accepted and the alternative hypothesis is rejected. We can affirm that the data of the dependent variable come from a normal distribution.

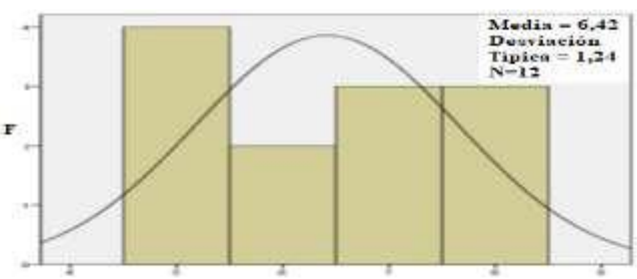

Fig. 1. Frequency distribution of the scores in the EG pre-test [1].

In Fig. 1, it can be seen that the distribution curve does not differ from the normal curve.

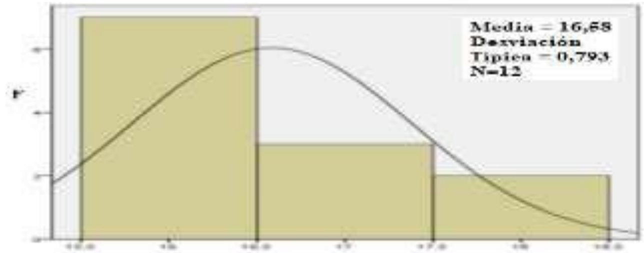

Fig. 2. Frequency distribution of the scores in the EG post-test.

In Fig. 2, it can be seen that the distribution curve does not differ from the normal curve.

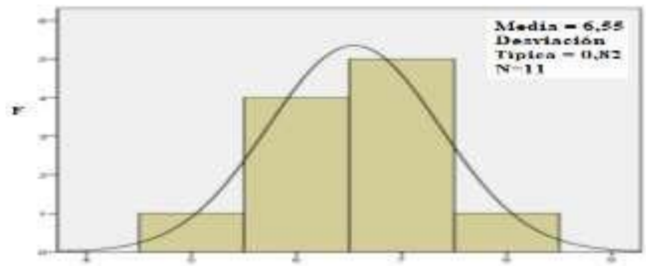

Fig. 3. Frequency distribution of the scores in the CG pre-test.

In Fig. 3, it can be seen that the distribution curve does not differ markedly from the normal curve.

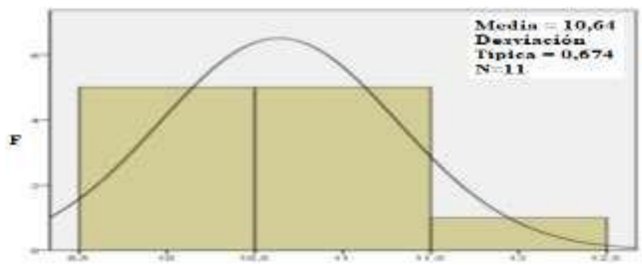

Fig. 4. Frequency distribution of the scores in the CG post-test.

In Fig. 4, it can be seen that the distribution curve does not differ markedly from the normal curve.

Likewise, it is observed that the level of significance Asymptotic Sig. (bilateral) for the Kolmogorov-Smirnov Z is greater than 0.05 in both the pre-test and post-test scores, so it can be deduced that the distribution of these scores in the EG and CG do not differ from the normal distribution.

F. *Verification of the general hypothesis*

In this work, the approach of Mason [8] was chosen, who proposes a five-step procedure that systematizes the hypothesis test, when reaching step 5, one already has the ability to reject or accept the hypothesis.

Verification of the general hypothesis:

1) *Null Hypothesis (H0):* The application of ICTs does not significantly improve the learning of basic electronics in students of the Electronic Engineering and Telecommunications Career.

   Alternative Hypothesis (H1): The application of ICTs allows to significantly improve the learning of Basic

Electronics in the students of the Electronic and Telecommunications Engineering Career.

