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EXPERIMENTAL DESIGN FOR MEASURING 9TH GRADE STUDENTS' PERFORMANCE IN MATHEMATICS

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Abstract
The objective of this research is to determine whether the performance of students measured in the score obtained in the Saber 9 tests, specifically in the area of mathematics, depends on the competencies evaluated by the ICFES, reasoning and argumentation, communication, representation, modeling, and problem posing and solving, at the Policarpa Salavarrieta Educational Institution. The methodology used presents an experimental design under a type of applied research, with a transversal design and quantitative approach. As a tool for the collection of information, a questionnaire was administered, which was designed with questions released by the ICFES in 2015 and was applied to six students of the ninth grade of this institution, which was the sample chosen at random among all the students of this grade. Once the results of the applied experimental design were analyzed, the corresponding conclusions were drawn; that is, it was concluded whether the hypothesis proposed for the experimental design was rejected or accepted, thus providing a solution to the problem.

Keywords: Experimental design, Mathematical competencies, Saber 9 tests.

1. Introduction

The purpose of this project is to evaluate in advance the possible results that students would have in the SABER 9° test, in the mathematical competencies that are evaluated by it; in this way, with the results obtained, the right decisions can be made that contribute to the improvement of the quality of the education offered to students in mathematical competencies at the school level.

This serves as an input for the educational institution where the study was conducted. As with the results of the study, improvement plans can be designed that involve workshops, tests, and simulations where these competencies are evaluated, which in turn would be important for the preparation of the student at the time of presenting the test.

On the other hand, it would allow to identify in which of the evaluated competencies the students register strengths and in which they register weaknesses, and thus be able to work on the latter with a view to improving performance, without neglecting the former, of course.

Similarly, it is also possible to determine how much the final score that measures the student's performance depends on the mathematical competence evaluated.

2. Experimental Design

Experimental designs are used to study the performance of processes and/or systems in controlled environments, which can be a combination of machines, methods, drugs, materials, people, or other resources that transform a certain input (often a material, drug, object, or food) into an output that has one or more observable responses (Montgomery, 2004).

In such experiments, tests involving one or more input variables belonging to a process or system are performed to observe and identify the reasons for the changes that might occur in the response or output variable.

Such processes or systems can be represented by the model illustrated in Figure 1.

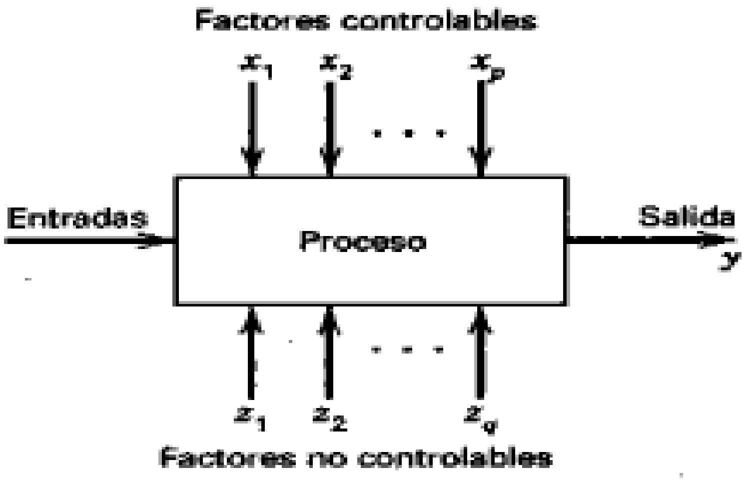

Figure 1. Representation of the Experimental Design. Source: Montgomery (2004).

Where the process variables X1, X2,…,XA are controllable, qualitative, input, or independent variables, whereas the variables Z1, Z2,..., ZQ are non-controllable (although they may be for the purposes of a test). This process produces output Y, which is a quantitative, response, or dependent variable.

Examples of experiments may include, but are not limited to,

- "Determine whether the yield of a crop depends on the type of fertilizer used."
- "Determine whether the type of feed given to a group of animals influences their growth."
- "Determine if the academic performance of students depends on the methodological strategy used."
- "Determine if the average score of the students depends on the subject evaluated."

2.1 Structural Elements of the Design of Experiments.

2.1.1 Dependent Variable.

It is the variable associated with the phenomenon we are interested in studying and which we symbolize with Y; as mentioned above, it is the dependent, response, or output variable, and is quantitative.

2.1.2 Independent Variable or factors of interest.

The variable that is tested by setting it to certain levels before conducting the experiment, symbolized by X, is the independent or input variable, and is qualitative.

The aim is to determine whether the levels of variable X influence the response variable Y; these levels are also known as factor levels or factor treatment levels, symbolized by X1, X2, ---, and Xa, if X has levels or categories.

2.1.3 Experimental Units.

The elements involved in the experiment (people, animals, materials, objects, etc.) were observed at a given level of the factor(s) of interest.

2.1.4 Replicates.
Number of experimental units tested at each level or treatment of the factor(s) of interest.

2.2 Completely randomized single-factor design
A Completely Randomized Unifactorial Design is one in which a single factor of interest is tested with its corresponding treatment levels, that is, the "a" treatment levels of the factor of interest are evaluated on a group of randomly selected experimental units.
The objective of a single-factor experimental design is to test and estimate the hypotheses about the mean of the “a” treatment levels.
With this, we also seek to establish whether there is a dependence relationship between variables X and Y, which is achieved by testing the following hypotheses:
Ho: $\mu_1 = \mu_2 \ldots. = \mu_a$ vs.
Hi: $\mu_i \neq \mu_j$ for at least one "i, j" pair.
When the null hypothesis is rejected, then it can be said that variable Y does depend on variable X. However, if the null hypothesis is accepted, one can conclude that variable Y does not depend on variable X.
The procedure to test these hypotheses is based on an Analysis of Variance (ANOVA).
The analysis of variance is focused on testing whether there is equality in the mean of the response due to the levels of the factor that is being subjected to experimentation.
For this purpose, an analysis of variance (ANOVA) table was constructed, which has the following elements:

