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A method based on neuroscience for teaching mathematics in a primary School

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ABSTRACT:

Currently, adequate learning is promoted in students, especially in the area of Mathematics, whose greatest difficulty is the low level of problem solving. Solving problems is based on cognitive processes that seek to find a way out of a difficulty, thus reaching an object that was not immediately reachable. The objective of this research was to know to what extent a program with strips based on neuroscience influences the resolution of mathematical problems in second grade students of Primary at an Educational Institution in Trujillo, Peru. In this study, the sample was 50 students of both sexes, distributed in a control group and a group to which the Program with strips was applied. Problem-solving assessment instruments were used, which consisted of posing five problem situations (combination type 1, change 1, change 2, equalization and comparison) directly related to the dimensions of the independent variate (vision, action, calculation, procedure and reflection), which allowed determining the developmental level in solving mathematical problems in second grade children before (pre-test) and after (post-test) the execution of the program with strips. Some routines were used in the nparLD package of R by means of non-parametric statistical analysis of longitudinal data (WTS and ATS statistics). The understanding of the problem, the design of a strategy and the execution of the strategy were the dimensions that showed a significant improvement in the resolution of mathematical problems. 42.3% of the students obtained a level in process in solving mathematical problems after the execution of the program with rules. The neuroscience-based with strips program significantly improved math problem solving in second grade students. The nonparametric analysis of longitudinal data is a powerful tool to determine the level of development in solving mathematical problems in second grade children before (pre-test) and after (post-test), which allows studying the temporal evolution of students subjected to a neuroscience-based method.

Keywords:

Program, strips, problem solving, longitudinal data.

INTRODUCTION

At present, a series of innovations in education have been taking place seeking to change traditional methods that have presented shortcomings, which implies the lack of adequate learning in students, especially in the area of Mathematics whose main difficulty is reflected in the Problem resolution. In this sense, the emergent field of educational neuroscience is gaining attention as the potential for neuroscience to support theory-informed classroom instruction and teacher professional development (PD) strengthens (Sze & Johnstone, 2019). De Smedt y Grabner (2015) enfatizan que “en la última década, ha habido un tremendo aumento en la investigación en neurociencia sobre el aprendizaje de las matemáticas”, mientras que “el campo del aprendizaje de las matemáticas se ha propuesto como un espacio de trabajo ideal para hacer aplicaciones de la neurociencia a la educación”. Poylá (1965) states that problem solving is based on cognitive processes that seek to find a way out of a difficulty, thus reaching an object that was not immediately reachable. Jaimes (2013) considers that the strips constitute a useful tool for the teacher to capture and maintain the student's attention. Likewise, this technique allows the student to understand mathematics from a very early age, making it necessary for the teacher to be able to use it properly, always seeking the student's attention (Adalid, 2010). In these sense, Franco & Sánchez, (2015) propose that the correct execution of a program with strips will allow the student an active learning according to the acquisition of knowledge, being important to recognize the quality of the use of each didactic material in the methods of construction and progress of mathematics teaching for the different levels of education. That is why, given the need for a significant improvement in the process of solving mathematical problems, the present research is based on the execution of a program with strips based on neuroscience whose objective is to know to what extent the program influences solving mathematical problems at students of the second grade in a primary school from Trujillo, Peru.

MATERIAL AND METHODS

In this study, the sample was 50 students of both sexes, distributed in a control group and a group to which the Program with Strips was applied.

The instruments used were: 1) problem-solving evaluation based on (Pólya, 1965) that consisted of the approach of five problematic situations (of type combination 1, change 1, change 2, equalization and comparison) each with 4 items being a total of 20 questions directly related to the dimensions of the independent variable (vision, action, calculation, procedure and reflection), which allowed determining the developmental level in solving mathematical problems in second grade children before (pre-test) and after (post-test) the execution of the program with strips, 2) the observation guide that served to collect information about the progress that second grade students were making in solving mathematical problems during the course of the program and in this the dimensions of the dependent variable were included (understanding the problem, designing a strategy, executing the strategy and reflecting on the process or result of the problem).

Statistic analysis

For data analysis, non-parametric tests were used for longitudinal data (measurements repeated over time, case control group and experimental group) as described below (for details see Brunner et al. 2001):

F1-LD-F1 design.

