



Electronics prototypes in development of formal thoughts Prototipos electrónicos en el desarrollo de pensamientos formales

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Abstract: This research was realized in Universidad Francisco de Paula Santander in Cucuta (Colombia), during the II-2014 and I-2015, comparing two methods of teaching through a sample team where partial equations students develop prototypes to determine and analyze mathematical models and other control teams that receive classes without development of prototypes. The objects were determining the influence of use of electronics prototypes in the academic performance and development of mathematical thought of students of differential equations in Engineering. Using and quantitative focus in type fields, interviews, daily log observation, and tests of development of mathematic thought analyzed with Fuzzy technics as instruments with the results of evaluations, permit to observe improvements in the development of mathematical thought of students and positive perception of differential equations.

Keywords: Learning, prototypes, differential equations, superior education, academics performance.

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Resumen: El artículo presenta los resultados de la investigación, realizada en la Universidad Francisco de Paula Santander de la ciudad de Cúcuta – Colombia- durante el II-2014 y I-2015, que comparó dos métodos de enseñanza, a través de un grupo prueba donde estudiantes de ecuaciones diferenciales desarrollan prototipos para determinar y analizar modelos matemáticos, y un grupo control que recibió clases sin el desarrollo de los prototipos. Su objeto fue determinar la influencia del uso de prototipos electrónicos en el rendimiento académico y desarrollo del pensamiento matemático de estudiantes de ecuaciones diferenciales en ingeniería. A través de un enfoque cuantitativo, de tipo campo, entrevista, diario de observación y test de desarrollo del pensamiento matemático analizada a través de técnica Fuzzy como instrumentos junto a resultados en evaluaciones, permitieron observar mejora en el desarrollo del pensamiento matemático de los estudiantes, y percepción positiva hacia las ecuaciones diferenciales.

Palabras claves: Aprendizaje, prototipos, ecuaciones diferenciales, educación superior, rendimiento académico

1 Introduction

Development and construction of electronics prototypes was done with the goal of introducing a didactic proposal of pedagogical Support for teacher function in differential equation classes based on a formative profile cycle for development of electronic products and competences formation base in sum of different terminal capabilities. The comprehension of any actual situation in a context follows the take of decisions, generally ruling for the predominant mind models that surge for everyday social and cultural behavior, most of the time is not enough to understand situations with counter-intuitives [1] and where it is expected that scientific knowledge, generally acquired in the basic formation cycle in university provides the situational experience to make decisions. On the other hand, the teach-

ing of science and technology contributes to developing capabilities where the applications of methods and principles of scientific research to reasoning resolutions or problematic situations, behave the use of implied skills to generate, evaluate, and review evidence and theories, thus, the skill to reflect on the process of acquisition and the review of knowledge [2]. Use of tools improve the academic performance of students [3], and promote permanency and graduation, allowing for student development. Under certain conditions it would improve the development of mathematical thought in the students [4] to be the theme that is associated to academic performance, aspects that worry international ambits. Thereby, Goel [5] used as evaluation techniques of logical thought, the comprehension of connective known conditional. For Ardevol [6] in Spain, 32% in age between

20-24 years, don't successfully graduate, Erazo [7] concluded that failure is a symptom of youth with psychosocial problems, specifying that students of regular performance are more reduced in adverse situations, which require the presence of prevention programs to reduce academic performance [8].

A prevention program could constitute in the creation of electronic prototypes to offer tools, inclusive in the evaluation fields. In this context, the use of applications implies changes in didactics of mathematics, particularly in differential equations, and given its application, entails questions like if the developments of present mathematic thought in electronic prototypes have incidence in the development of mathematical thought of students, and if in similar situations with traditional elements in class, would consider new inputs for the development of creativity and innovation [9].

Also, other factors influence in the performance and development of mathematical thought, just like those concluded by Atencia and Garcia [10] that teachers have difficulties with application of TIC due to intrinsic factors, like lack of knowledge and disinterest, along with extrinsic factors like time to plan strategies of use. In the university ambit, explicative variables take into account motivation, self-concept and conduct [11-13] referring to proposed research models by Shenhouse, whose goal is to compromise teachers where plan execution constitutes in a research which emanate permanent innovation proposals. Therefore, the goal of research is to analyze the incidents of construct and develop mathematical thought through electronic prototypes in the academic performance and development of mathematic thoughts of students in differential equations, identifying developed competencies.