Table 1. Anova Table

Source of variation	Sum of squares	Degrees of freedom	Mean square	Fc	F
Treatments	$SS_{TRAT} = n\sum_{i=1}^{a}(y_i^- - y_n^-)^2$	a - 1	MS_{TRAT}	$\frac{MSTRAT}{MSE}$	
Error	$SS_E = SST$ - SS_{TRAT}	N – a	MS_E		
Total	$SST = \sum_{i=1}^{a}\sum_{i=1}^{n}(y_i^- - y_n^-)^2$	N – 1			

3. Methodology
3.1 Type of Research
The type of study to be carried out is as follows: applied research, with a cross-sectional design and quantitative approach.

3.2 Target Population
The target population is the 9th grade students of the Policarpa Salavarrieta Educational Institution in the city of Sincelejo.

3.3 Sample
Simple random sampling will be applied to select a sample of 9th grade students who will be part of the study. The sample size was determined as follows.

$$\phi^2 = \frac{nD^2}{2a\sigma^2} \qquad \text{Ec. 1}$$

Where, n=6 (sample size); a = 3; σ^2 = 533.7; and D = 5

Table 2. Sample Size

n	$\emptyset^2$	$\emptyset$	$a(n-1)$	β	$(1-\beta)$
4	3.12	1.77	9		
5	3.90	1.97	12		
6	4.68	2.16	15	0.10	0.9

3.4. Data Collection Technique

Questionnaires were designed with questions of the SABER 9° test type, where competencies corresponding to the area of mathematics were evaluated. These questionnaires will be applied to the sample of 9th grade students chosen for this purpose.

3.5 Data Processing

To collect the necessary information, a questionnaire will be designed with questions of the SABER 9° test type, which will be distributed in three components: numerical-variational, geometric-metric, and random, and in three competencies: reasoning and argumentation, communication, representation and modeling, and problem posing and solving.

Since the maximum score of the mathematics test is 500 points, each question will have an equal evaluation, such that the sum of these values adds up to 500 points per competency.

Once the information is collected, the most appropriate experimental design for data analysis is applied.

Subsequently, using the results of the analysis of variance, we will identify whether students' performance depends on the mathematical competence evaluated.

For this purpose, we define two variables, X and Y, such that

Variable X is an independent and qualitative variable, which, in this study, represents the mathematical competence assessed.

Variable Y is a dependent and quantitative variable, which in this study represents the score recorded for each competency; these scores range from 100 to 500 points.

4. Results

4.1 Descriptive Analysis

The following is a descriptive analysis of the test results.

Table 3. Descriptive Statistics of the Data

Competences	minimum	maximum	mean	variance	Standard Deviation
Reasoning	180	360	277	6786.6667	88.381
Problem solving	100	340	260	10240	101.193
Communication	100	340	233	9386.6667	96.885

4.2 Analysis of the single-factorial design applied in the study

To analyze the data, a unifactorial design was applied with a qualitative independent variable and a response variable as a quantitative dependent variable, as described below.

Table 4. Definition of Variables

Qualitative Independent Variable	Dependent Variable
Mathematical Competence	Score Obtained

4.2.1 Hypotheses to be Tested

Mathematical Competence Factor.

Ho: The score does not depend on assessed mathematical competence.

Hi: The score depends on assessed mathematical competence.

4.2.2 Analysis of Variance
The results of the applied unifactorial design are shown in the following analysis of the variance table or ANOVA table. Analysis was performed at a significance level of α = 0.05.

Table 5. Analysis of variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	Fc	P-value
Treatments	5733.333	2	2866.667	0,3256	0.727
Error	132066.667	15	8804.444		
Total	137800.000	17			

According to the results yielded by the ANOVA table, the p-value associated with the Mathematical Competence factor is greater than significance (α = 0.05); therefore, the null hypothesis is accepted as true. That is, the score does not depend on the mathematical competency evaluated, indicating that the score obtained by the student does not depend on the mathematical competency in which he/she is being evaluated.

5. Conclusions

The scores that the students of the Policarpa Salavarrieta Educational Institution have obtained in the area of mathematics in the saber ninth tests in the last few years have not been the best when implementing the analysis of a unifactorial design to validate the proposed hypothesis; the results showed that the hypothesis was rejected, which leads us to affirm that this factor does not affect the performance of ninth-grade students in the saber tests applied to them, that is to say, what the ICFES evaluates in mathematics is in accordance with the level and skills of the students.
It could also be evidenced with the instrument applied, that the students presented higher performance in problem-solving competence, since most of them showed strengths, as well as in the same way they showed deficiency in reasoning competence; a deficiency was noticed since it was the lowest weighted in the test applied to collect the information.
It should be noted that this research paper is a descriptive analysis, since we only intended to look for dependence between the study variables mentioned above. It should be noted that this research paper is a descriptive analysis, since we only intended to look for the dependence between the study variables mentioned above.

6. Recommendations

With the analysis of the information previously presented through the experimental design and considering the competencies related to the saber tests, problem solving, communication, and reasoning, the following recommendations are made to provide a solution to improve academic performance in the development of these competencies related to the area of mathematics in the saber ninth tests.
- To carry out this type of research on other types of mathematical thinking and non-generic competencies.
- To build a tool that strengthens the competency in which they came out with the lowest weight reflected in the applied instrument.
- Appropriate the mathematics teachers of the institution to work by competencies, to the point that the student himself is aware and identifies each one.

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