Suppose that different groups of subjects are observed repeatedly at different times in time, and each group is randomly assigned a treatment (treatment 1, treatment 2,..., treatment a). In that case, the k-th subject in treatment i is observed on t occasions and the underlying statistical model of this design can be described by the random vectors $\mathbf{X}_{ik} = (X_{ik1}, \dots, X_{ikt})', k = 1, \dots, n_i, i = 1, \dots, a$, with marginal distributions $X_{iks} \sim F_{is}, i = 1, \dots a; s = 1, \dots, t$, for which independence is assumed. In this sense, the structure of this F1-LD-F1 design is shown in Table 1.

In this experimental arrangement with longitudinal data, the treatment effects are described by the relative marginal effects $p_{is} = \int H dF_{is}$, where $H = N^{-1} \sum_{i=1}^{a} \sum_{s=1}^{t} n_i F_{is}$ is the weighted average of all the marginal distribution functions of the experiment and $N = t \sum_{i=1}^{a} n_i = t.n$ s the total number of observations (dependent and independent).

Table 1. F1-LD-F1 design and the corresponding marginal distributions.

Factor A Treatment	*Subject*	*Vector*	*Data* — *Time* $s=1 \cdots s=t$	*Marginal distributions* — *Time* $s=1 \cdots s=t$
i = 1	$k = 1$	X_{11}	$X_{111} \cdots X_{11t}$	$F_{11} \cdots F_{1t}$
	$\vdots$	$\vdots$	$\vdots \quad \vdots \quad \vdots$	$\vdots \quad \vdots \quad \vdots$
	$k = n_1$	X_{1n_1}	$X_{1n_1 1} \cdots X_{1n_1 t}$	$F_{11} \cdots F_{1t}$
$\vdots$	$\vdots$	$\vdots$	$\vdots \quad \vdots \quad \vdots$	$\vdots \quad \vdots \quad \vdots$
i = a	$k = 1$	X_{a1}	$X_{a11} \cdots X_{a1t}$	$F_{a1} \cdots F_{at}$
	$\vdots$	$\vdots$	$\vdots \quad \vdots \quad \vdots$	$\vdots \quad \vdots \quad \vdots$
	$k = n_a$	X_{an_a}	$X_{an_a 1} \cdots X_{an_a t}$	$F_{a1} \cdots F_{at}$

Source: Brunner et al. (2001).

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A particular case of the F1-LD-F1 design (2x2 cross-over design).

Let us consider a study where the effect of two treatments (control and experimental group) is evaluated, on the response of the subjects in two periods of time (Pre-test and Post-test), for which some routines were used in the nparLD package of R software (R Core Team 2020) by non-parametric statistical analysis of longitudinal data (WTS and ATS statistics).

RESULTS AND DISCUSSION

Table 2 shows the results of the non-parametric analysis (ANOVA-type statistic) for the study of a method based on neuroscience for teaching mathematics in primary school. The main question of this experiment is whether the time profiles of the two groups (control and experimental) are parallel, that is, if there is a statistically significant interaction between the group (treatment) and time (pre-test and post-test). The results suggest that there is a statistically significant interaction ($p < 0.05$) between the group and time in relation to three dimensions: understanding the problem, designing a strategy and executing the strategy, while for the dimension reflection on the process or outcome interaction was not significant ($p > 0.05$). The absence of such an interaction would be indicated by parallel time *profiles. In this sense, in* Figures 1-3 it is observed that the profiles of the relative marginal effects p_is related to the dimensions of understanding the problem, design of a strategy and execution of the strategy are not parallel, which coincides with the results of the statistical ANOVA-type, while in Figure 4, the profiles of the relative marginal effects p_{is} is related to the reflection dimension on the process or result show some parallelism between the time profiles (pre-test and post-test) of the two groups (control and experimental). These results suggest that there are significant differences ($p < 0.05$) between the results obtained by both groups (control group and experimental group) in relation to the three dimensions mentioned above (understanding of the problem, design of a strategy and execution of the strategy), which involves a change after (post-test) the application of the neuroscience-based method for the teaching of mathematics in primary school, while there is no evidence of a change in relation to the reflection dimension on the process or result.

Table 2. Nonparametric test statistics for a study on a neuroscience-based method for elementary mathematics teaching.