2. Methodology

The research follows the focus quantitative descriptive type with a quasi-experimental design, using data collection to prove hypothesis, based in the numerical measurement and the statistics analysis, by the way that is able to establish patterns of behaviors and to prove theories. Supported in principles of methodology such as qualitative-phenomenologies, information was treated with strategy of content analysis to recover the subjectivity of participants. The research was made during second semester 2014 and first semester of 2015 with a population of 150 students of differential equations. The sample was distributed in two groups. Group A was composed of systems engineering students, divided a group A of sample (Class that develops prototypes); group B control was conformed with industrial engineering students.

The groups were compared, before and after use of applicative, applying diagnostics tests (pretest) to measure the development of mathematical thought was to use final grade registers. Using the notion of 'metric space Fuzzy' of George and Veeramani [14] was considered the Fuzzy metrics $F(d)$ standard induced for Euclidean metric (d), over the set x given for the model $F(d)L_{x,y,t} = t/(td(x,y))$, where d is the Euclidean distance and t is a parameter greater than zero. Considering that $d(x,y)=0$, then $F(d)=1$, that is interpreted like extreme closeness; and given as $d(x,y)$ is increasing, $F(d)$ is approaching to zero, is tending to extreme farness, value reached in the limit when $d(x,y)$ trends to infinite whenever the t value is greater than zero.

High performance, graded between 4 to 5 and the scholar failure graded between 1 to 1.9, express the absence of knowledge and failure of pedagogical action in the development

of basic competences in mathematics. The applied test t-student to compare the group independently, previous tests of normal independence and homogeneity of variances.

Instruments were used to test performance in differential equations, in which the student must show comprehension capabilities and item resolution. The test used exercises and application problems of differential equations featuring Fuzzy metrics, with the purpose of measuring the mathematical thought of students. To measure the constructive ability of learning, we used the inventory of Weinstein and Palmer [15], analyzing dimensions of attitude and interest toward differential equations, self-control, time management, use of support techniques, attention; the internal consistency of adapted test alpha de Cronbach is 0.96. Was applied to interviews of students to identify perceptions about differential equations calculated validity though Kendall judges was 0.91. Statistics processes was realized with SPSS software, modelled processes and equation solutions were made using Software MatLab. Each category was reviewed by frequency of appearance, to the sentence was added an enumeration for quantitative valuation and demonstration for sum of sentences in a determined category; the consensus through repetition of sentences and validity of results, demonstrating frequency, intensity and contingency, objective condition of speech and descriptive valuations.

Factors that might invalidate the test were controlled, to avoid control group unknowns, the existence of a sample group and vice versa, impeding comparisons between them, random selection was realized previously, verified by other department personnel and areas around the dynamics, signals, and systems that offer external assessment to students in

corresponding themes. Before these items, a diagnostics test in mathematics knowledge was applied to determine if they are in same level of knowledge and competences. Given that distribution of some items of instruments show response patrons with concentrations in high scores, with asymmetrical negative distribution and deviation of normality multi variation, the statistical scaled Chi-square Satorra-Bentler was used to analyze multi variation data that did not comply with parametric suppositions. To analyze the relationship between dimensions of development of mathematical thought and academic performance, thus with other adjusted criteria was applied correlations Tau de Kendal, Gamma, and the Kappa index of Cohen.

3. Results

The reliability of applied instruments in the research was calculated by the statistic value of reliability alfa of Cronbach for instrument surveys applied to students with a value of 0.877 for tests with exercises with defined integrals, with a value 0.860 for tests with application problems of defined integrals with a value of 0.863. The previous results were interpreted like high reliability values that assure that information collected with each of the instruments is reliable and significant.

In Table 1, it is observed that any of the groups approved the mean score of diagnostics (0.0 – 5.0), obtain the best mean value group B. Once realized, the test Chi-square, $p=0.09>0.05$, indicates that variable tests and groups are independents, meaning that the results don't depend on how the groups were selected. In the Smirnov-Kolmogorov, each value p is greater than 0.05, therefore, it is accepted that groups are normally distributed. In homogeneity test of variances with

Group	Mean	Standard deviation	Kolmogorov-Smirnov			Shapiro-Wilk	
			Statistic	gl	p	Statistic	P
Group A Test	1,8	1,57	0,181	74	0,051	0,912	0,206
Group B Control	1,9	1,08	0,172	74	0,164	0,865	0,129

Table 1. Normality Test of pretest development of mathematics. Source: own.

statistics Levesne $p=0.367 > 0.05$ assuming that variances are equals for two groups. Once checked, these suppositions realize the test “t” to compare mean with $p=0.071 > 0.05$, thus, there is no evidence to support that groups differ between them.

