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Presentation of the Content

In the first article we present, *Programming as a didactic technique in the teaching-learning process of the complex variable subject*, by ALANÍS, Reynaldo, MOTA, Juan and URUETA, Daniel Edahi, with adscription in the, Universidad Politécnica del Estado de Guerrero, as the next article we present, *Characterization of uses of trigonometric notions in Mechatronics Engineering from Mathematics Education*, by TORRES-CORRALES, Diana del Carmen & MONTIEL-ESPINOSA, Gisela, as the next article we present, *Teaching thermodynamics in Engineering based on competences*, by RANGEL-ROMERO, Carlos, ROJAS-GARNICA, Juan Carlos, FLORES-MARTÍNEZ, Guillermo and MUÑOZ-MATA, José Lorenzo, with adscription in the, Universidad Tecnológica de Puebla, as the next article we present, *AppPECS: Mobile Application for Children with Autism Spectrum Disorder*, by ENRÍQUEZ-RAMÍREZ, Carlos, CRUZ-RESÉNDIZ, Juan Carlos, OLVERA-CUEYAR, Miriam and SÁNCHEZ-HERRERA, Roberto Arturo, with adscription in the, Universidad Politécnica de Tulancingo.

Content

Article
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Programming as a didactic technique in the teaching-learning process of the complex variable subject

La programación como técnica didáctica en el proceso enseñanza – aprendizaje de la asignatura variable compleja

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Abstract

The use of computer programming in some programming language as a teaching tool in the teaching - learning process of the Complex Variable subject is proposed and the results of the major in Telematics Engineering at the Universidad Poltécnica del Estado de Guerrero are presented. It will be indicated in which subjects the proposed technique was used, the programming language used in its implementation, a schematic model of the process followed by its implementation and the obtained results. The methodology used that will be detailed in the corresponding section is to locate the subjects of the subject, being: arithmetic of complex numbers and transcendental functions with argument of complex numbers for those that present on the one hand greater difficulty in understanding and, on the other, are those that can be programmed in a simple but meaningful way. The subject of arithmetic of complex numbers will be explained in detail. The programming language used is the one that the students master, since this subject is taught in the fifth semester of the major in Telematics Engineering.

Teaching techniques, Teaching Mathematics, Education

Resumen

Se propone el uso de la programación de computadoras en algún lenguaje de programación como herramienta didáctica en el proceso enseñanza – aprendizaje de la asignatura Variable Compleja y presentan los resultados de la experiencia en la carrera de Ingeniería en Telemática en la Universidad Politécnica del Estado de Guerrero. Se indicará en que temas de la asignatura se utilizó la técnica propuesta, el lenguaje de programación utilizado en su implementación, un modelo esquemático del proceso seguido de su implementación y los resultados obtenidos. La metodología utilizada que se detallará en la sección correspondiente es ubicar los temas de la asignatura, siendo: aritmética de los números complejos y funciones trascendentales con argumento de números complejos por ser los que presentan por un lado mayor dificultad en el entendimiento por parte del alumno y por otro son los que se pueden programar de manera sencilla pero significativa. Se explicará en detalle el tema de la aritmética de números complejos. El lenguaje de programación utilizado es el que los estudiantes dominan, dado que esta asignatura se cursa en el quinto cuatrimestre de la carrera de Ingeniería en Telemática.

Técnicas didácticas, Enseñanza de las Matemáticas, Educación

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† Researcher contributing as first author.

Introduction

Information technologies have been used in recent years as tools for support in the learning-teaching process in academic environments from elementary school to higher levels and this is known, encouraged and accepted (Salinas 2004). Teachers and students use different computer technologies in both academic and research activities, from large or personal computers, to gadgets, among others. End-user applications are frequently used, such as: PC applications and/or gadgets, calculators, spreadsheets, browsers, and many others. The coding of applications is a formal process and the errors that can be made (logical errors) or even before, in the compilation (syntactic errors) are evidenced. On the other hand, those specific applications are evidenced during the execution of the final application to an area of knowledge, how difficult but structured to learn some subjects in the area of basic sciences such as Mathematics. The use of programming is explored as a didactic technique both for teaching-learning the subject of, in this case, Complex Variable, as well as for reviewing and reinforcing programming skills. The use of programming languages and the coding of programs in the corresponding compilers can be a helpful tool in learning formal subjects (Fernández 2013).

In polytechnic universities, the basic educational model is that of Competency-Based Learning (Tobón 2008). The core competencies are: know-how-to-do, know-how-to-be and know-how-to-know (Tobón 2008). The know-how-to-do is to obtain knowledge in the development of related products in the area of knowledge. The know-how-to-be is that the student can develop solutions to problems of their socio-economic environment. Finally, know-how-to-know is that the student, in addition to the knowledge presented by the teacher, can be able to obtain, by searching in different sources, information to structure and obtain additional and complementary knowledge on specific topics related to their area. The Network and Telecommunications Engineering major consists of a series of subjects that allow the development of products that can be academic but also a solution to the needs identified in the student's socio-economic environment.

The subject of Complex Variable was used as an academic context in the development of the competence know-how-to-know, know-how-to-do and with less emphasis know-how-to-be, relying on previous knowledge and experience in coding, with basic programming concepts and implementing them in some programming language. If we focus mainly on the fundamental concepts of programming, that is, the bases or structures of program construction: sequence, decision and repetition as well as analysis of the different programming languages, being able to be procedural and/or object oriented, mainly in C, C++, Java or even C#. Developing a program necessarily implies including, in addition to coding, specific tasks aimed at building useful, efficient and reusable code (Pressman 2010), such as:

1. Investigate and diagnose the problem to be solved;
2. Perform an analysis to create a model of the system to be developed and to solve the identified problem and finally
3. Design the elements to be programmed (using analysis methodologies and the design of programs such as flow charts and concepts of the problem area, the knowledge acquired or necessary to acquire in the area of Complex Variable).

For the diagnostic activity, a recommended strategy for its usefulness is to be guided using the steps of the Diagnosis of the Current Situation (Pressman 2010). It helps the developer to identify the need or problem to solve; the environment where the need or problem is detected; the environment where the solution will be implemented; and the feasibility of the solution. The students in this semester have not completed the subject of Software Engineering, however basic aspects or principles of this were included, particularly, the initial phases of the development of computer-based systems: analysis and designing of programs. The generic process model was explained and for the analysis and designing phase, flowcharts were used.

The Complex Variable subject begins with the classification of numbers and identifying the creation of complex numbers and the justification of their need. Focusing on Complex Variable, it begins with the definition of complex numbers and Arithmetics, as well as their properties.

The different ways of representing a complex number are explained. It is in this part of the course that the complications and difficulties of understanding complex numbers begin. Given, for example, a complex number in its binomial representation, identify its module and argument, that is, locate the complex number on the Argand plane (Churchill 1986). Subsequently, the arithmetic of complex numbers continues: addition, subtraction, multiplication, division, powers and roots. The foregoing further complicates the process of understanding, especially the root part, since students are accustomed to only obtaining a root even though there may be two or more depending on the order of the root. For this, it was necessary to understand the representation of Moiver and Euler, especially for potency and obtaining roots. It is followed later with functions of Complex Variable. Of these, trigonometric, logarithmic and exponential functions present a great difficulty for students to understand and manipulate them.
Since programming is a discipline that requires a clear understanding of what is going to be codified, as well as the handling of exceptions, it can support the understanding of the issues mentioned.

If it is not understood how to determine, for example, the quadrant in which the complex number is to be plotted based on its argument, it cannot be programmed and the results will be wrong (Distéfano, ML, Aznar, MA, & Pochulu, M. 2012). If the student wants to experiment by changing values of complex numbers, it can be tedious and prone to error, since the procedure to perform it involves arithmetic operations, as well as trigonometric functions. To program the above, it is necessary to develop the algorithm and, for this, it is necessary to clearly understand the process of transforming the complex number into a rectangular representation to a graph.

The knowledge and mastery of the algebraic skills of complex numbers, as well as the Complex Variable are of paramount importance for students, professionals and researchers in engineering and science. The difficulties involved in teaching and learning the above motivate teachers to search and try different strategies, so it is justified to explore the use of programming as a didactic technique.

Objectives

The objective of this paper is to present the use of programming as a strategy and didactic tool in the teaching-learning process of the subject of Complex Variable, as well as to present the workflow and the results of its application.

Methodology

A didactic technique is a didactic process that helps in part in the realization of learning (Carrasco 2004). There are various techniques and each of them has advantages and areas of opportunity. For the Complex Variable course, the exhibition teaching technique was applied, which consists of presenting the information in an orderly manner using various means of support. The Complex Variable course begins with the presentation of the agenda. The explanation of the content of the subject begins with the construction of the set of numbers: natural (N), integer (Z), rational (Q), irrational (I), real (R), and finally, imaginary and complex are presented. Figure 1 shows said construction.

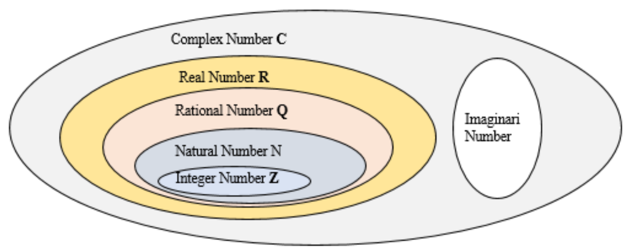

Figura 1 Set of numbers

The above is addressed through the solution of algebraic expressions of the form $x^n + b = c;\ a, b, c \in R\ and\ n\ \in N$ in such a way that when trying to solve the equation in particular:

$$x^2 + 1 = 0 \quad (1)$$

The need to include the imaginary numbers ai, (with $a \in R$) that represent the even root of negative numbers is imperative, in the form:

$$i = \pm \sqrt[2]{-1} \quad (2)$$

(In this case, the square root of -1). Complex numbers are constructed when it comes to solving a quadratic equation of the form:

$$ax^2 + bx + c = 0 \quad (3)$$

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Using the discriminant that results when applying the general formula:

$$x_{1,2} = \frac{-b \pm \sqrt[2]{b^2-4ac}}{2a} \quad (4)$$

$$b^2 - 4ac < 0 \quad (5)$$

The solution of which is

$$x_{1,2} = a \pm bi \quad (6)$$

With a and b $\in R$.

This is the binomial representation of a complex number. Subsequently, the Argand plane is exposed and the graphic form of the complex number is presented, as shown in Figure 2.

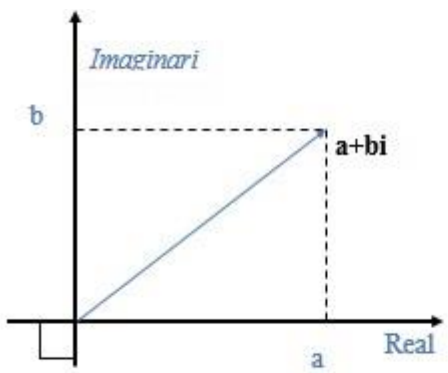

Figure 2 Graphical representation of a complex number

Subsequently, the polar representation of the complex number $z = (r, \emptyset)$ in Figure 3 is shown.

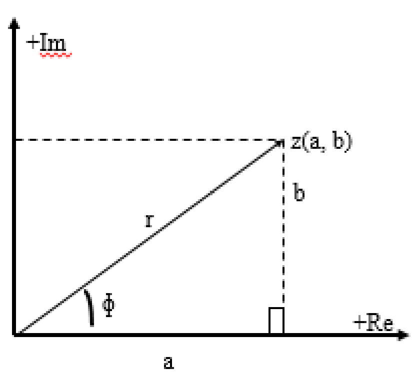

Figure 3 Polar graphical representation of a complex number z

Where r is the module of z and $\emptyset$ the angle or argument. Depending on the values of a and b, the complex number is located in one of the four quadrants of the Argand plane. The following table shows the details.

a (x axis)	b (y axis)	Quadrant
+	+	I
-	+	II
-	-	III
+	-	IV

Table 1 Location of the complex number in the Argand plane

The r module is calculated as follows:

$$r = \sqrt[2]{a^2 + b^2} \quad (7)$$

And $\emptyset$, the argument of the complex number z, is generally calculated as follows:

$$\emptyset = tan^{-1}\left(\frac{b}{a}\right) \quad (8)$$

Based on table 1, $\emptyset$ is calculated to locate z in the Argand plane according to the following table:

a	b	$\emptyset$	Quadrant
+	+	$tan^{-1}\left(\frac{b}{a}\right)$	I
-	+	$tan^{-1}\left(\frac{b}{a}\right) + \pi$	II
-	-	$tan^{-1}\left(\frac{b}{a}\right) + \pi$	III
+	-	$tan^{-1}\left(\frac{b}{a}\right) + 2\pi$	IV

Table 2 Calculation of the value of the complex number argument for the Argand plane

It is in this moving from binomial algebraic representation to the graphic part where students have more difficulties and where the greatest number of mistakes are made. A set of exercises was applied where the following errors were identified:

1) When calculating the module of z, not only the coefficient b of the imaginary part was squared but also included i;
2) The same happened when obtaining the argument of z without knowing how to perform the division of bi by a;
3) Errors when placing z in the corresponding quadrant in the argand plane.