Factor	P value associated with the ANOVA-type test statistic			
	Understanding of the problem (D1)	Design of a strategy (D2)	Execution of the strategy (D3)	Reflection on the process or result (D4)
Treatment (Control-experimental group)	4,468869 x10-01	0,607589828	0,702084359	0,01631699
Time (Pre-test and Post-test)	3.585136 x10-07	0,003692478	0,041546463	0,01085170
Treatment x time	1.349296 x10-14	0,005602867	0,003522623	0,23846870

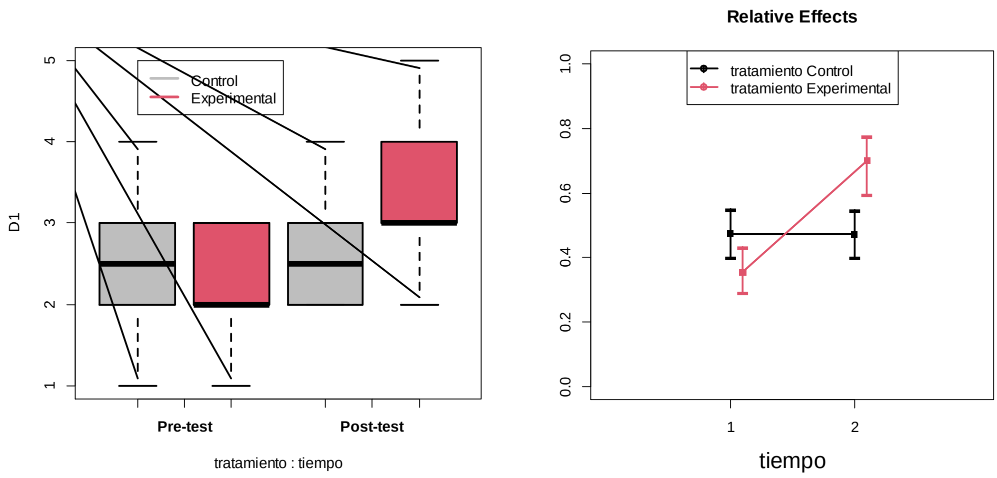

Figure 1. Box plots and 95% confidence intervals for the p_{is} effects related to the problem comprehension dimension in the study of a neuroscience-based method for teaching mathematics in primary school.

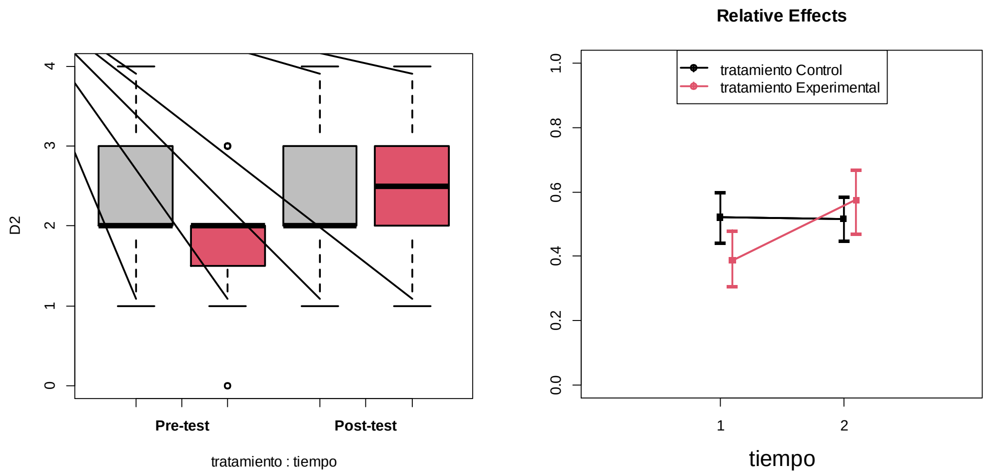

Figure 2. Box plots and 95% confidence intervals for the p_{is} effects related to the design dimension of a strategy in the study of a neuroscience-based method for teaching mathematics in primary school.