With respect to the development of mathematical thought, a hypothetical student with a score $x = [1,1,0,0,1,1,1,0]$ or $y = [1,1,0,0,0,1,1,1]$ in the solution test for differential equations, a score $x=[0,1,0,1]$ or $y = [0,0,1,1]$ in the application of differential equation tests that define the threshold between the intra and inter level, been able to identify the elements of the test, but with difficulty in establishing all the relationships. The Fuzzy metrics in this supposed is

$F_d(x, y, 0.57)=0.248$ where any student with a valuation below 0.248 has difficulties establishing any type of relation and is located in the infra level.

On the other hand, a hypothetic student with score $x = [1,1,0,0,1,1,1,1]$ or $y = [1,0,1,1,1,1,0]$ in the differential equation test and a score of $x = [1,1,1,0]$ or $y = [1,0,1,1]$ in the applications test defines the threshold between the levels infra and trans where $F_d(y,x,0.57)=0.363$ and a student with a valuation below 0.363 is located in the inter level.

Overall probabilities between results transformed to Fuzzy metrics of formal reasoning test applied to measure the appropriation of

concepts of differential equations and the applications of same engineering group found a probability of 0.992 of students in intra level in both tests, e.g. taking in account the metrics, a 99.2% of students that are in the intra level don't recognize all the elements of differential equations and it's difficult to correlate them. In the appropriation of concepts in most applications to solve engineering problems just 1.5% of students are in the inter level, meaning they recognize the relationship between elements of schema being bigger than their possibility of power and deductive capability, and any student can build a subjacent structure of the whole type. These values of probabilities are interpreted with high similarity to measure the applied instruments.

By implementing the methodology in experimental groups, the students develop prototypes that involve basic conceptions from introduction to point of view multi variations in this situation already found that allows students to introduce the concepts of calculus starting on cases in which they have the possibility to control their own experience.

A simple case studied in physics course [16] for Ohm's law in an electric circuit with an electro potential power supply (G) and amperere meter (A) and a Voltmeter (V) measured the characteristics of currents that pass through a resistance (R) expressed for the linear relation between differential of potential V in volts and the intensity I in amperes

$V=R*I$. Students can observe that points in the graph are located with good precision over the straight line and introduce two types of interpretation (inductive and deductive) with the register that shown differences between mathematics and physics, introduce elements like condensing to a circuit, led and analyzed variations, determining differential equations and their solution.

On the other hand, designs of radio transmitters like electronic devices though antennas irradiate electromagnetic waves that can contain information, as occurs in the case of radio signals that permit evidence and apply Maxwell equations for static electromagnetic fields, electric field E, Ampere Law, displacement currents and others, like a pistol toy made with PVC pipes that is charged with solar energy or an air pump, determining differential equations for projectile movement with an error of 0.02 optimum for equation and predictions, permitting to analyze similitudes in mechanical and electronics systems, routing broadcasting stations through internet [17], between other prototypes and applications.

Hypothetical indications assume significant differences in final average scores between group control B and the test group A, in both differential equations, including Industrial Engineering and Systems Engineering (Table 2).

Similarly, there are indications to assume significant differences of results in formal thought tests between control group B and test group A, e. g. that development of electronic prototypes had incidence in the development of formal thought on students of differential equations. Likewise, the results affirm that students with development of formal thought in an inter-level have the skills in the solution of problematic situations of differential equations. This analysis shows how

to apply pedagogic focus that correlates significantly with development of formal thought of students, (Table 3):

In table 4, (scales transformed to percentages, except objective tests), students of experimental groups develop higher interest in learning and applications of differential equations. The correlations matrix show this to be significant, congruent, thus the adjustment criteria are related positively between them y negatively with criteria that implies maladjustment, besides interpersonal relations with results of objective tests associated this result to age, gender; then dimension of motivation are positively related with adjustment indicators and negatively with maladjustment criteria. Shown also are more intense relations between them and the closeness criteria (academics self-concept and motivation of development of prototypes).

Elsewhere, correspondence analysis and similarity show conformation of three clusters where the micro curriculum methodology is associated with a final score in test; the third vicinity is formed by gender, age of student, and type of application or prototype. Similarities don't exist in implemented test results between control group and test group. With a significance level of 0.002 the bi variable correlational analysis shows high correlation between variables development of formal thought test and learning skill (0.89) and low correlation with teacher competence. Thus, is observed that variable learning skill explain it with 72.1%.