2) *Level of significance:* It is the probability of rejecting the null hypothesis when it is true, some authors consider that it is more convenient to use the term level of risk. It is denoted by the Greek letter alpha α.
For this work it has been determined that $\alpha = 0.05$.
3) *Statistical value of the test:* t-Student test has been considered for this hypothesis. See table X.

TABLE X. STATISTICAL VALUES OF GENERAL HYPOTHESIS

Groups	n	Y	S²
EG	n_1 = 12	16,58	0,793
CG	n_2 = 11	10,63	0,674

4) *Decision rule:* Statement of the conditions under which the null hypothesis is accepted or rejected, for which it is essential to determine the critical value, which is a number that divides the acceptance region and the rejection region. The proposed hypothesis does not mention directionality, so it is determined that it is a two-tailed statistical test, this means that $\alpha/2 = 0.025$ with 21 degrees of freedom is taken. Reject the null hypothesis if, $Tc > 2.08$ or $Tc < -2.08$. Illustrated graphically in Fig. 5.

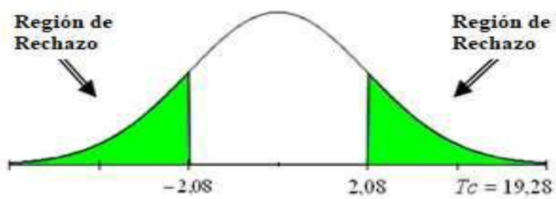

Fig. 5. Region of acceptance and rejection of the hypothesis.

5) *Decision making:* Since the T calculated in step 3 is greater than the Tc of the table with 18 degrees of freedom (19.28 > 2.08), then the value found is located in the rejection region; therefore, the null hypothesis (Ho) is rejected and the alternative hypothesis (H1) is accepted.
It means that the application of ICTs allows to significantly improve the learning of basic electronics.

G. *Verification of specific hypotheses*

Contrast of the specific Hypothesis No. 1

As was done with the general hypothesis, following Mason's approach, a test could be reached. The data from table XI was used

TABLE XI. STATISTICAL VALUES SPECIFIC HYPOTHESIS N°. 1

Groups	n	Y	S²
EG	n_1 = 12	15.8	1.749
CG	n_2 = 11	10.45	1.128

A T greater than t-Student was calculated by table with 21 degrees of freedom (8.67 > 2.08), then, the value found is located in the rejection region; therefore, the null hypothesis (Ho) is rejected and the alternative hypothesis (H1) is accepted. This means that the application of ICTs has significant effects in improving the learning of ***Electrical Circuits [9].***

Contrast of the specific Hypothesis No. 2

As was done with the general hypothesis, following Mason's approach, a test could be reached. The data in table XI was used. See table XII

TABLE XII. STATISTICAL VALUES SPECIFIC HYPOTHESIS Nº 2

Groups	n	Y	S²
EG	n_1 = 12	16.08	0.996
CG	n_2 = 11	10.18	0.982

A T greater than t-Student was calculated by table with 21 degrees of freedom (14.3 > 2.08), then, the value found is located in the rejection region; therefore, the null hypothesis (Ho) is rejected and the alternative hypothesis (H1) is accepted. This means that the application of ICTs has significant effects in improving the learning of ***Electronic Circuits [10]***.

Contrast of the specific Hypothesis N° 3

As was done with the general hypothesis, following Mason's approach, a test could be reached. The data in table XI was used. See table XIII

TABLE XIII. STATISTICAL VALUES SPECIFIC HYPOTHESIS Nº 3

Groups	n	Y	S²
EG	n_1 = 12	16.5	0.674
CG	n_2 = 11	11.09	1.136

A T greater than t-Student was calculated by table with 21 degrees of freedom (8.67 > 2.08), then, the value found is located in the rejection region; therefore, the null hypothesis (Ho) is rejected and the alternative hypothesis (H1) is accepted. This means that the application of ICTs has significant effects in improving ***Instrumentation [11]*** learning.