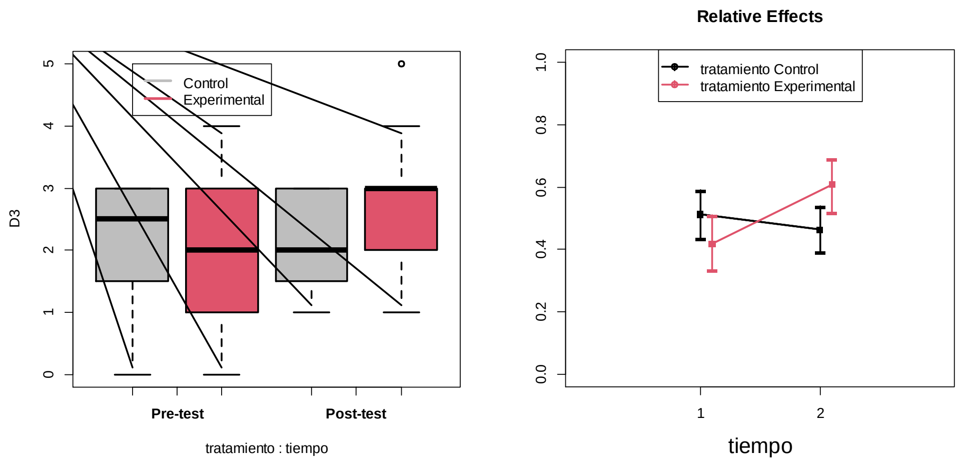

Figure 3. Box plots and 95% confidence intervals for the p_{is} effects related to the strategy execution dimension in the study of a neuroscience-based method for primary school mathematics teaching.

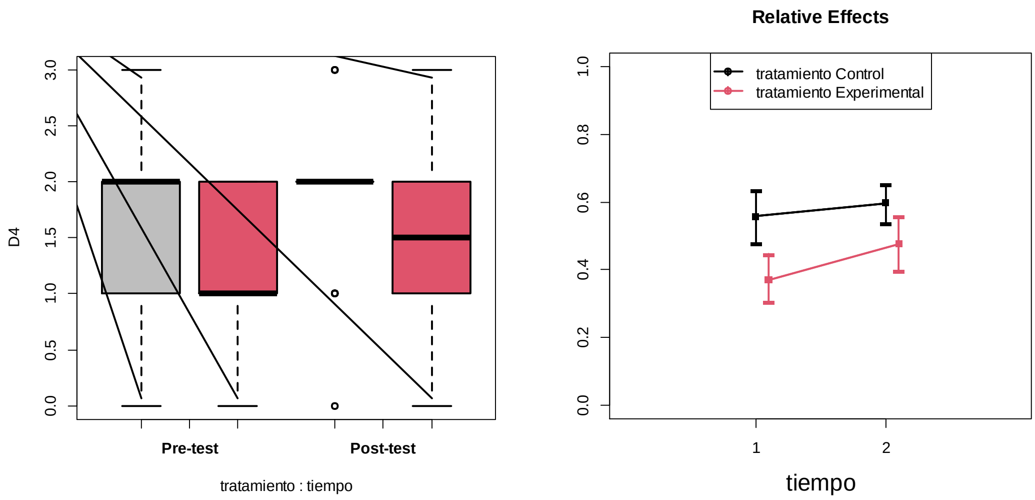

Figure 4. Box plots and 95% confidence intervals for the p_{is} effects related to the reflection dimension on the process or result in the study on a method based on neuroscience for teaching mathematics in primary school.

Table 3 shows that, in relation to the experimental group, in the dimension understanding the problem in pre-test, 65.4% of the students obtained a starting level and in post-test, 46.2% obtained a level in process. In the dimension to design a strategy in pre-test, 76.9% of the students obtained a starting level and in post-test 46.2% obtained a level in process and another percentage obtained a beginning level. In the dimension executing the strategy in pre-test, 65.4% obtained a starting level and in post-test, 46.2% of them obtained a level in process. In the dimension reflect on the process or result in pre-test, 100% of the students obtained a starting level and in posttest 88.5% of them obtained a starting level. In the control group, in the dimension understanding the problem in pre-test 50% of the students obtained a starting level and in post-test 50% of them obtained a starting level.