Students that design electronics prototypes and develop mathematics models in differential equations manifest a useful tool in mathematics to comprehend and innovate in engineering, help learning, solving equations turns into an easy aspect goal and provides a solid formation for their personal lives, and show devel-

Test for equality of variances	Average	Standard deviation	F	P	t	p value	mean difference	Interval 95%	
								Lower	Higher
Group A Group B test-Control	4,3	0,759	1,124	0,253	2,86	0,008	0,698	0,193	3,194
	2,8	0,668	0,122	0,629	1,96	0,048	1,424	0,007	2,019

Table 2. Test to differentiate average samples independent of final score. Source: own.

Symmetrical Measurement		Value	Error tip. asint.a	T aproximadb	Sig. aproximado
Ordinal por ordinal	Tau-b de Kendall	-.237	,055	-2,299	,018
	Tau-c de Kendall	-.129	,054	-2,299	,018
	Gamma	-1,000	,000	-2,299	,018
N of valid cases		74			

Table 3. Correlation between development of electronics prototypes that generate mathematical models and formal thought test. Source: own.

	Experimental Groups	Control Group		Experimental Group	Control Group
Time Management	96	68,5	Attention-concentration	82	61,3
Attitude and Interest to differential equations	98,7	40	Motivation design	76,8	57,6
Self-Control	69,9	65,9	Argumentation	65,3	51,2
Teacher competence	76	75	Student implication	66,2	55,8
Teacher cohesion	90	65,9	Support Student other semesters	65,5	42,2
Personal relations	70	43,2	Implication teacher Electronic Engineers	95,02	53,05

Table 4. Descriptive Statistics. Instrument interpersonal relations, learning. Source: own.

opment of competences (Table 5). However, they also sometimes lack knowledge to development of mathematical models in nonlinear systems. Students of control groups show that reach to concept and apply; however, time is limiting to continue in topics, is marking the use of formulas and getting results.

The process of development of formal thought, according with Cantoral (2005) is interpreted as a spontaneous reflection that a mathematician made about the nature of his knowledge and about the nature of process discovering and invention of mathematics, turning the classroom into a scientific environment in which the concepts and mathematics technics surge and develop in problem resolution and construction of designs and electronics prototypes; furthermore, if psychology is successful in understanding how to educate an individual to make certain task

and how to perform certain activities, then, the formal thought is associated with the thinking people. Students start comparing or searching existing models through document analysis, experimenting and then modeling the process of comprehension of mathematics concepts itself.

Maneuvering academic performance, as a demonstrated level of knowledge in an area [18], can be compared with age and academic levels. In this research, the use of apps allows an advanced level of knowledge where age wasn't an associated factor to academic performance. Likewise, associate factors differ to manifesting factors in analysis made by Vergel, Gallardo, and Martinez [19] who points out that gender, family expectative goals, and learning style are factors associated with academic performance and redeem from this study motivation as a factor. As proposed by

	Experimental Group A	Control Group
General competences	Ability to initiate and participate in research projects. Creativity, Curiosity, persistence, flexibility	Individual work
	Ability to understand, explain, formulate, interpret and solve problems to be addressed through differential equations models through electronic prototypes with linear and nonlinear designs. Ability to recognize applications models	Ability to understand and solve problems that can be addressed
Procedure competences	effective use of time Cost analysis Analysis of algorithms for solving problems	Cannot see all program content
	Analyzes each simulated or actual situation based on concepts and poses resolution mechanisms using methods appropriate differential equations. Solves problems in context, concludes and makes decisions	Concepts used as a basis to analyze, plan and develop simulated problems
Knowledge competences	Interprets results obtained from the analysis in context of a real or simulated situation. He argues: Identify the problem and appropriate knowledge, defining boundaries between related problems. Identifies tools that you should know to address the problem. It enters independently in new methodology. Uses knowledge gained originality and rigor to formulate and argue new results are integrated into solution. It proposes new models, designs. It understands concepts associated with physical laws. Solves problems Identifies real or simulated situations and find differential equations method to solve the real situation. Identify and list specific problems to be resolved. Identify and collect the published literature on the problems to address or similar. Compare, analyze dynamic systems. Plan designs and cost and scope of knowledge in differential equations. Prepares prototypes. Develop formal thought	He seizes tools needed by studying the listed bibliography, compiled and web consultation
Attitude competences	Participates in groups or teams, provides and discuss solutions proposed problems. It is critical, with broadmindedness creative in generating new prototypes Assumes with creativity, confidence, self-control, honesty and responsibility the design, development and implementation of real or simulated problems. It recognizes the importance of differential equations in mechanical and electronic systems. Related science and equations.	Generate proposals for data analysis Works independently

Table 5. Competences students Control group and Experimental group. Source: own.