Subsequently, the properties of complex numbers and the arithmetic operations of addition, subtraction, multiplication, division, powers and roots were exposed.

Again, there were difficulties in learning the above. For the addition, subtraction, multiplication and division the binomial representation was used and later, when the power and roots were explained, the representation of Moivre (Churchill 1986) was explained and the multiplication and division operations were resumed and again the bidirectional conversion of algebraic z-graphic. Again, a questionnaire was applied to evaluate the arithmetic operations as well as the Moivre representation of $z = rCIS(\emptyset) = rcos(\emptyset) + risen(\emptyset)$. The most frequent errors, when they were able to solve them, were the same as those mentioned, in addition to the difficulty of obtaining the multiple roots of $z^{1/n}$ in particular, where

$$z^{1/n} = r^{1/n}\, CIS\left(\frac{\emptyset+2k\pi}{n}\right)\; k = 1, 2, \dots n-1 \quad (9)$$

The explanation was made using the didactic exposition technique and supported by exercises and problems. Subsequently, Euler's representation of the complex numbers $z = re^{i\emptyset}$ was explained, which will illustrate the trigonometric, logarithmic and exponential functions. The trigonometric functions are evaluated and explained:

$$sen(z) = \frac{e^{iz}-e^{-iz}}{2i} \quad (10)$$

$$cos(z) = \frac{e^{iz}+e^{-iz}}{2} \quad (11)$$

$$tan(z) = \frac{(e^{iz}-e^{-iz})}{i(e^{iz}+e^{-iz})} \quad (12)$$

$$ln(z) = \ln(r) + i(\emptyset + 2k\pi)k = 0, \pm 1, \pm 2 \dots \quad (13)$$

Again, a questionnaire was applied to diagnose the progress on these last issues and the mistakes mentioned above were made, as well as the difficulty of calculating trigonometric and logarithmic functions.

It was proposed as product evidence to develop a program in the programming language of their liking that would automate all the operations mentioned. For this, the traditional software development process was explained: Analysis, Design, Construction, Testing, and Installation (Pressman 2011). The sequence of the mentioned phases is presented below.

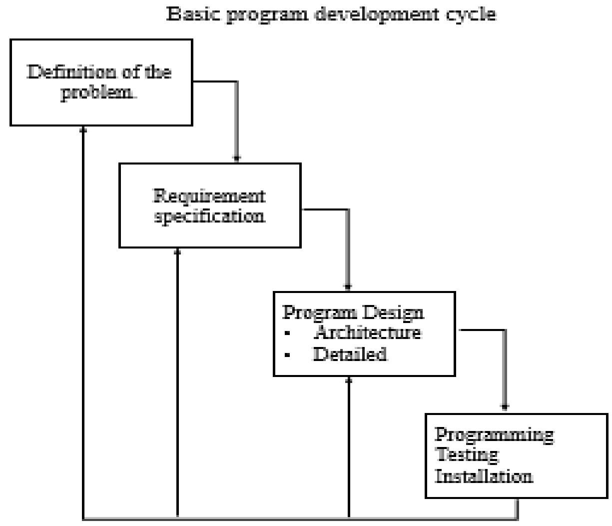

Figure 4 Traditional process for program development

The work model shown in the following figure was developed and implemented.

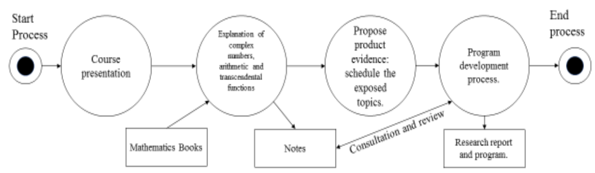

Figure 5 Workflow of the Complex Variable subject

As it can be seen, the process is systematized and the activity where programming is used as a didactic technique is included. For the last activity, development process applies the sequence that was shown in Figure 4. The following is broken down.

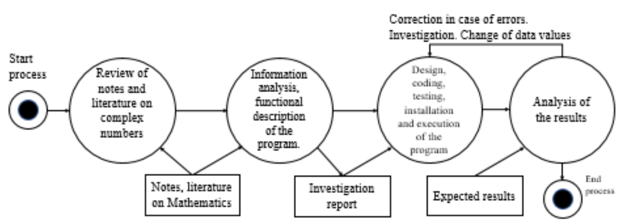

Figure 6 Development process of product evidence

Once the product evidence is proposed, it begins with the revision of the notes and appropriate literature in Mathematics.

Subsequently, the writing of the research report begins, the contents of which are: introduction, objectives, theoretical framework, development, results, conclusions and references.

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In the theoretical framework, the student writes the corresponding theory and develops the steps to follow for the programming of the application.

The external characteristics of the program, exception handling, user conditions, program installation and validation test plan are indicated. It is in this section where the analysis and design of the program is carried out.

In the development, what is explained in the theoretical framework is coded, as well as the semantic and logical correctness of the program is evaluated.

In the results, the program's correctness is finally evaluated, comparing the results of the program output with the expected results. If there is a discrepancy, both the theoretical framework and the analysis, design and coding of the program are reviewed until the program is correct.

The calculation of r is not complicated. For example, the student understands that only the coefficients of z are used to obtain the result. Since in order to program something it is important to determine the type of variables to be used, their declaration would be real or decimal.

During the exposition of the theory, only whole numbers are used. Since the arithmetic operations are requested to be programmed, it must be validated that when dividing two complex numbers z_1 and z_2, the module of z_2 must be different from zero. For the other operations it is not necessary.

It was requested that the numbers z be transformed to their polar and Euler's form, obtaining not only the module but also the argument, it is in the calculation of the argument where the students should pay attention and "explain" to the computer how to obtain r and the argument. The corresponding flowchart is presented in the following figure.

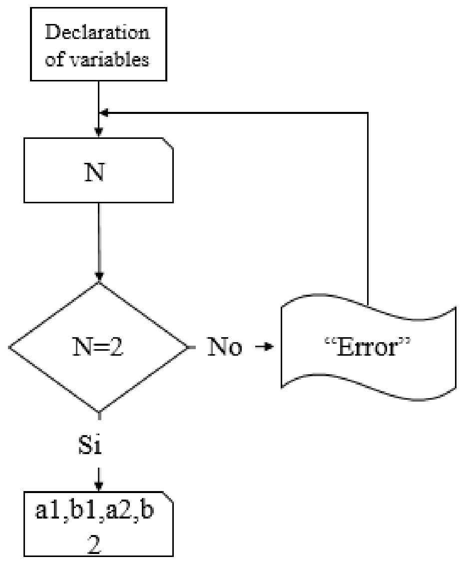

Figure 7 Flowchart reading of z´s

Since it was requested to work with two complex numbers, it is validated that the number of data to be read is two, otherwise, error. This process of "explaining" to the machine helps the student pay attention to what they are going to do. Subsequently, r1 and r2 would be calculated, as well as the corresponding arguments. The corresponding flowchart is shown in the following figure. Emphasis is placed on the identification of the quadrant where z_1 and z_2 are to be located. Again, the fact that the student "explains" to the machine how to identify the quadrant leads the student to attend to it.

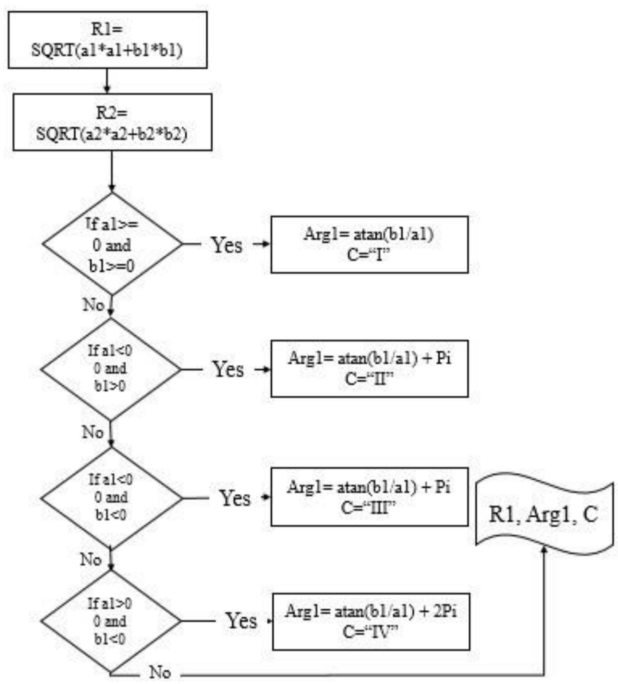

Figure 8 Flowchart to obtain module, argument and quadrant of z1

The calculation of the argument of z_2 is not detailed but is the same as that of z_1.

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Once having the module and argument of z_1 and z_2, the required operations can be performed, as well as represent them in their binomial, polar, Euler and even graphic form. The student can program these operations sequentially or can do it by selection. If z_1 is to be divided by z_2, it must validate that z_2 is different from zero.

To program the calculation of trigonometric functions, the student must develop formulas 10 and 11 in their binomial form first and calculate their polar form.

The following figure shows the binomial form of sen(z) using only exponential and trigonometric functions with real arguments. The deduction of this formula helps the student to exercise not only what is seen in the subject of Complex Variable, but also the algebraic part.

$$\sin(z) = \frac{1}{2}e^{-y}\sin(x) + \frac{1}{2}e^{y}\sin(x) + i\,(\frac{1}{2}e^{y}\cos(x) - \frac{1}{2}e^{-y}\cos(x))$$

Figure 9 Binomial representation of sen(z)

The cos(z) function is developed in the same way and the tan(z) function can be evaluated by first calculating sin(z), then cos(z) to later perform the division by calling the routine that calculates the arithmetic operation in the program or developing it as equation 12.

The function ln(z) is easier to calculate and it is interesting how students discover that logarithms of negative real numbers and the famous Euler equation can be calculated:

$$\ln(-1) = i\pi \qquad (14)$$

Results

As mentioned in the previous section, the presentation and explanation of the content of the subject of Complex Variable was initially supported using the didactic technique of exposure.

Exercise questionnaires were used on the topics of arithmetic of complex numbers and trigonometric functions. The students made, when they were able to solve the exercises, several errors and deficiencies.

When proposing to carry out a program to implement the obtention of the module and argument of z, the arithmetic operations, as well as to evaluate the trigonometric functions and the natural logarithm function, the students had to “teach and explain” to the computer how to perform these operations, they were forced to review the basic theory about complex numbers, the management of attributions, consult the teacher with specific questions on the subject, review algebra and discover the application of programming in somewhat arid subjects, such as arithmetic and trigonometry of complex numbers.

After the completion, execution and evaluation of the program, questionnaires on the topics were again applied and showed a substantial improvement in the results. The questionnaires not only focused on the operational part, but also on the reasoning. They were asked to solve non-numerical exercises and approached them satisfactorily. In the process of research, analysis and design of the program, the students asked for advice and their questions were formulated more concrete and timely. The undersigned, in advising them, identified the progress in the knowledge and mastery of the subject. At times, the students showed that they already understood what the operations meant but were looking for a way to "exploit" the computer on how to perform these operations. Some students took advantage of the programming language libraries (Phyton) and they were asked to explain the algorithms of the bookstores or how they thought these functions had been programmed and included them in detail in the research report.

Conclusions

An improvement is perceived when comparing the results obtained when diagnosing learning and progress through problems using only the didactic exposure technique with the results after the completion of the program and preparation of the research report. The advice given to the students during the development of this work helped the subscriber to evaluate the progress in the management and knowledge of the topics addressed. The work was developed in teams of two students and this not only supported the know-how-to-do and know-how-to-know skills but also the know-how-to-be, as it favored and strengthened collaborative work.

The know-how-to-know competence was addressed and strengthened by having students investigate on their own to clarify some points in the development of, for example, trigonometric functions. The know-how-to-do skill was developed by having students create an application that would help them solve some exercises related to complex numbers and arithmetic operations. With some simple modifications, the student could take this application to an exploration and research instrument. For example, if complex numbers are very large in their real and imaginary part, they may encounter the problem of calculations that in turn require evaluating trigonometric, exponential and/or logarithmic functions and would lead them to review their knowledge in programming. Some improvements that can be made include that the application can be executed via the Internet or developed for mobile devices.

In general, the objective that the students, through the formalism of programming, learn and master in a better way the topics addressed at the beginning of the Complex Variable course was achieved.

