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The value of knowing the reason to learn numerical methods

Marta Graciela Caligaris [a1], San Nicolás, Regional Faculty, National Technological University, (2900) San Nicolás , Argentina

Georgina Beatriz Rodriguez [b], Engineering & Education Group San Nicolás Regional, Faculty National Technological University.

Lorena Fernanda Laugero [c]**,** Engineering & Education Group San Nicolás, Regional Faculty National Technological University

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Abstract

Engineering students are often unclear about why it is necessary to study certain mathematical concepts. Mathematics in the Context of Sciences, through the didactic phase, contributes to the acquisition of mathematical competencies. The main objective of this work is to show a didactic proposal designed for teaching numerical methods for non-linear equations, posing mathematics within the context of a problem. Additionally, rubrics were developed to evaluate the problem-solving process taking into account the expected learning outcomes of the experience; one of them will also be shown. The work proposes that the teaching of numerical methods under the approach of mathematics in the context of science is an alternative not only for students to build meaningful learning but also for developing or strengthening different mathematical competencies.

Keywords: Competences; Contextualized problems; Mathematical; Numerical Analysis; Non-linear equations.

***** ADDRESS FOR CORRESPONDENCE: Marta Graciela Caligaris, San Nicolás, Regional Faculty, National Technological University, (2900) San Nicolás , Argentina

E-mail address: mcaligaris@frsn.utn.edu.ar

1. Introduction

The accelerated changes occurring in today's society require highly trained professionals who can adequately respond to the various problems that they should face in their professional life. In this sense, higher education must project, with adequate theoretical and practical bases, educational models that provide the epistemological, methodological, and practical foundations to achieve the learning that is required in the current era (Capote León, Rizo Rabelo & Bravo López, 2016). Under this perspective, engineering education should stop being a mere transmitter of knowledge that students will know how to abstract, articulate and apply effectively. Professors must look for alternatives where students can be active subjects in their academic training.

In particular, in the teaching of Mathematics, the introduction of methodologies where learning is centered on the student and approaching the different topics with a new focus, are alternatives to meet the challenge that teachers have to contribute to the training of competent engineers. Mathematics in the context of engineering (Camarena Gallardo, 1995) is a didactic strategy that integrates mathematical knowledge with that of engineering in students. Mathematics in context is an ideal means for teaching mathematics in an engineering school, more precisely in schools where mathematics is not a goal in itself. There are diverse studies showing the way this theory contributes to the meaningful teaching of certain mathematical concepts (Camarena Gallardo, 1987; Suárez & Camarena Gallardo, 2000; Muro & Camarena Gallardo, 2002; Caligaris, Rodríguez, Liria & Laugero, 2012; Caligaris, Rodríguez, Schivo, Romiti, Laugero, 2012; Caligaris, Rodríguez, Laugero, 2012).

Proposing the teaching of Mathematics in context allows students to acquire the necessary tools to face problems that require analytical capacity and innovation and improves their attitude towards learning Mathematics. This approach helps students to build their knowledge and develop different mathematical skills, by solving problems related to the career they have chosen.

1.1. Conceptual background

In Argentina, the Federal Council of Deans of Engineering Faculties (Consejo Federal de Decanos de Facultades de Ingeniería, CONFEDI, in Spanish) establishes that competence is the ability to effectively articulate a set of schemes (mental structures) and values, allowing to mobilize (make available) different knowledge, in a given context to solve professional situations. This definition indicates that competencies refer to complex and integrated capacities, are related to knowledge (theoretical, contextual, and procedural), are linked to know-how (formalized, empirical, relational), are related to context and professional performance, and allow incorporating ethics and values (Giordano Lerena, 2016).

There are many definitions of competencies but, regardless of the considered one, competence is made up of three components: knowledge (knowing how to know), skills (knowing how to do), and attitudes (knowing how to be).

1.1.1. Mathematical competences

According to Morgen Niss (2003), mastering mathematics means having mathematical skills. That is, having the ability to understand, judge, do and use mathematics in a variety of situations and contexts, mathematical or extra-mathematical, in which mathematics plays or could play a role.

This study defines eight mathematical competencies, organized into two groups. The first group is related to the ability to formulate and answer questions, in and with mathematics, while the second group is related to the ability to handle and manage mathematical language and tools. Table 1 shows each of the competencies according to the group to which it belongs.