Vanegas and Escobar [20] it must be assumed that learning is not exclusively related with cognitive aspects but also involves social and affective factors.

In problem solutions, it was evident their communicative competences to design and develop strategies of oral communication to promote between students theories and results of projects, design and document elaboration to report results of real projects [21],

give them scientific arguments, made a valuation of methodology of existing differential equations from a critic perspective, identify limitations of methods to be applied in real and definite conditions. Identify limitations and advantage methodologies: identify requirements and computational limitations of apps used, recognize the transient of methodology strategies, reach to change paradigms of students.

Methodologies using apps improve academic performance, however is not associated with gender and age [22]. In research, significant differences in characteristics of population object of study do not exist, the research shows improvement in level of development of formal though associated with age, gender, development of prototypes, self-concept in academic dimensions as variables. Like Vergel and Gallardo [23] in the teaching is teach for discovering, based on exercises approaches for students to discover concepts and properties and with teacher's support build knowledge network, teacher perform control function, staying the course and addressing the purpose of study and indicating definitions, results or improper procedures, permitting that students explore, interpret and settle questions about proposed procedures, rediscovering and generating new knowledge. Using this methodology to propose one or various new situations, which resolution includes the management of concepts and development projects in research, allow the development of conscience to the young to apply in the classroom, visualizing unsolved needs and other applications of the unknown, changing the perception of students about the learning of differential equations, reaching to enter into prospectivist paradigms.

The psychopedagogic factors have a high influence on the prediction of academic performance of intelligence, and is reasonable to use of standardized instruments to detect risk of scholar failure [24] where the indicator of educative level acquired will be the scholar score [24], respect to the research permits besides of results in scores, to analyze the reached competences for students like indicator of level where the experimental group reach general competences, procedures, conceptual, manifest aptitude in curriculum of differential equations.

Use of apps allow the quick advance of development of manifest topics in curriculum, reaching in 4 weekly hours of micro curriculum, complying with the objectives of differential equations, basic concepts, on the other hand the development of prototypes with support of professionals of other sciences foments the interdisciplinary to student reach the concept sharing at stablish by Guerra, González and Garcia [25] who affirm that some research reveals the lack of didactical use of university teachers made of technology and coinciding with Imbernon, Silva and Guzman [26] new tools and resources are useful, likewise, is observed the expressed respect to satisfaction in students for this kind of designs [27].

Significantly, when using apps it is important to reflect on what one is trying to do, and about what still needs to be done. Teaching must develop competences, evaluating their though and progress, acquiring conscience about need and use [8] The student must be guided to create cognitive conflicts that lead to search of solutions and new designs or creations, like found the way to conceptualize and generate models using differential equations.

Development of competences creating electronics prototypes locates the teaching and learning of mathematics as powered of social practice, innovation of self-formation, therefore the didactics of mathematics, install today new redefinitions and challenges [28-29]

Predicted undesirable events include the cost of electronics devices, software licenses, socio economic level of students, level of knowledge in applications, that required gave resources and generate an space in different hours the student get individual assessment or search external assessment with advance

semesters students of electronica engineering, link with research seedbed or asking assessment to professionals in other areas like physics, dynamics, electromagnetism, simulation and others, variables that confirm that any research must forget the context [30].

4. Conclusions

Development of electronics prototypes for teaching of differential equations show favorable incidences in academic performance and the development of formal practice through student experimental groups.

Designing prototypes allows students to generate ideas, create, explore, compare, and interpret, discovery, conjecture, make deductions, justify, test arguments, develop concepts and generate mathematics models of differential equations analyzing its validity and error.

Students reach to improve general competences, procedures, conceptual and aptitude, as evidenced goals in interpretation, resolution of differential equations, problems solutions, argumentation, logic though, formal, technologic and communicative.

Students reach to give more importance to differential equations, an area required to comprehension and advance of other sciences. Their interest to develop projects is in the application, problem solution, and mathematics model analysis. Students that used apps and made design of electronics prototypes showed more motivation to obtain results, they feel more competent analyzing results, students shown communicative competences are empowered to control actions in the project development thus analyze more effectively differential equations. 60% of goals in the generation of mathematic models were reached.

Electronic prototypes creation permit comply with the proposed content in the micro curriculum of differential equations, like, help the analysis of results in the development of transversal projects through field job integrating students to research, empower teamwork, and the interrelation between different areas to search the results comprehension and generate mathematic models. This experience permit to observe the increase of teamwork, pointing to generate new forms of study, job labor independent and evaluation, positive for students as for teachers.

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