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Characterization of uses of trigonometric notions in Mechatronics Engineering from Mathematics Education

Caracterización de usos de las nociones trigonométricas en la Ingeniería Mecatrónica desde la Matemática Educativa

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Abstract

From the Socioepistemological Theory we propose that even with the curricular articulation presented in school programs of Engineering it exists a disarticulation of uses of mathematical knowledge, this is displayed more emphatically when a student takes professionalizing courses. We proposed the research question of: what uses of trigonometric notions are given in Mechatronics Engineering when students solve problems in Robotics? we use the Socioepistemological Theory in tandem with the ethnographic method to identify and characterize them in their cultural framework. By the delimitation of the study to a community of Mechatronics Engineering in a Mexican university and the direct kinematics problem in the subject of Industrial Robotics, we characterize that trigonometric notions are given an arithmetic, metric, quantitative and algebraic usage, and by them, the Trigonometry acquires more significates aided by the construction of visual references that allow the mathematical modelling that was done, and from which we recognize in the pseudo-concrete models (drawing and kinematic schemes) the reason to be for Trigonometry as a tool for Robotics: the determination of the position in a circle or circular sector.

Mathematics Education, Engineering education, Trigonometry

Resumen

Desde la Teoría Socioepistemológica plateamos que aún con la articulación curricular que presentan los programas de Ingeniería existe una desarticulación de usos del conocimiento matemático, que se manifiesta con mayor énfasis cuando el estudiante cursa las asignaturas profesionalizantes. Para dar cuenta de ello se planteó la pregunta de investigación: ¿qué usos de las nociones trigonométricas se dan en la Ingeniería Mecatrónica cuando los estudiantes resuelven problemas de la Robótica?, y en articulación con la teoría, empleamos el método etnográfico para identificarlos y caracterizarlos en su marco cultural. Al delimitar el estudio a una comunidad de Ingeniería Mecatrónica de una universidad mexicana, y al problema cinemático directo de la asignatura de Robótica Industrial, caracterizamos que se dan los usos aritmético, métrico, cuantitativo y algebraico de las nociones trigonométricas, y de los cuales la Trigonometría adquiere más significados gracias a la construcción de referentes visuales que permiten modelar el problema en el espacio; asimismo documentamos el proceso de modelación matemática que hicieron y del cual reconocemos en los modelos pseudo concretos (dibujos y esquemas cinemáticos) la razón de ser de la Trigonometría como herramienta de la Robótica: determinación de la posición en la circularidad o sector circular.

Matemática Educativa, Formación de ingenieros, Trigonometría

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Introduction

Engineering is distinguished by design, which it develops through models (diagrams, tables, mathematical expressions, etc.) that allow engineers to represent, systematize, analyze and communicate their work (Bissell and Dillon, 2012). That is why modeling has been the subject of study for the academic training of engineers from various disciplines, including Mathematics Education, a discipline whose object of study is the didactic phenomena related to the teaching and learning of mathematics.

In research in Mathematics Education, mathematical modeling has been identified as the main competence that an engineering student must have (Faulkner, Earl and Herman, 2019). However, its complexity is recognized to develop mathematical modeling from the Mathematics classroom. For example, Langereis, Hu and Feijs (2013) reported a mathematical modeling experience in the Microcontroller subject of an Industrial Design Engineering program, from a competency-based learning approach and in a project-oriented environment; where the project was the design of a game.

To achieve this, the researchers required an inverted curricular proposal, finding that the modeling that goes from design to the model - the opposite case of the traditional curriculum that goes from the mathematical problem to the engineering problem - links mathematical and disciplinary knowledge, and also allows a more robust understanding problem.

The curricular adjustment proposed by this authors has complex implications and, we believe, must be the product of an interdisciplinary work in which the various actors involved in the Engineering training process participate. However, in the background seems to continue the criticism of Herrera (1990) towards the orthodox curriculum model that segments the subjects in Basic Sciences, Engineering Sciences and Professionalization.

Our research does not seek a discussion about the curricular structure, but it does recognize a problem that can be linked to the way in which mathematics is put into use in each of these curricular blocks.

Specifically, in professionalizing subjects, we have identified a mathematical disarticulation in three recurring situations: (1) the student does not recognize mathematics, (2) the student remembers mathematics but does not use it because he does not master the algorithms associated with it and (3) Given the two previous situations, the Engineering teacher gives a review of the necessary mathematics in his subject, in order to reduce the drop-out and rejection rate.

Hence, we propose, even with a curricular articulation, a disarticulation of uses of mathematical knowledge does not facilitate the processes of mathematical modeling in professionalizing subjects. Where it becomes indispensable to understand what mathematics is put into use and how it is put into use in the Engineering of interest, to propose what to teach and how to teach it, in Basic Sciences, before deciding when to teach it.

Mathematics for Engineering

Our research is located in the Socioepistemological Theory (ST), specifically in the studies of the culturally situated uses of mathematical knowledge in Engineering. So far, we have identified three strategies to demonstrate and address this mathematical disarticulation: historical-epistemological analysis, the staging of learning situations and studies of homework in the classroom.

In the historical-epistemological analysis the emergence of a mathematical knowledge is recognized in a selected original work; the social and cultural circumstances of the time are identified, the author's mathematical activity is reconstructed, the value of the use of knowledge around the problem that was solved and the elements that allowed to construct meanings are identified.

A study in this strategy found that in the works of three scientists in the electrical area the use of the notion of steady state is transversal to them, but in the teaching of Electrical Engineering the notion is not discussed. This, as reported in (Hinojos and Farfán, 2017) causes its nature to darken and limited meanings are promoted around the mathematical notion of steady state.

In the strategy of staging learning situations, a controlled design is developed that is applied extra-class to a group of students; This design is based on historical-epistemological analysis, which contrasts the mathematical activity of students in order to recognize the invariant elements that allow the construction of uses and meanings related to mathematical knowledge. A study in this strategy (Mendoza-Higuera, Cordero, Solís and Gómez, 2018) found that in the problem of fluid accumulation of a dam in Civil Engineering, mathematical activity is oriented to establish the trend behaviors through simulations, while that in the Mathematics subject it is limited to calculate, in an analytical and algebraic way, the solution of the differential equation.

In the study of classroom task, the researcher accompanies (in person or with video recording) in their classes to students and the teacher to study situations of their discipline, in order to understand the use and meaning they give to mathematical knowledge in the problem they solve, generally in contexts of Engineering Sciences and Applied Engineering; and later contrast the mathematical activity that occurs with its respective historical-epistemological analysis. A study in this strategy (Tuyub and Buendía, 2017) found that in the didactic component of the construction and environmental problems of a Master's Degree in Engineering, there are two uses of linear Cartesian graphs: organize information and show procedures and techniques , giving a meaning of the context to the slope and the order of origin; none of which work in the Mathematics subjects.

From these studies, it is recognized that there is a mathematical disarticulation that is attributed to a teaching, in Basic Sciences, that has privileged the use of formulas on the nature of mathematical knowledge (origin, conditions to be used and need to respond, among others). We recognize that, although this teaching has allowed learning, from our theoretical vision we seek to broaden these meanings with the intention of reducing this disarticulation.

Research Problem

Our research proposes the study of trigonometric knowledge put into use in Engineering, and from the review of some plans and programs of a Mexican university, we delimit research at three levels.

First, we chose the Mechatronics Engineering program because it shows the largest number of trigonometric content in their subjects. Second, we select a professionalizing subject, Industrial Robotics, because its contents show curricular articulation with the previous subjects (Engineering Sciences and Basic Sciences). Third, from the problems that are solved in the professionalizing subject we choose the direct kinematic problem because it illustrates the mathematical modeling process that it reports (Rodríguez-Gallegos, 2010): it transits between the real-pseudo concrete-mathematical domains; pseudo concrete models are elaborated (drawings, sketches, etc.) that allow to take the variables of interest of the real situation and from them mathematical models are constructed (graphical, numerical, algebraic, analytical, etc.) that allow to solve the situation, which is subsequently validated and confronted with disciplinary knowledge and the real situation.

With these delimitations, the research question was raised: what uses of trigonometric notions occur in Mechatronics Engineering when students solve Robotics problems?, and we use the ethnographic method to identify and characterize them in their cultural framework.

Theoretical considerations

Under the positioning of the Socio-epistemological Theory, we attribute the identified mathematical disarticulation to the limitation of uses and meanings promoted by the School Mathematics discourse (SMd). The SMd is a theoretical construct that explains the forms of communication and collective agreements that structure mathematical knowledge as an absolute truth, with a particular procedure to access it through its representations, and therefore, with the admission of unique meanings (Cantoral *et al.*, 2006).

Therefore, the theory is that the social construction of mathematical knowledge and its institutional diffusion is proposed as an object of study (Cantoral and Farfán, 2003); the social refers to the invariant practices that accompany the use of mathematical knowledge, and secondarily, group interaction and situational conditions.

It is assumed by the use of mathematical knowledge to “the ways in which a certain notion is used or adopted in a specific context” (Cabañas, 2011, p. 75), “whether the subject is aware of it or not, manipulates explicitly or implicitly, or that uses typically school or context-specific representations” (Rotaeche, 2012, p. 27).

Therefore, the theory considers that only in the use of mathematical knowledge are relative, contextual and functional meanings generated to the particular scenario, which will be in constant construction by the human group as they are used to solve different problems, what they call the principle of progressive significance or resignification (Cantoral y Farfán, 2003).

One way to study the use mof mathematical knowledge is to recognize or analyze the dependence of the context through three levels: the cultural, the situational and the significance; what he calls contextualized rationality principle. The cultural context gives pertenence to human groups because their dominance in the behavior and social interactions of the subjects is recognized; the situational context recognizes the influence of time, place and conditions where the mathematical activity is carried out, these conditions are determined by the problem or can be established with the design of learning situations; and the context that gives form and meaning to the mathematics at stake, we call it context of meaning. The ST explains the social construction of mathematical knowledge through the nesting model of practices (figure 1), which is composed of an organization of practices that accompany the use of mathematical knowledge and increase complexity at each level.

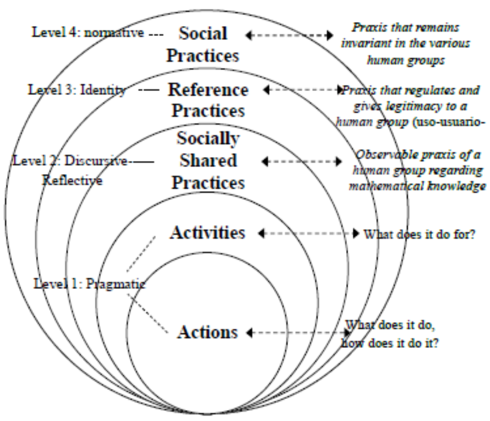


Figure 1 Nesting model of practices

Source: adapted from (Cantoral, Montiel y Reyes-Gasperini, 2015, p. 13)

In particular, we take the first level of the nesting model: pragmatic to qualitatively analyze the social construction of mathematical knowledge that is given, and from it infer the context of significance. The direct action of the subject (individual, collective or historical) before the milieu is analyzed by questioning from the “what does” and the “how does it”, in its relation to the mathematics at stake; and with the articulation of actions, response is given to the “what it does for”, configuring a culturally located activity (Cantoral, Reyes-Gasperini y Montiel, 2015).

Social construction of trigonometric knowledge

Montiel (2011) identified in a historical-epistemological analysis that the problem of astronomers to calculate inaccessible distances of non-manipulable objects (sun, moon, planets, etc.) was the emergency scenario of the trigonometric problem, which they solved by modeling macro (object) with the micro (model) in a geometric context. Therefore, it is recognized as the social nature of Trigonometry to the study and quantification of the non-proportional relationship ‘central angle-subtended string’, in the circle; which would be equivalent to the study of the non-proportional opposite-adjacent angle-leg ratio in the right triangle (figure 2).

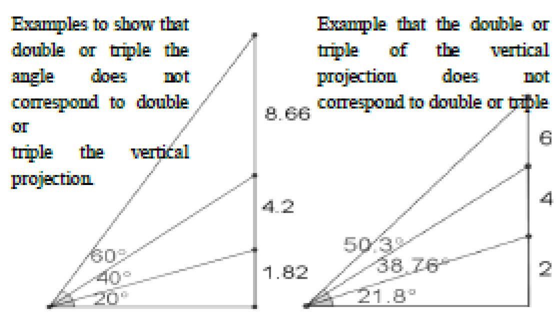


Figure 2 Trigonometric relationship
Source: adapted from (Cantoral, Montiel and Reyes-Gasperini, 2015, p. 17)

The adaptations for Trigonometry to be taught have established as a School Mathematical discourse: to study the relationship between the lengths of the sides in the right triangle.

Thus, solving an exercise or problem consists in giving the student a drawing of a triangle with sufficient measures to identify the data, choose the right reason for the situation, replace the data in the calculator and obtain a unique missing value, converting trigonometric knowledge only in an application of the proportional; and as a consequence devoid of the geometric context, which has caused, for example, the difficulty of not conceiving the variation of the angle because there is a case (drawing) that is not reflected that varies.

This teaching has allowed learning, but it has caused a didactic phenomenon that Montiel (2011) calls trigonometric arithmetization, which refers to the loss of the geometric process where the angle-leg ratio arises. The study with the right triangle is not the cause itself, but what is promoted by the student with it: a mathematical activity devoid of taking measurements, developing models (to scale or sketches) of triangles, making relationships between its sides and angles, and reflect if the calculations obtained are congruent with the triangle.