Contrast of the specific Hypothesis No. 4

As was done with the general hypothesis, following Mason's approach, a test could be reached. The data in table XI was used. See table XIV

TABLE XIV. STATISTICAL VALUES SPECIFIC HYPOTHESIS Nº 4

Groups	n	Y	S²
EG	n_1 = 12	16.75	1.055
CG	n_2 = 11	10.55	0.687

A T greater than t-Student was calculated by the table with 21 degrees of freedom (16.53 > 2.08), so the value found is located in the rejection region; therefore, the null hypothesis (Ho) is rejected and the alternative hypothesis (H1) is accepted. This means that the application of ICTs has significant effects in improving the learning of ***Digital Circuits [12]***.

IV. DISCUSSION OF RESULTS

In the field work, the objectives set out in the research have been verified precisely.

Regarding the problem, *to what extent the application of ICTs allows improving the learning of basic electronics in the students of the Electronic and Telecommunications Engineering Career?* According to the statistical analysis, it is evident that before the application of the methodological proposal based on the use of ICTs, no significant differences were found in the CG and the EG

After the application of the proposal, it is evident that the response percentage in the EG students, when evaluating the level of learning, reaches an approximate percentage of 83%, evidencing a significant improvement, while the scores obtained by the CG students, at the same levels around 53%.

Regarding the application of the post-test, it can be observed that the median scores of the EG is 16 and that of the CG is 10; which means that in the CG half of the students have grades lower than 10 and the rest higher than that amount, while in the EG 50% have scores lower than or equal to 16 and the rest have scores higher than 16.

Likewise, the variance of the EG is 0.62 and that of the CG is 0.45, which means that in the CG there is a greater dispersion of qualifying data.

As for the coefficient of variation of the EG, it is 0.5% and that of the CG is 0.6%, which means that the qualifiers of the EG are more homogeneous or have less variability than the qualifiers obtained by the CG.

It can be seen that the EG and the CG obtained a mean of 16.58 and 10.63, finding a significant difference of 5.95 between the scores obtained. Similarly, the values obtained in the hypothesis test using the T (Tc = 19.28) allow the validation of the general hypothesis.

The results obtained at the level of electrical circuits and electronic circuits, it is observed that the EG obtained an average of 15.8 and the CG an average of 10.45, finding a significant difference of 5.35.

Conclusions

1) Through the descriptive analysis, we find that, before the application of the module of the proposed methodology through ICTs, both groups do not show significant differences, finding practically similar averages in the pre-test of both groups.
2) After the application of the module of the proposed methodology through ICTs, the post-test scores show a significant difference of 5.9 points in favor of the EG.
3) Comparing the scores obtained by the EG at the pre-test and post-test levels, which shows a significant increase.
4) L The scores obtained in the contrast of the general hypothesis by means of the hypothesis test allow to validate the proposed hypothesis: "*The application of ICTs allows to significantly improve the learning of Basic Electronics in the Students of the Electronic Engineering and Telecommunications Career*".
5) The scores obtained in the verification of the specific hypotheses (HE):
   - *5.1) HE No. 1*, the application of ICT has significant effects in improving the learning of Electrical Circuits.
   - *5.2) HE No. 2*, is also verified, showing that the use of ICT has significant effects on the learning of Electronic Circuits.
   - *5.3) HE Nº 3*, has been verified with the evaluation of the results obtained in the learning of the Instrumentation.
   - *5.4) HE Nº 4*, could demonstrate that the use of ICT has favorable effects on learning the fundamentals of Digital Circuits.

It is shown that the pedagogical level rises, and a significant increase in the level of learning in the EG is observed, which is verified in the results obtained at the post-test level; as well as, it shows the statistical level.

Recommendations

1) When teaching the Basic Electronics Course, the needs, interest and learning opportunities of the requirements that the students need must be taken into account.
2) For a better understanding of the subject of basic electronics, work groups should be formed that allow interaction between students in order to improve group work and learning skills.
3) Apply various active methodologies to improve the level of learning.
4) Promote the development of didactic modules such as the ones elaborated for this work, in different topics of electronics that allow better learning.
5) Replicate this research using other research designs in order to deepen the study between the study variables.

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