In the dimension design a strategy in pre-test, 62.5% of the students obtained a starting level and in post-test 66.7% of them obtained a starting level, in the dimension execute the strategy in pre-test 50% of the students obtained a level in process and another percentage had a level of beginning and in posttest 66.7% of them obtained a level in beginning, in the dimension reflect on the process or result in pre-test 83.3% of the students obtained a level At the beginning and in the post-test, 87.5% of them obtained a beginning level. These results coincide with Manzano (2014), Páez and Santana (2010) and Adalid (2010) who consider that the application of programs with rules based on neuroscience optimizes the resolution of mathematical problems related to learning in students. Regarding the hypothesis contrast analysis with the experimental group, to validate the research hypothesis, we find that there are significant differences between the scores obtained in the post-test with those obtained in the pre-test, which allows us to affirm that if we applied the rule-based program based on neuroscience, then the resolution of mathematical problems is significantly optimized in students of the second grade of primary education ($p <0.05$). Likewise, what has been analyzed agrees with Martín (1999), Franco and Sánchez (2015) who used programs with rules based on neuroscience for years, and also had positive results, which means that the proper application of these programs really has a lot of importance in optimizing the resolution of mathematical problems related to learning in second grade students of primary education. The other authors considered in the references of this work are those who have given me guidelines and with whom I can contrast the results obtained in the present investigation, who reached positive results similar to mine. Neurocognitive investigation can enrich mathematics education by contributing to our understanding of the underlying cognitive processes involved in different types of mathematical performance and by explaining the roots of success and difficulties in mathematics learning, proving, problem solving and creative, intuitive, and critical reasoning (Leikin, 2018).

Table 3. Distribution of second grade students from the experimental and control group in dimensions of mathematical problem solving in an Educational Institution in Peru.

Dimension		Experimental group				Control group			
		Pre test		Post test		Pre test		Post test	
		Nº	%	Nº	%	Nº	%	Nº	%
D1. Understanding the Problem	Outstanding Achievement			1	3.8				
	Expected Achievement	1	3.8	9	34.6	2	8.3	1	4.2
	In process	8	30.8	12	46.2	10	41.7	11	45.8
	Start	17	65.4	4	15.4	12	50.0	12	50.0
	Total	26	100	26	100	24	100	24	100
D2. Design a Strategy	Outstanding Achievement								
	Expected Achievement			2	7.6	1	4.2	1	4.2
	In process	6	23.1	12	46.2	8	33.3	7	29.1
	Start	20	76.9	12	46.2	15	62.5	16	66.7
	Total	26	100	26	100	24	100	24	100
D3. Execute the Strategy	Outstanding Achievement			1	3.8				
	Expected Achievement	1	3.8	3	11.5				
	In process	8	30.8	12	46.2	12	50.0	8	33.3
	Start	17	65.4	10	38.5	12	50.0	16	66.7
	Total	26	100	26	100	24	100	24	100
D4. Reflect on the Process or Result	Outstanding Achievement								
	Expected Achievement								
	In process			3	11.5	4	16.7	3	12.5
	Start	26	100	23	88.5	20	83.3	21	87.5
	Total	26	100	26	100	24	100	24	100

CONCLUSIONS

The execution of a program with rules based on neuroscience significantly improved the resolution of mathematical problems in students of the second year of primary education in an institution in Trujillo, Peru. The understanding of the problem, the design of a strategy and the execution of the strategy were the dimensions that showed a significant improvement in the resolution of mathematical problems in the students of the second grade of primary education. 42.3% of the students obtained a level in process in solving mathematical problems after the execution of the program with strips.

ETHICAL APPROVAL

As per international standard or university standard ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

Appendix. R code for the non-parametric analysis of a study on a neuroscience-based method for teaching mathematics in primary school.

```
datos<-data.frame(sqlFetch(canalexcel,"Hoja1"))
d1_pre_t_control<-datos$d4_Pre_Test[1:24]
d1_pos_t_control<-datos$d4_Post_Test[1:24]
d1_pre_t_experimental<-datos$d4_Pre_Test[25:48]
d1_pos_t_experimental<-datos$d4_Post_Test[25:48]
datos.f<-
data.frame(d1_pre_t_control,d1_pos_t_control,d1_pre
_t_experimental,d1_pos_t_experimental)
```

```
library("nparLD")
D4<-
c(d1_pre_t_control,d1_pos_t_control,d1_pre_t_experimental,d1_pos_t_experimental)
ue<-c(rep(1:length(d1_pre_t_control),4))
tiempo<-
c(rep(1,length(d1_pre_t_control)),rep(2,length(d1_pre_t_control)))
tratamiento<-
c(rep("Control",2*length(d1_pre_t_control)),rep("Experimental",2*length(d1_pre_t_control)))
data.ci<-data.frame(D4,tratamiento,tiempo,ue)
ex.f1f1np <- nparLD(D4~ tiempo*tratamiento, data = data.ci,subject = "ue", description = FALSE)
```

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