The learning that has been documented with this type of teaching admits the construction of a linear meaning (figure 3), both in students and in teachers: consider that the leg (the adjacent one in figure 3) and the angle grow or decrease in shape constant (Montiel and Jácome, 2014), as opposed to the non-proportional nature of the trigonometric relationship.

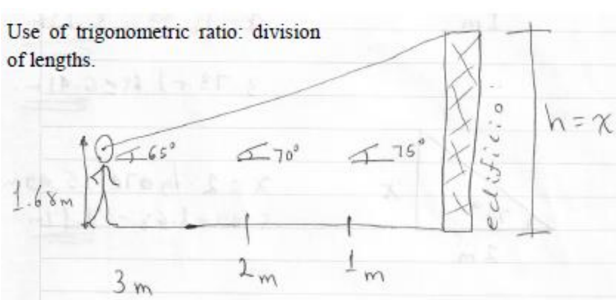


Figure 3 Significado lineal
Source: adapted from (Jácome, 2011, p. 126)

From the study of Montiel (2011), an epistemological hypothesis is configured for the social construction of the trigonometric, which has been the basis for various didactic-experimental studies, proposing that: studying its nature implies identifying the non-proportional of this relationship (the trigonometric ratio).

But analyze and quantify it with the proportional (trigonometric ratio), in mathematical activity of geometric construction. Hence, for the design or didactic analysis, we start from the following elements of social construction of trigonometric knowledge (Cantoral, Montiel and Reyes-Gasperini, 2015): (1) measure and reflect on proportionality, (2) build models (to scale or sketches), (3) model the passage from the macro (real object) to the micro (model) and (4) make relationships of the 'angle – length in the triangle or string in the circle'.

In the search to counteract this linear meaning, didactic-experimental studies have been carried out with students from the upper middle (Scholz and Montiel, 2015) and higher (Torres-Corrales, Montiel and Cuevas, 2015), where the most relevant thing was to identify that by integrating Geometric construction processes for the resignification of trigonometric reason, this is accompanied by various mathematical reasoning (empirical, arithmetic, algebraic and geometric) and occurs naturally, the articulation with other mathematical knowledge; reasoning understood as the ways of acting before a problem.

Ethnographic Method

Our study is qualitative, non probabilistic, and given the research problem in conjunction with the access and facilities that the university has provided to the project we opt for the ethnographic method (table 1), which we configure in five stages, organized in three moments.

Moment	Stage
I. Collection	1. Stage Documentation 2. Planning field work
II. Production	3. Field work
III. Analysis	4. Descriptive analysis 5. Qualitative analysis of mathematical activity

Table 1 Ethnographic research method
Source: built from (Geertz, 2006; Hammersley and Atkinson, 1994; Rodríguez-Gómez and Valldeoriola, 2012)

During the moment I, a documentation was carried out (stage 1) with the non-participant observation technique and analytical tools of the ST to indirectly study the mathematical culture through the review of documentary sources.

The purpose was to preliminary understand the knowledge (mathematical and disciplinary) related to the direct kinematic problem. Also, during the moment I, the field work was planned (stage 2) where we chose the techniques and designed the instruments to record the data during stage 3; In addition, we design a work plan and formats for consent and data processing.

At the moment II we carry out the field work (stage 3) where we use and adjust the designed instruments. With the participant observation technique (Hammersley and Atkinson, 1994) we study broad aspects of culture from its natural context (as a native does), and to record the data we use two instruments: notebook and field diary, the first allowed to document each class session and the second to reflect on the development of the topics discussed and the participants' actions.

Also, we use the conversation technique (Rodríguez-Gómez, 2016) in order to contrast what was observed. The modalities were: discussion group with which we generated a wide range of ideas, opinions and experiences around the object of study, and individual interview when it was necessary to approach and understand the assumptions of the person interviewed; for both semi-structured interview scripts were used.

The combination of techniques and instruments constitutes the triangulation strategy, which allows them to be compared and compared, providing the study of rigor and quality (Rodríguez-Gómez and Valldeoriola, 2012); To ensure the objectivity and ethics of the study, the field work was followed by two academics from the target institution: tutor, who gave methodological follow-up to the work plan, and co-tutor, who received in his Industrial Robotics classes a the principal investigator (first author), validated the interpretation of disciplinary knowledge and gave consent to make the registered information public.

The project is currently at the moment III, with the descriptive analysis (stage 4) the cultural and situational contexts were characterized by a dense description (in the sense of Geerz, 2006); and with the analysis of the mathematical activity (stage 5) the uses of trigonometric knowledge were obtained and inferred the context of significance, based on which we responded to the research question.

In this paper we delve into the moment III, in particular we show an example of the qualitative analysis of the mathematical activity of a robot with which we infer the context of significance and accompany it from the cultural and situational contexts.

Results

Cultural context

In stage 1 with the non-participant observation we review various sources to prepare the documentation: specialized engineering journals, some Internet sites (wikis, blogs, videos, etc.), Handbooks (disciplinary manuals) and books. From here we identify Mechatronics Engineering as a reference practice, as it will provide the engineer with identity and regulate his work in Robotics: he will be responsible for the synthesis of aspects of the functioning of the human body (Craig, 2006; Siciliano and Khatib , 2016) through the design and analysis of robots, through mechanisms, sensors, actuators and computers (Spong, Hutchinson and Vidyasagar, 2004; Saha, 2010).

In stage 3 with the participant observation technique, we documented the behavior of the students and the teacher for 55 hours through 42 notebooks, 4 field diaries and with complementary records (71 audios, 24 videos and 196 photographs). From here we identify that Mechatronics Engineering uses and builds various models to study the problems it solves: direct kinematics, reverse kinematics and speed analysis. In particular for the direct kinematic problem, where there was the greatest variety of models, these were used as representations to simplify, systematize and study the robot's movements through disciplinary and mathematical knowledge; and although they were drawings (without scale), they allowed them to relate and analyze some element of Robotics.

In this cultural context of the mechatronics engineer, for the purposes of our object of study, we identify three essential aspects: the circular movement, which is generated thanks to a rotational kinematic pair, the displacement by a prismatic pair, and the mathematical modeling process that is gives to model the transition from the macro (robot) to the micro (model).

In particular, the circular movement and the construction of diagrams, because they are part of the context of significance of the trigonometric found in historical-epistemological studies.

Situational context

Also during stage 3 with the participant observation we document some characteristics of the participants and their roles in the Industrial Robotics classes. The project was carried out in a Mechatronics Engineering community of the Technological Institute of Sonora (ITSON), a public and decentralized university located in northern Mexico. The field work was during the August-December 2018 semester with students of the 2009 plan who were studying Industrial Robotics, a subject located in the seventh of nine semesters, which is composed of a theory class (3 hours a week) and a laboratory (2 hours a week, operating robots operation).

47 students participated (42 men and 5 women), who were between 21 and 24 years old, and a tenured professor who taught both classes; The teacher has an academic training for a bachelor's degree, masters and doctorate in the same discipline and has working and teaching experience in that engineering field.

The theory was taught in two different classrooms equipped with a computer, projector, door with sensors that are operated with an electronic card and two air conditioners (they generate high levels of ambient noise). For the explanation of the classes the teacher used the support of the board in two modalities: written notes and projected notes of a presentation, while the students took notes in their notebooks and / or photographs.

The teacher's explanation (figure 4) was aided by body mevements (hip, shoulder, elbow, wrist and hand) to represent the movements of the robot. He also used four colored markers (black, blue, red and green) to emphasize the notes he made and to represent the movement of axes and linkages; in a consistent way the professor resumed the laboratory practices, assignments, previous sessions topics and some previous subjects for his explanations, in addition to mentioning the technical terms in Spanish and English.

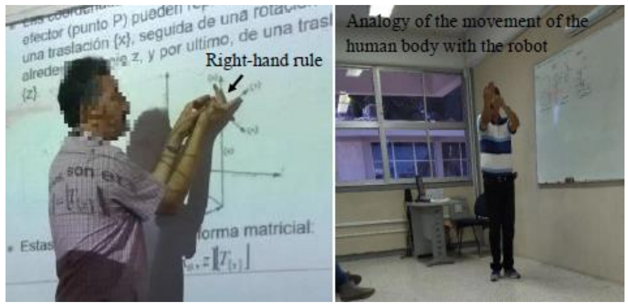


Figure 4 Explanations of the teacher in theory
Source: photographs of (field work, 2018)

The laboratory was taught in a classroom with three industrial robots of four, five and six degrees of freedom; equipped in accordance with safety regulations (for example, safety signs, smoke detectors and first aid kit).

In the laboratory class there were two behaviors: explanation and practice. In the explanation, the professor presented the content of the practice, what it is intended to achieve and comments at the technical level; the students attended the teacher's explanation, and some made comments and / or questions. In the realization, the students (individual or team) manipulated the robot through the teach pendant following the instructions of the manual under the supervision and evaluation of the teacher (figure 5).

Figure 5 Realization of laboratory practices
Source: photographs of (field work, 2018)

Consistently the students: (a) while a student manipulated the robot the rest of the team gave directions or suggestions to their partner in turn, (b) made comments between classmates to validate what they understood or resolve doubts before programming and executing any movement, (c) physically made the rule of the right hand before giving instructions, and (d) at the end of the session a different student performed the shutdown routine to return it to the geometric resting configuration indicated by the manufacturer.

In addition, all laboratory practices were conducted limiting its speed to a 50% of its maximum, in order to maintain student safety.

In this situational context of the mechatronics engineer in training, for the purposes of our object of study, we identify two essential aspects in the theory and the laboratory: the body movement to explain the movement of the robot, and the rule of the right hand that was used to differently even by the same person, because it depended on the physical conditions of the problem: a certain movement of the hand is more natural if it is an object embodied in a surface (2D, blackboard, book or notebook) or in space (3D, at manipulate the robot).

Mathematical activity analysis

Also, with the participant observation we document what the teacher and the students did to solve the direct kinematic problem. We take the case of the solution of the SCARA robot (robotic arm for selective trust assembly), through the six-step method, an adaptation and interpretation of the teacher (M. Herrera, personal communication, 22 / 10/2018) of the article by Denavit and Hartenberg (1955).

In steps 1 and 2 (figure 6) they developed pseudo concrete models (drawing and scheme) to select the variables of interest of the robot.

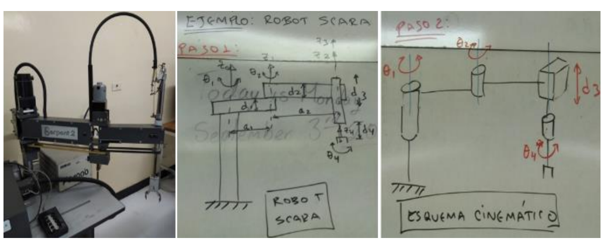


Figure 6 Steps 1 and 2
Source: (photographs of fieldwork, 2018)

In step 1 they articulated two reasonings: (1) the spatial, made the change from 3D to 2D for the drawing; and (2) graph, elaborated the drawing and identified that the robot has all the axes (z_0, z_1, z_2, z_3) parallel. While in step 2 they articulated the reasoning: (1) spatial, they made the change from 2D (drawing) to 3D (geometric figures) and pointed out the direction (turn or slip) of each pair; and (2) geometric, they represented the degrees of freedom of rotating pairs (θ_1, θ_2, θ_3) by means of a rectangular cylinder and for the translation pairs (sliding, d_1) with a rectangular prism.

And identified that the volume of Work generates a straight rectangular cylinder. For both steps they used the angle as quality (shape) in their dynamic character (turn).

Therefore, in steps 1 and 2 the construction of visual referents and modeling is manifested when they draw up the drawing and the kinematic scheme, and with them they model their movement, to perform the activity of identifying the axes, the quantity and types of pairs kinematics, and visualize the workspace; only the measurement is not given in the theory class, although in the laboratory class where the students took measurements with a flexometer and compared them with the robot's technical data sheet.

In steps 3 to 5 they developed new mathematical models: vectors, parameter tables and matrices of elements; that require establishing coordinate systems and calculating the resulting homogeneous linear transformation matrix. The validation of the mathematical result was carried out with the models elaborated in steps 1-3 and the Theory of Machines and Mechanisms to ensure that it was mechanically consistent with the movement.

In step 3 (which they also called a wire diagram) they articulated two reasonings: (1) the graph, assigned a coordinate system to each element systematically following the algorithm and the rule of the right hand.

With (2) metric reasoning, for rule 1 they assigned the z_i axis of each link with the direction of movement allowed in the pair, and for rule 2a they assigned the x_i axis as a perpendicular segment to z_i and z_{i-1} (figure 7).

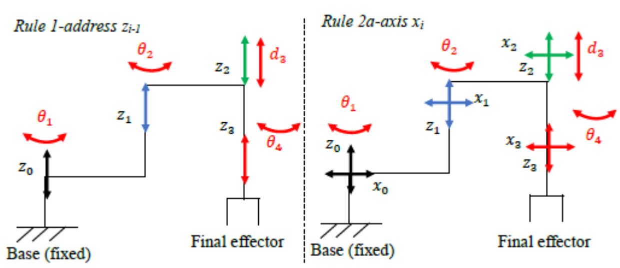


Figure 7 Rules 1 and 2a
Source: Our Construction

For rule 2b, they chose the positive direction of the x_i and z_i axes, indicating the individual movement of the pair, which indicated that it would facilitate the calculations.

For rule 3 they assigned the y_i axis forming a tri-rectangle trihedron with the right hand ruler: on the z_i axis the 4 fingers were upright, as the x_i axis turned the 4 fingers towards the palm of the hand and pointed like the y_i axis where the thumb pointed; finally for rule 4 they placed the origin at the intersection of the common normal between the axes (figure 8).

Therefore in step 3, the use of angle is given as a quality in its dynamic character; and the construction of visual referents and modeling is manifested when they elaborate the coordinate systems diagram because they generate a metric to study the problem and with it they model the direction and sense of the elements with respect to the adjacent element, to perform the activity of establish a particular kinematic configuration of the robot.

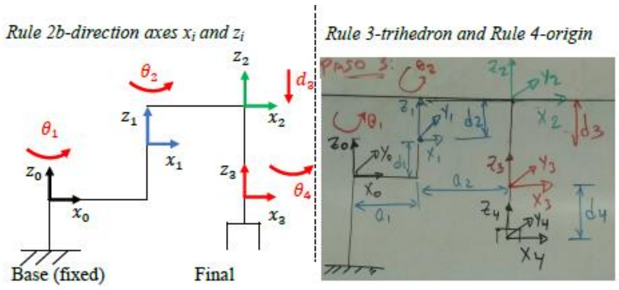
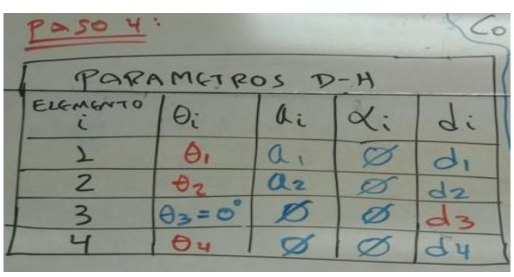


Figure 8 Rules 2b, 3 and 4
Source: (our construction and photography of field work, 2018, respectively)

In step 4 (figure 9) they articulated five reasonings: (1) the spatial, when they identified for each element and its adjacent, axes, angles and distances; (2) the metric, when establishing lengths by means of the axis-axis relation; (3) the graph, when they made relations between two adjacent links, for example, when the axes are parallel (collinear) the angle is zero and when the distance is cut it is zero; (4) the covariational, when they studied the angle-distance relationship of the elements across the axes; and (5) the quantitative, when they calculated the fixed or variable amount of the parameter recognizing its origin.



PASO 4:

PARAMETROS D-H

ELEMENTO i	θ_i	a_i	α_i	d_i
1	θ_1	a_1	Ø	d_1
2	θ_2	a_2	Ø	d_2
3	$\theta_3=0°$	Ø	Ø	d_3
4	θ_4	Ø	Ø	d_4

Figure 9 Step 4
Source: (photography of field work, 2018)

The kinematic torque angle (θ_i) was determined as the one formed between the x_{i-1} and x_i axes around z_{i-1}, and only exists when it does not coincide with x_i; the length of the element (a_i) was measured from the intersection of the z axis (i-1) with the x_i axis to the origin of the reference system of the element (i); the torsion angle of the element (α_i) was established as that formed between the z_{i-1} to z_i axes around the x_i axis; and finally the distance between pairs (d_i) was measured from the origin of the reference system of the element (i-1) and the point of intersection of the z axis (i-1) with the x_i.

Therefore, in step 4, the use of the angle is given as relation (x-axis, y or z) and quantity (variable), both in its static and dynamic character; static by the case study, when the angle is an inclination with respect to the adjacent and dynamic element because it changes with the movement of the robot.

Also, they made relationships of perpendicularity, parallelism, turns and displacements in the diagram of step 3, where the variable values were placed in red and the constants in blue; and they carried out the activity of identifying the value of the four parameters (two angles and two distances) of the kinematics of the problem and organized them in a table.

In step 5 (figure 10), with the algebraic reasoning they developed the matrices of elements taking up the value of the parameters of step 4, and the use of the angle was given as quantity (variable).

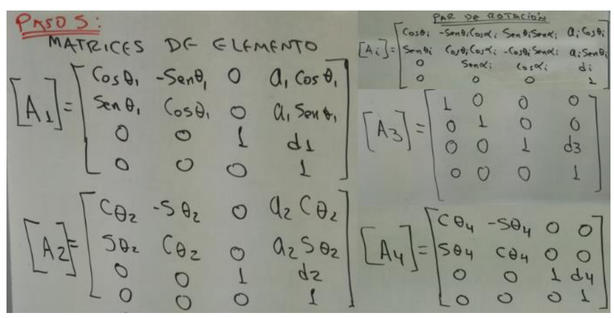


Figure 10 Step 5
Source: (photography of field work, 2018)

In step 6 (figure 11), with the algebraic reasoning they calculated the homogeneous linear transformation matrix from performing the operations with the matrices of elements in the order of the robot's movement, justifying that in the case of mobile systems the transformation matrix it is written from left to right.

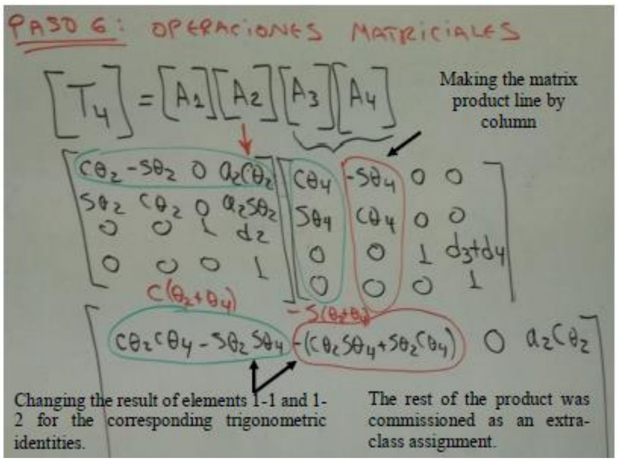


Figure 11 Step 6
Source: (photography of field work, 2018)

In particular:

– They started operations by the matrices [A_3] [A_4] and commented that since [A_4] is the identity matrix, the product was not required because it would give the same result, except element 3-4 where they added $d_3 + d_4$;
– They wrote the matrix [A_2] indicating that it was going down with an arrow to multiply it by the result of the matrices [A_3] [A_4], from which they made the product to obtain row 1, the rest of the operations were carried out as an extra assignment. Class;
– And the result of row 1 of the matrices [A_2] [A_3] [A_4] changed it to trigonometric identities justifying the need to simplify operations to avoid the lag between the response time of the control (must be faster) and the mechanical of the robot.

Finally, in step 6 they validated the resulting transformation matrix with the previous diagrams (step 1-3) to confirm that the mathematical result was congruent with the proposed kinematic configuration for the robot, that is, that the position vector be mechanically congruent with the movements. They also used the angle as relation and quantity (variable), both in the static and dynamic character.

With the particular kinematic configuration, in the static character they considered the angle as a scope in the total transformation of the base with respect to the final effector and with the dynamic one that can be variable by the movement of the robot.

Discussion

By doing a cross-sectional analysis of the six-step method to solve the direct kinematic problem, we can characterize the complete mathematical modeling process that Mechatronics Engineering does (figure 12).

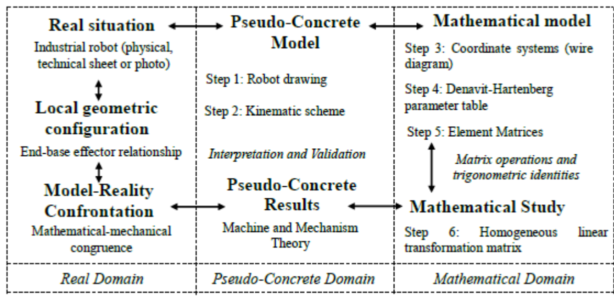


Figure 12 Mathematical modeling process of the direct kinematic problem
Source: built from (Rodríguez-Gallegos, 2010, p. 197)

In this process we recognize that there were three of the four elements of social construction of trigonometric knowledge that point out (Cantoral, Montiel and Reyes-Gasperini, 2015): build geometric models (sketches), model the transition from the macro to the micro and make relations of 'length-length and angle-distance of the robot elements through the axes'; only the measurement was not given as such because the data were given or established based on the Denavit-Hartenberg algorithm.

Of the elaborated models, we recognize as a geometric model the kinematic scheme (step 2), and although it was not to scale but a drawing of geometric figures (cylinder and prism), with this they established the type of movement allowed by the kinematic pair (turn or move) and identified the geometric configuration generated by the robot (a rectangular cylinder).

Although in steps 1-4 there was no use of trigonometric notions, actions and activities were manifested that allowed them to contextualize the problem of Robotics to the scenario of Kinematics, and later, in steps 5 and 6, to mathematize it.

In the problem of the SCARA robot we identify that there are four uses of the trigonometric notions to perform the activity of calculating the position and orientation of the final effector with respect to the base: (1) arithmetic of the sine and cosine ratios of the angle when dividing lengths to set the values of the rotation matrix; (2) metric of the angle-distance and distance-distance relationship when calculating the four parameters of the algorithm with the axis-axis relationship; (3) quantitative and algebraic of the matrices of elements when recognizing the origin and operating fixed amounts and symbolic variables; and (4) algebraic identities double an angle and Pythagorean by simplifying the operations performed by the control for the balance of the mechanical part.

By identifying these uses of trigonometric notions, we identify that the context of significance is the construction of visual referents to model the problem in space; where the principal aspect is the circular movement (or sections of this one) and the composition of several of these along with the displacements, their representation and mathematization. In this process the right triangle "implicit" is a tool to determine the position, which like the coordinate systems are not provided or have their elements assigned a priori as it happens in the Basic Sciences.

Although a particular kinematic configuration of the robot is constructed (step 3), it is considered that it changes as the robot moves, which admits to recognize the static character with the particular case and with the movement the dynamic character of the angle , which allows attention to be maintained in the angle - position relationship, and this in turn is linked to the arithmetic use of the trigonometric ratio.

The uses of the angle are given as form, relation and quantity in this problem of Robotics, but unlike the Mathematics subjects (figure 3), as a relation it is defined and defined with respect to the axis indicated by the algorithm and not only to the preset by the given triangle; and as a quantity it can be fixed, when studying a particular case, or variable when considering the movement of the robot.

In the construction of visual referents, spatial reasoning prevailed, with which they studied the robot and its elements, either by changing from 2D to 3D and vice versa (steps 1 and 2), or by making perpendicularity relationships, parallelism, turns and displacements taking the observer perspective indicated by the Denavit-Hartenberg algorithm, in conjunction with the right hand rule (step 4).

Also, with the fieldwork we identify that there is no single way to use the right hand rule, which allowed us to expand the documentation (stage 1) of the books of Physics and Linear Algebra: thumb points to the right (axis y), index up (z axis) and middle finger to the heart (x axis).

Conclusions

From the results of the participant observation, it was identified that to solve the direct kinematic problem, the Mechatronics Engineering community gives epistemic value to specific pseudo models, in contrast to what happens in the Mathematics subjects, where only the models are usually prioritized which include arithmetic, algebraic and analytical processes (Faulkner, Earl and Herman, 2019). Also, based on the results of the non-participant observation, we identify in these models the raison d'etre of Trigonometry as a Robotics tool: determination of the position in the circularity or circular sector. This implies movement, attending to particular cases (positions) and that gives a trigonometric ratio a context of broad significance.

Although we do not know the academic moment where the Mechatronics Engineering student develops the spatial reasoning that is used for the direct kinematics problem, it can be deduced that it is possible to acquire it through training because it is transferable and malleable to any stage of human development (Newcombe, 2010) ; Some tasks that encourage it are: symbolic representations (language, maps, diagrams, sketches and graphs), make analogies (similarities between phenomena) and gestures (move hands) (Newcombe, 2010). However, we identify in stage 1 that this type of reasoning is absent in the Mathematics subjects, where the trigonometric content to be used in the professionalizing subjects is addressed.

In that sense, mathematics may be playing an obstacle role instead of potentializing a necessary STEM (Science, Technology, Engineering and Mathematics) skill required (Lowrie and Jorgensen, 2017).

In the data collection there were episodes where we identify, both in the teacher and in the student, actions or arguments that allude to the transcendent nature of the trigonometric quantity (or in the case of students, to a non-linear nature), related to its handling in the circle. Hence, identifying the context of significance where trigonometric reason is put into use provides us with elements to redesign School Mathematical discourse, as it points to possible situational contexts (designs) that do not favor or admit linear meaning (or the illusion of linearity, in the sense of De Bock, Van Dooren, Janssens and Verschaffel, 2007) when working with the relationship between an angle and the string or leg that subtends. We are analyzing these episodes in depth, as a way to support the uses and context of significance that we have identified and characterized with the SCARA.

In studying the uses of trigonometric notions from the Socioepistemological Theory we problematized the questioned mathematics what and how it is constructed and transmitted in particular scenarios; in this way mathematics was made part of the didactic phenomenon and the responsibility was only depersonalized only to the teacher or the student of the difficulties associated with their teaching and learning.

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Teaching thermodynamics in Engineering based on competences

Enseñanza de la termodinámica en Ingeniería con base en competencias

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Abstract

This paper shows an analysis of the activities carried out in the classroom on topics which involve thermodynamics. This proposal contemplates methodological aspects and competences of the subject on basic topics that involve the understanding of the phenomena involving the first and second laws of thermodynamics. The proposal aims for the student to develop a cognitive process which can be used as a tool to help improve their learning. This process is characterized by a feedback between the implementation of the changes concerning the teaching-learning process and the evaluation process of the achieved learning. The analysis of the evaluation is based on the phenomena that involve fundamental concepts such as energy, work and heat, as well as the need to develop assessment instruments according to the competence that the student needs to develop. The results show a significant progress, in terms of the level of learning achieved, by making an annual comparison of school performance based on a competency scheme.

Teaching, Thermodynamics, Competency

Resumen

El presente trabajo muestra un análisis de las actividades realizadas en el aula sobre temas que involucran a la termodinámica. Esta propuesta contempla aspectos metodológicos y de competencias de la materia sobre temas básicos que involucran la comprensión de los fenómenos que involucran a la primera y segunda ley de la termodinámica. La propuesta pretende que el alumno desarrolle un proceso cognitivo que pueda ser usado como herramienta que ayude al proceso de mejora en cuanto a su aprendizaje. Este proceso se caracteriza por una retroalimentación entre la implementación de los cambios referentes al proceso de enseñanza aprendizaje y el proceso de evaluación del aprendizaje logrado. El análisis de la evaluación se realiza con base a los fenómenos que involucran a los conceptos fundamentales como energía, trabajo y calor, así como en la necesidad de elaborar los instrumentos de evaluación de acuerdo a la competencia que el alumno necesita desarrollar. Los resultados encontrados muestran un avance significativo, en cuanto al nivel de aprendizaje logrado, al realizar una comparativa anual de aprovechamiento escolar basado en un esquema de competencias.

Enseñanza, Termodinámica, Competencias

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Introduction

In the development of the teaching practice, lack of analysis and reasoning of significant knowledge is manifested daily in students; memorization has been strengthen, largely replacing reasoning, fractioning learning on small islands, without relating the contents in a scientific way.

This pedagogical breakdown, with the development of skills and competences, leads the teacher and the student to an uncertain pedagogical process not in accordance to the needs of the labor market. Therefore, the model focused on competencies considers important aspects towards the student, such as: focusing on the student the responsibility of building and structuring their knowledge, leaving teachers the role of facilitators, guides and motivators of student learning, likewise, that of achieving coherence between the curricula and the training processes which involve the teaching-learning process, and that of obtaining a balance between the theoretical teaching activities with the objective of reaching the required skills and competencies of the student in their professional training and consequent labor insertion. It is also essential that students develop reading abilities that allow them to understand knowledge in all its magnitude and also incorporate a sense of social responsibility.

In this pedagogical context, and given the challenges of current education, it is believed that competences can be grouped in 3 domains: training and personal development, communication, and development of scientific thinking.

Selected knowledge, specific skills and values reflected in professional attitudes and behaviors concur during the development of the competences. For this, we carried out a pedagogical strategy which begins with the learning process in the field of thermodynamics; this was complemented with other techniques to ensure that students acquire the competence that the subject requires in order to define the areas in which the professional develops, thus delineating the skills from the domains of the subject.

Development

In the development of the aforementioned competences, it is necessary to recognize that the strategy, method, techniques and assistance must be focused on student learning, so inherently the teacher must surround the learning process with the necessary scientific information with an appropriate pedagogical strategy.

That is why the teaching-learning process is considered as a set of dynamic interactions which involve the teacher and students, where the former has as main purpose integral formation, including the knowledge of the subject, the skills for the teaching process and attitudes, all of them aimed at the student's own cognitive process, as well as an organized management which includes the knowledge acquired. To develop a competence, it is necessary for the teacher to guide by creating situations focused on reality within the work context, using strategies that give the best results to exchange, share, confront and debate ideas, making students form new structures. It is important to mention that the strategy to be used should consider reflection as an important part to deal with practical problems and thus face the discrepancy between reality and what was expected. When teaching with reflexive activity, not only do students get used to understanding the concepts, but they contribute new meanings and structure their ideas, analyzing the processes and expressing their thoughts in a better way.

For teaching the subject of thermodynamics, we chose to apply the cooperative learning strategy. It is an organized and structured method that includes team building activities, the preparation and formal presentation of the information acquired, practice in solving problems and the evaluation of each student. It is important to mention that the progress achieved by the students is very significant, since it encourages students to be self-taught, to be more sociable and that they try to generate their own learning in terms of the subjects they do not understand. Cooperative learning promotes collaborative work because it allows for better relationships between students, those who learn better, feel more motivated and, in addition, make their social skills much more effective by being part of a cooperative group.

It is relevant to point out that each of the teams strives to obtain recognition for the work done by each member, which translates into a noticeable improvement in their school performance.

Likewise, individual responsibility develops from the moment in which each of the members knows that they will have to be evaluated in relation to the proficiency of the subject presented. The team members prepare, practice together and explain to each other the topics that are not understood, since the grade of the team is based on the progress demonstrated by the students, a situation that forces them to pay more attention when the topic is explained by the teacher.

Result analysis

It is important to mention that not all work group is a cooperative learning group, since there are still traditional work groups in which the most skilled students assume leadership and benefit from the team experience; also there are students who only perform functions such as photocopying, drawing or capturing texts. In these teams, cooperative learning is forgotten and becomes very personal. This inappropriate distribution of activities usually causes problems such as struggle for power, division, distrust, selfishness and segregation of the group.

This type of situations is often reflected in the development of professional activities and is the reason why many people still do not believe in teamwork. That is why it is important to be aware of how much this happens, since it implies individualistic situations and there is no relationship between the objectives pursued by each student, because their goals are independent of each other. For cooperative learning, the action of cooperating represents the fact of working together to achieve shared goals and, for this, teamwork has very positive effects not only on academic performance, as evidenced by the fact that interpersonals relationships develop very favorably, as they increase respect and solidarity, as well as feelings of obligation and help.

Student name								
Date	**Subject**		**Total points**		**Points earned**		**Group**	
Indicators	**Autonomous (10)**		**Outstanding (9)**		**Satisfactory (8)**		**Deficient (7)**	
Evaporator 2.5 points	Cognitive area	Knows the evaporation process where the refrigerant changes phase, as it absorbs heat from the space to cool.	Cognitive area	Knows the evaporation process, but doesn't know the difference between superheated vapor and saturated vapor.	Cognitive area	Has little knowledge of the evaporation process, and confuses superheated vapor and saturated vapor	Cognitive area	Total ignorance of the evaporation process.
	Procedural area	Perfectly locates the evaporation point on the Mollier diagram, and uses correctly the thermodynamic tables to locate this point	Procedural area	Does not locate the point in the region of saturated vapor in the Mollier diagram, which is not correct and leads to misuse of thermodynamic tables	Procedural area	Does not know how to plot in the Mollier diagram	Procedural area	Does not know anything about Mollier's diagram
	Attitudinal area	Performs correctly the operations for the calculation of the COP, in addition to interpolating the functions in the thermodynamic tables.	Attitudinal area	Does not use the interpolation calculations correctly and miscalculates the COP	Attitudinal area	Does not know how to interpolate, which leads to the wrong calculation of the COP.	Attitudinal area	Des not know how to interpolate nor the COP formula.
Compressor 2.5 points	Cognitive area	Knows the compression ratio and perfectly locates the pressure in the suction and the pressure in the discharge.	Cognitive area	Knows the compression ratio, but does not know that the suction pressure is sometimes less than the evaporation pressure	Cognitive area	Does not know if the discharge pressure in the compressor should be higher than the room temperature.	Cognitive area	Has no knowledge of the compression process, does not understand that the fluid cannot enter the compressor as saturated vapor.
	Procedural area	Uses thermodynamic tables correctly in the superheated vapor region.	Procedural area	When performing the operations, locates the suction pressure in the compressor with difficulty on the Mollier diagram.	Procedural area	Has difficulty finding the compressor suction and discharge point in the superheated vapor table.	Procedural area	Total lack of knowledge of thermodynamic tables.
	Attitudinal area	When using the thermodynamic tables performs triple interpolation correctly.	Attitudinal area	Finds it difficult to perform triple interpolation.	Attitudinal area	Uses the thermodynamic table and perform triple interpolation incorrectly.	Attitudinal area	Does not know how to perform triple interpolation.
Condenser 2.5 points	Cognitive area	Knowledge of the change of phase of superheated vapor to subcooled liquid, correctly applies the condensation heat formula..	Cognitive area	Does not understand the process of de-heating, but does place the points on the Mollier diagram.	Cognitive area	Does not know phase change, locating the point at the condenser outlet as a vapor-liquid mixture.	Cognitive area	Total lack of knowledge of the process, locating the compressor inlet as saturated vapor.
	Procedural area	Uses the tables for condensation vapor calculations correctly	Procedural area	Confuses the regions of superheated vapor and saturated vapor for the calculation of condensation heat.	Procedural area	When interpolating, confuses the use of thermodynamic tables.	Procedural area	Has no idea how to use the thermodynamic tables for the calculation of condensation heat.
	Attitudinal area	Uses the interpolations correctly and applies the condensation heat equation correctly	Attitudinal area	Confuses which table to use to interpolate	Attitudinal area	Has problems to interpolate and confuses which thermodynamic table to use.	Attitudinal area	Does not know how to interpolate and what table to use.
Expansion valve 2.5 points	Cognitive area	Knows the iso-enthalpy process and also the quality of the refrigerant.	Cognitive area	Does not understand why it is necessary to know the quality of vapor.	Cognitive area	Does not know where the point is located at the outlet of the expansion valve.	Cognitive area	Ignores the iso-enthalpy process, and locates the outlet of the expansion valve as saturated liquid.
	Procedural area	Perfectly locates the points of the expansion valve in the Mollier diagram.	Procedural area	Uses the thermodynamic tables for the location of the points incorrectly.	Procedural area	Calculates de refrigerant quality incorrectly	Procedural area	Does not know the location of the points in the Mollier diagram, has no idea of the use of thermodynamic tables.
	Attitudinal area	Uses the thermodynamic tables correctly to calculate the quality.	Attitudinal area	Confuses the interpolation, but does get the points for the calculation of the quality of the refrigerant	Attitudinal area	Has a vague idea regarding the use of the equation of the calculation for the refrigerant quality	Attitudinal area	Does not know how to interpolate what is necessary to find the quality of the refrigerant.

Table 1 Rubric used for the evaluation of a refrigeration system
Source: Prepared by the authors.

The results achieved with the implementation of the competency approach can be discussed from different perspectives, the most relevant being the following: In relation to the training modality, it can be indicated that by implementing the competency method it is possible to clearly define which strategies, methodologies and activities should be used by the teacher so that students can reach the competences and abilities which obviously facilitate the evaluation process.

Regarding the students, there was an increase in their direct participation during the learning process. Approximately 30% of the teaching hours correspond to activities carried out by the students themselves. During their development, they expressed approval of the activities designed, since they could better visualize what they are capable of doing. The evaluation system was more varied and adapted to the new conditions, in which the relevant point is to check the achievement of competencies. A diverse range of assessment instruments were available, such as essay tests, laboratory work, reports, collaborative work, etc., which allow for a better decision regarding the passing or faling of a particular student in each unit, depending on whether or not they have developed the defined competencies. Table 1 shows a rubric used to evaluate thermodynamic concepts of a refrigeration system.

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Conclusions

The student has to know the professional and labor field in order to develop the skills and competencies essential in their professional development.

The development of competences is strictly related to the pedagogical strategy that focuses on the development of the student's scientific thinking, leaving behind the reduced vision of memorizing isolated and meaningless concepts.

The concrete expression of the development of the process-learning has to do with insertion success in the labor field. The dialogue between those who integrate and act in the learning process will be effective as long as it addresses and links capacity development, discipline, values, and cognitive processes which form and forge professionals capable of analyzing the circumstances and transform them into cognitive initiatives that lead them to professional success. The teacher as facilitator and generator of learning must master the scientific field of their area and propose the most appropriate pedagogical strategy for the student to develop skills and competencies.

Learning, assets and knowledge, when they are the product of joint work, collective and individual analysis, have more possibilities to build paradigms and projects that raise the quality of learning based on concrete-collective reality.

Future work

In a future work it is essential to systematically record the evidence which allows us to analyze and evaluate the progress attained.

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AppPECS: Mobile Application for Children with Autism Spectrum Disorder

AppPECS: Una aplicación móvil para niños con trastorno del espectro autista

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Abstract

The study of treatments for children with autism and interventions through educational games is growing because researchers have seen an acceptance by users with autism spectrum disorder in this type of applications. Allowing this type of users to acquire and develop new skills such as digital, the development of writing through the use of the keyboard, as a means of communication and a mechanism of reinforcement in sociable aspects. Taking into account the benefits of using games through mobile applications in the treatment of targeted therapies in children with autism spectrum disorder, a mobile application has been developed to obtain an experience that interactively stimulates children for the purpose of Reinforce areas of learning development, such as repetition of activities (socialization), concentration, reinforcement of short-term memory, order and development of kinesthetic skills through the use of digitization. This project was applied in the Unidad de Servicios de Apoyo a la Escuela Regular No. 21 (USAER) instance of Special Education, dependent on the Secretaría de Educación Pública de Hidalgo.

Digital skills, Autism, Mobiles application

Resumen

El estudio de los tratamientos para niños con autismo e intervenciones a través de juegos educativos está en crecimiento debido a que los investigadores han visto una aceptación por parte de los usuarios con trastorno de espectro autista. Lo anterior permite a este tipo de usuarios adquirir y desarrollar nuevas habilidades como pueden ser las digitales, el desarrollo de la escritura mediante el uso del teclado como un medio de comunicación y un mecanismo de reforzamiento en aspectos sociables. Tomando en cuenta los beneficios del uso de juegos mediante las aplicaciones móviles en el tratamiento de terapias dirigidas en los niños con trastorno de espectro autista, se ha desarrollado una aplicación móvil para obtener una experiencia que estimule de manera interactiva a los niños, con la finalidad de reforzar áreas de desarrollo del aprendizaje como es la repetición de actividades (sociabilización), concentración, el reforzamiento de la memoria a corto plazo, el orden y el desarrollo de habilidades kinestésicas mediante el uso de la digitalización. Este proyecto se aplicó en la instancia de Educación Especial de la Unidad de Servicios de Apoyo a la Escuela Regular No. 21 (USAER), dependiente de la Secretaría de Educación Pública de Hidalgo.

Habilidades digitales, Autismo, Aplicaciones móviles

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Introduction

Autism spectrum disorder (ASD) is a general term that describes a series of individuals who have atypical behaviors in two diagnostic settings: social communication and restricted or repetitive behaviors (A.P.A., 2013). It is also associated with language delays and intellectual disability in a large proportion of cases (Fombonne, 2005).

Atypics in social interaction can manifest as difficulty in understanding nonverbal behavior (Mundy & Neal, 2001), and understanding the thoughts, beliefs and intentions of others (Baron-Cohen, Leslie, & Frith, 1985), and peer relationships (Calder, Hill, & Pellicano, 2012). The domain of restricted and repetitive behaviors can manifest as a need for uniformity and routine, or as an inability to generalize information (Leekman, Prior, & Uljarevic, 2011).

Advances in digital technology can contribute to broadening the focus to educators, health professionals and others in the integral development of children with ASD (Pontes, et al., 2019). Several investigations have suggested that computer assistance can be used to teach some skills to children with ASD, such as the one proposed by Pennington (2010), which suggests that computer assistance can be effective in teaching academic skills, specifically as literature to students with ASD (King, Thomeczek, Voreis, & Scott, 2014).

Within the technology, there is mobile technology such as smartphones or tablets, the latter, due to its technical characteristics, facilitate some tasks for users besides communication, some of these are: as assistants to individuals with ASD in the academic area, in the reinforcement of social areas, in the modeled video, as reinforcement of language therapies, in the development of fine motor skills, as visual support, in life development skills, in the organizational capacity and in increasing independence.

In summary Cantabran (2019) indicates that technology, in this case the mobile, is an effective communication strategy in the face of an emergency situation between external elements and the autism patient.

Using the technological capabilities that tablets provide in individuals with ASD, the use of the AppPECS application, based on the Image Exchange Communication System (PECS), which is a digital form of Alternative communication developed to teach children who have limited speech, in order to strengthen some skills (Bondy & Frost, 1994), taking advantage of the fact that mobile devices are a bridge of communication in most autistic children, allowing their language progresses little by little as it affirms (Hill & Frith, 2003).

Mobile technology has penetrated education and through this device students with ASD develop or strengthen certain capabilities such as: communication, digitization skills, language, writing through a keyboard, among others (Law & Neihart, 2019). It is essential for an autistic child to maintain interest in what he learns because they are easily distracted, but with the help of mobile device technology such as iPads® they can focus their attention, motivating them to develop activities that strengthen their skills. Due to the display characteristics of this device, it becomes one of the strengths (Schmidt & Heybyrne, 2004) and the use of touch technology, that is, touching and dragging objects in the screen environment, allowing the development of digital skills because some people with autism find that writing on paper is an aversivity, so they prefer to use a touch screen or keyboard for written expression (Kluth & Danaher, 2010).

Due to the variety of multimedia elements, children with ASD are conducive to the identification of emotions as seen in (Nieves, Hamburger, Vargas, & Escobar, 2019), through graphic and interactive support arousing interest, such as that is proposed in this work.

Among the contributions that an iPad® presents, there is the increase in attendance in children with ASD, so it has become a popular device for education in students with these neurological characteristics; This is due to the particularity of having a touch screen, personalization in educational materials and a wide variety of educational applications (Neely, 2013). The versatility of the device is one of the aspects that gives the possibility of integration with children with ASD at work. This can be observed in the research proposed by (Murdock, Ganz, & Crittendon, 2013) where its use is directed towards strengthening the ability to play.

In (Neely et al., 2013) it is used to increase academic participation; in (Lorah et al., 2013), as a voice generator. Kagora et al. (2013) provides a review of the literature on the use of iPads® and iPods® in individuals with developmental disabilities. The review identifies 15 articles that show that these devices have been used for academic tasks, communication teaching, leisure skills development, among others. Taking into account these advantages of technology, the portable nature and attractiveness of iPads® and its easy-to-use touch screens, they provide instant gratification for children with ASD.

Due to the benefit of mobile applications developed on an iPad® platform or on any other touch device for children with ASD in their special learning process such as those mentioned in (Weng & Bouck, 2019); (Parsons, Wilson, & Vaz, 2019). This work aims to demonstrate the use of the AppPECS application, which is its own mobile application, developed at the Polytechnic University of Tulancingo by students of the Computer Systems career, aimed at strengthening digital skills and using semantic fields for language strengthening through the use of constructs to children with ASD in a limited semantics. The application software engineering was done by university-level students applying an operation construction methodology that is based on the plan-do-verify-act cycle.

Through this period, the specifications of the psychologists and pedagogues were obtained to carry out the design and construction of the solution taking as a central element the use of pictograms, taking advantage of the visual capacity that children with ASD have and thus adapting visual elements that facilitate the activities that were dictated by specialists. Research questions focus on analyzing whether a mobile phone application, designed specifically for children with ASD, (P1) can encourage learning and help improve some of their fundamental skills, such as language and social skills. In addition, we have tried to explore the ability of the mobile application to improve the learning process, all in an interactive and playful way so that it attracts the attention of children. This type of application should strengthen the child's therapy process to maintain attention and iteration with the health professional (P2) by identifying the quality of work time that is had with the child during the use of the application.

Finally, from a point of software engineering the design characteristics are evaluated, that is, if it is applicable in an easy and intuitive way for use by the child with ASD. For the appraisal of the application, an experimental design was applied in five children, working together with the Unit of Support Services to the Regular School (USAER 21) of Hidalgo that allowed access to the program of children with Special Educational Needs (NEE) to have the opportunity for children with ASD characteristics to use the AppPECS as an element of gamification as proposed in Godoy (2019), that is, the way to use game-based mechanics, aesthetics and thinking of the game, this, in order to motivate people, promote learning and solve problems.

Methodology

For the development of AppPECS, the requirements were raised based on the review of research papers related to the usability of mobile applications in children with ASD, in addition to interviews with USAER 21 specialists and the observation that during 8 months The work carried out by therapists (psychologists and pedagogues) was carried out in the field where the treatment of children with ASD was carried out. Prototypes of the work were carried out to show the previous designs and the explanation of how the functionality would be finally the coding was done in a programming language for the construction of the application, we worked in the integration environment xcode®.

The application was used exploratoryly in five children with ASD examining the effects on the intervention through the use of the AppPECS by specialists in the children selected directly to examine the effectiveness of the application, based on the results of the previous evaluations (Yee, 2004) such as those shown in the results section and thus iteratively improve the final version. In the following sections the implementation methodology is detailed.

Participants

For the evaluation with the end user, five students were selected according to the specification of the number of stakeholders required to evaluate a mobile application (it is proposed that it be made from 5 to 10 users) Kaikkonen, Kekäläinen, Cankar, Kallio, & Kankainen, 2005.

The application was used by children with ASD and the data that originated was recorded in a data container housed in the device. For example, the subject they worked on, the duration and number of movements were recorded according to the activity carried out. The children involved in the test have been in a therapy process between 12 and 18 months. The grade of ASD has been diagnosed by the USAER 21 specialist based on a previous diagnostic process, most of them show problems with communication, language and learning skills. The criteria used for the evaluation of the application, was based on the age of the users and the level of learning disability. In the following sections a description is made of the phases that were carried out for the construction and release of the application.

Process

Through multidisciplinary work sessions formed by psychologists and education specialists, both functional and non-functional requirements of users were obtained. Presenting the types of skills that you want to strengthen in the end users, such as: the identification of words, the reinforcement of immediate memory, the identification of images and colors, ordering of figures, use of sequences for social interaction, traceability of figures by using image coloring and reading. For the presentation of the requirements it is important to mention that:

Primary users are children with ASD and their caregivers are secondary users.

The use of the scenarios depends on the cognitive abilities of the users.

Demand 16 scenarios, with different activities that help to reinforce a specific skill. In addition to obtaining the metric of successes and working times in each of the options. The therapist can see the section where the work information of the end user is stored individually and together. And also, the activities can be selected at random, that is, there is no circuit of activities as such.

For the definition of both functional and non-functional requirements, they were segmented into priorities (high and low) in order to give a hierarchy in the application development process, in the following sections both segments are detailed:

High priority functional requirements. They include activities that help end users to develop or strengthen the fields of sociability, written communication, immediate memory, sequence of orders, drawing and coloring of figures, in addition to developing the ability to concentrate; in order to develop competencies in daily life and thus have a reinforcement in achieving it. In addition to motivating the child with ASD to carry out the activities, as well as establish a feedback on them.

The low priority functional requirements allow to customize the activities of the end user and have a historical record of the activities, time, successes and dates of work. This allows to have elements for the therapist to work in the new sessions reinforcing the activities not yet reified in the child with ASD.

For high priority, over non-functional requirements, the application must be compatible with iPad® devices and iOS operating system. In this way, making the usability of the activities attractive to the end users as mentioned in (Schmidt & Heybyrne, 2004).

One of the characteristics of importance in the construction of applications for this type of users is that it should not contain distracting elements such as sounds or buttons; In addition, it must be appropriate for the age of the participants. The reason is because the user must be kept focused on the purpose of the ability to reinforce or generate.

According to ISO 9126, the usability feature is defined by "The ability of the software product to be understood, learned, managed and attractive to the user, when used under specified conditions" this is subdivided into four basic features: 1) Understanding: "the ability of the product to allow the user to understand if the software is suitable and how it can be used for specific tasks and conditions of use". 2) Learning: "the ability of the software product to allow the user to learn". 3) Operability: "the ability of the software product to allow the user to operate and control it". 4) Attractiveness: "the ability of the software product to be attractive to the user".

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Taking into account the four previous characteristics, a series of activities were designed based on the ability of children with ASD to acquire new skills independently with computer technology as documented (Pennington, 2006) and (Roschelle, Pea, Hoadley , Gordin, & Means, 2001), in addition to allowing to generate stimuli, correctly reinforce responses and demonstrate errors under the strict control of the caregiver.

Davis et al., Recommend that the specific factors that should be taken into account when designing learning environments for these types of users in order to improve their strengths and reduce the need for skills that are difficult for them to develop or carry out, they are tasks that are consistent, predictable and gradually introduce novel elements (Weiss, et al., 2011). Taking as reference to these authors, the lifting of the requirements and making use of the PECS concept, the application has been developed so that users can communicate their wishes or needs as indicated in (Bondy & Frost, 1994).

Once the application is finished, it was implemented on the iPad so that users with autism will carry out their recreational activities and strengthen skills such as: the development of their digital capabilities at first sight and other skills described in the following sections.

In the process of design, development and evaluation it was necessary to integrate an interdisciplinary team, involving close collaboration between the humanities and technology areas, working together as design partners. One of the challenges was to convey the therapeutic objectives of the application and formulate them in specific recommendations for its creation. The design team assisted in determining the details of the project, and the programmers had to write code to produce the desired results. A specific example of this process was the need to ensure that each application scene seemed different, avoiding boredom or mechanization of responses by repeating activities.

Description of the application and activities

AppPECS is an interactive software, aimed at children and young people with ASD, which reinforces the verbal process, the use of immediate memory, the socialization of certain behaviors and the use of their digital skills.

The application consists of 16 activities that are presented in the following sections. Due to the delay or partial lack of oral language presented by children with autism, there is a need to compensate for this failure through alternative modes of communication such as pictograms, which, as will be seen in each of the actions, are used to recreational and learning purposes.

In Fig. 1 there is a screen for the validation of the user with the option of registering for the first time or giving access to the student in order to have an individualized registration of the child with ASD and follow up on their activities.

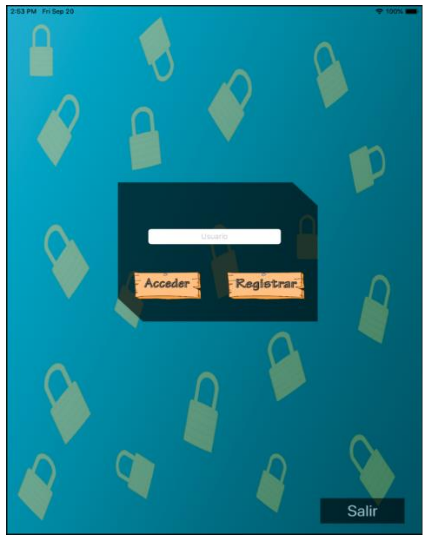

Figure 1 Registration screen to access the application as a user
Source: Self Made

Fig. 2 shows a view that represents the menu of options that the therapist can suggest as a guide in the work session.

Figure 2 Section for selecting options for the activity to be carried out
Source: Self Made

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Because people with ASD have difficulty interpreting social cues or their behavior is not as expected in situations of daily life and because they are unaware of the consequences of their actions or the difficulty of understanding how their behavior affects others, It makes use of the concept of social narratives, which has been used to mitigate these deficits. These narratives tell step by step (with simple texts and figures) how to act in real life situations (Gray, 2000).

Through the activities shown in Fig. 3-4, the concept of social narratives is implemented, that is, interventions that describe social situations in some detail, highlighting the relevant signals, offering in this case two instances that are the sequences of Go to school and bathe. They adapted to help students adjust their routine changes and accommodate their behaviors based on the social and physical signals of a situation.

The games to complete the word were designed with the intention of developing the ability to form words, comprehension, and identification of how the symbol displayed on the device is written, in addition to promoting the ability to use the keyboard.

The vowels are an integral part of the learning process of written reading in all people. For children who have ASD, having limited verbal abilities does not achieve the interaction of vowels with consonants, therefore the articulation of sentences is difficult. The use of a word and correspondence with the object and / or symbol allows the development of an oral language in the child as well as a linguistic skill.

Figure 3 Exercise sequences of activities before going to school
Source: Self Made

Figure 4 Exercise that indicates the sequence of activities when bathing
Source: Own Elaboration

Because some autistic children make efforts to accommodate their sensory and visual motor skills on paper, some students with autism fail to make these accommodations successfully due to the speed of writing and readability. For some students with ASD, touch-screen technologies, scanning and voice-to-text technologies can offer handwriting alternatives that allow you to generate written texts independently, but in a digital format (Coffin, Myles, Rogers, & Szakacs, 2016).

Often you can use your finger to create letters / words / phrases that are displayed on the screen without holding a writing element, which allows the student to develop the kinesthetic sensation of letter formation, this can also be achieved with The application shown in Fig. 5 which is a drawing application, that is, this activity helps students with ASD to understand the traces that are made on paper and that make sense.

In addition, it allows to develop a stimulus in the fingers while motivating the practice of their fine motor skills in other areas such as handwriting and the use of a keyboard.

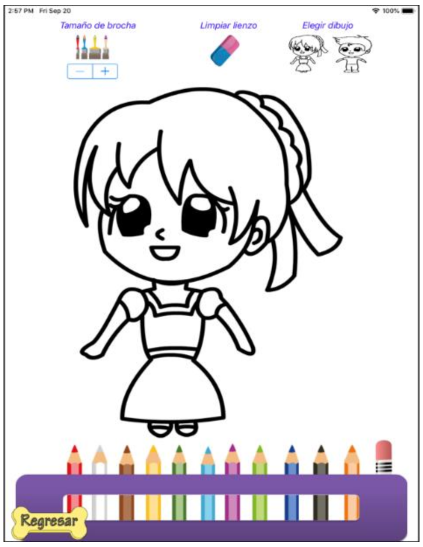

Figure 5 Colored area
Source: Self Made

Another session is the assembly of Tangram, which contains 9 forms as shown in Fig. 6 to assemble (House, Swan, Elephant, Chicken, Rabbit, Number 1, Letter A, Dog, Triangle). In which, by means of a guide drawing, it tells the student with ASD which piece should be placed and where. The application captures the number of movements the child makes and the time it takes to achieve the figure.

The pieces as seen in Fig. 7 have characteristics of color and various geometric shapes, which can reinforce concepts such as: circle, square, triangle, pentagon and rhombus.

The Tangram has the ability to improve various skills, such as imagination, spatial visualization, logic, concentration, spatial geometric thinking and knowledge of mathematics (Greczek, Kaszubski, Atrash, & Mataric, 2014). During the game the child drags the figure with his finger to the right place, when the piece is in its place, the puzzle is covered, at that moment a screen describing the achievement of the activity is displayed, together with the number of movements registered and the times of having obtained the result.

There are several levels of complexity depending on the form, so that the child with ASD does not lose curiosity and avoid stress, so the level of armed tangram is indicated by the therapist.

Figure 6 Tangrams set
Source: Self Made

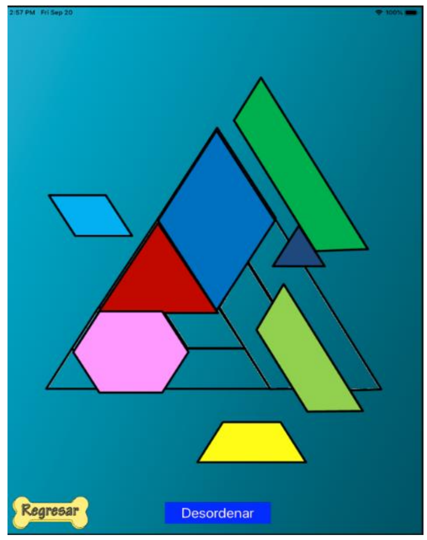

Figure 7 Messy Tangram example
Source: Self Made

This activity is reinforced with the memo set as shown in Fig. 8, which presents different levels of complexity ranging from 4, 16, 32 and 64 images. The purpose is to work with fine motor skills and your immediate visual and memory ability.

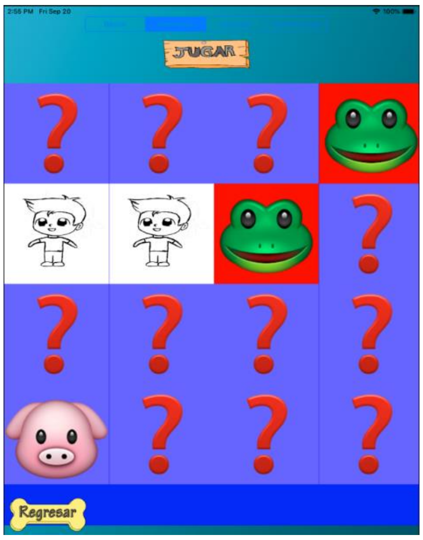

Figure 8 Memorization game
Source: Self Made

In each of the activities the name of the child, the beginning and end of the activity, as well as the number of movements performed in the activities are recorded, such as: the arrangement of figures and sequences as shown in Fig. 9, according to the demand that in the study of (Cisnero, Juárez-Ramírez, & Figueroa, 2016) indicates, where it is mentioned that the games of children with ASD do not provide an analysis of data or visualization tools that present progress and development of the child's skills.

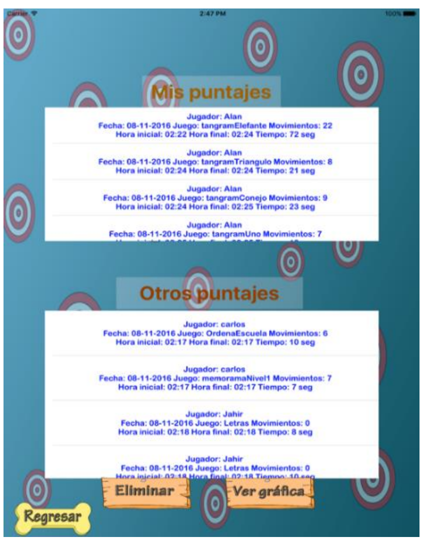

Figure 9 Individual and historical Scoring Session of other students
Source: Self Made

The non-functional requirements requested by the therapist are implemented in order to obtain information on the activities of children with ASD, which are shown in Fig. 9-10.

Based on the parameters, the evaluation of the usability of the application was carried out by observing the therapist when identifying the interest, in addition to understanding the correct procedure and actions of each of the activities that make up the application.

Figure 10 Advance chart per user
Source: Self Made

Therapist's perceptions data is concentrated in Table I.

Characteristics	1st User	2nd User	3rd User	4th User	5th User
Age (years)	14	15.7	13.1	13.3	13.6
Gender	Male	Male	Male	Male	Male
ASD level	High	Medium	High	Medium	Medium
Interest in the activities	Interested	Interested	Interested	Interested	Interested
Need for clarification	No	Yes	Yes	Some	Yes
They find the app confusing	No	No	No	No	No

Table 1 Students involved in the evaluation process
Source: Self Made

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The selection of the control group was made up of five students with an average age of 13 years, all of them reported with characteristics of ASD and learning and socialization problems.

Results

To evaluate the use of the application, an observation process was carried out where all the students showed preference for the use of the applications instead of carrying out paper activities. The application was aimed at capturing the attention of children with ASD, students with a high level of autism showed higher levels of time to complete activities than children with mild symptoms. In response to question number one, if a mobile application can encourage learning and help improve some of its fundamental skills, such as language and social skills, we identify in preliminary data an increase in overall scores in a short time frame.

Analyzing the data it was observed that the students had an improvement in the identification of the images, word recognition, increase in digital skills and the use of the keyboard; In addition to showing an interest in the functionality of the application. Students managed to enjoy the application while they learned or reinforced cognitive structures. Some students managed to reify the semantic fields used in the application. Finally, with the application we encourage children the ability to interact using a mobile device in their therapy.

Conclusions

In this work, we present the development of an application to support children with ASD to help them develop digital skills and also develop or strengthen the fields of sociability, written communication, immediate memory, sequence of orders, tracing and coloring of figures, as well as concentration through the use of various activities that were implemented in it. Highlighting that the application is not the panacea in its use in the practices of strengthening the activities of the specialist with the child with ASD, but is seen as an extra tool. According to the specialist, the use of the AppPECS allows to stimulate the capacity of attention in the activities proposed to children.

In this work we focus on the development of the mobile application which can enhance learning by improving one of its basic skills. Although some preliminary results are shown in this work, it gives us interesting perspectives of the use of mobile applications in the field of therapy with ASD children with which the application can be enriched and its use in children who showed progress in performance in short periods of time.

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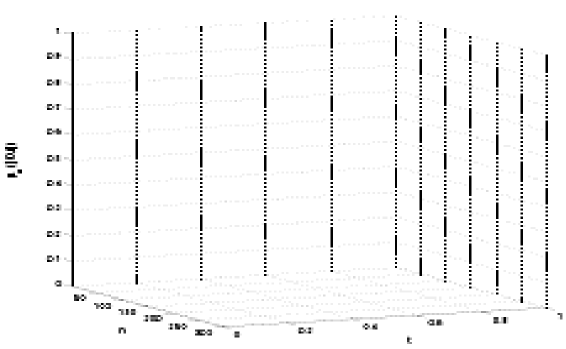

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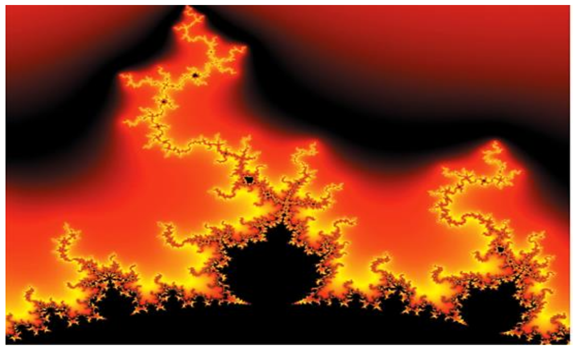

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