Table 1

Classification of mathematical competencies according to Niss

Group	Mathematical competence
First Group	**Thinking mathematically**: this competence includes the knowledge about the types of questions that are handled in mathematics and the types of answers that mathematics can and cannot provide, and the ability to present such questions. **Posing and solving mathematical problems**: this competence includes, on the one hand, the ability to identify and specify mathematical problems and, on the other, the ability to solve mathematical problems. **Mathematical modeling**: this competence is related to the ability to analyze and work on existing models and the ability to perform active modeling in a given context. **Reasoning mathematically**: this competence includes the ability to understand and evaluate an existing mathematical argumentation, the knowledge and the ability to distinguish between different types of mathematical statements, and the construction of chains of logical arguments.
Second Group	**Representing mathematical entities**: this competence includes the ability to understand and use mathematical representations and to know their relationships, disadvantages, and limitations. It also includes the ability to choose and switch between representations based on this knowledge. **Handling mathematical symbols and formalism**: this competence includes the ability to understand symbolic and formal mathematical language and its relationship with natural language, as well as the translation between both. It also involves the rules of formal mathematical systems and the ability to use and manipulate statements and symbolic expressions according to the rules. **Communicating in, with, and about mathematics**: this competence includes, on the one hand, the ability to understand mathematical statements made by others and, on the other hand, the ability to express oneself mathematically in different ways. **Making use of aids and tools (includes IT)**: this competence includes knowledge of the aids and tools that are available, as well as their potential and their limitations. It also involves the ability to use these consciously and efficiently.

1.1.2. Mathematics in the Context of Science

The educational theory of Mathematics in the Context of Sciences is a theory that was born in 1982 and reflects on the link that must exist between mathematics and the sciences that require it. In other words, this theory focuses on university careers where mathematics is not a goal in itself (Camarena Gallardo, 2009; Camarena Gallardo, 2015). Mathematics in the Context of Sciences is based on three paradigms:

- Mathematics is a support tool and formative discipline.
- Mathematics has a specific role at the college level.
- Knowledge is born integrated.

This theory conceives the teaching and learning process as a system in which several factors intervene. Among the most relevant are the cognitive, psychological, and affective characteristics of students, the knowledge and conceptions of the teachers, the epistemology of the content to be learned and taught, the type of curriculum and the didactics to be used. These factors give rise to the five phases contemplated by the theory of mathematics in the context of science: curricular, didactic, epistemological, teacher training, and cognitive. It is clear that the five phases are present in the learning environment, and they interact with each other with some weighted effect on the others, that is, they are not isolated from each other and neither are they alien to the sociological conditions of the actors in the educational process.

Mathematics in the Context of Sciences, through the didactic phase, contributes to the acquisition of the mathematical competencies indicated by Niss (Trejo Trejo, Camarena Gallardo & Trejo Trejo, 2013).

The didactic model includes two guiding axes: contextualization and decontextualization. With contextualization, one works in an interdisciplinary way, including contextualized sciences in the other subjects the student takes, contextualized sciences in professional activities, and contextualized sciences in everyday life situations. While the axis of decontextualization implies a didactic work of a disciplinary type, where the formality of the sciences to be taught and learned is present, according to the requirements of the career where these basic sciences are inserted. This didactic model presents three blocks that support the integral formation of students. These are:

- present the Didactic of the Context strategy in the learning environment
- and take extracurricular courses where activities are carried out for the development of thinking skills, metacognitive skills, and skills to apply heuristics.
- implement a comprehensive and interdisciplinary workshop in the last semesters of the students´ studies, where real problems in the industry are solved.

In the first block, Didactic of the Context, contextualized sciences are presented in the areas of knowledge of a student's future profession, in activities of daily life or professional activities, all through contextualized events, which can be problems or projects. Contextualized events can fulfill different functions: diagnostic, motivational, and knowledge construction, among others. This didactic strategy incorporates nine stages that are developed in the learning environment (Trejo Trejo, Camarena Gallardo & Trejo Trejo, 2013):

1. Identify contextualized mathematical events or problems.
2. Pose the contextualized problem.
3. Determine the variables and constants of the problem.
4. Include the themes and concepts, mathematical and corresponding to the context, necessary to develop the mathematical model and the solution of the event.
5. Determine the mathematical model.
6. Give the mathematical solution to the problem.
7. Determine the solution required by the problem.
8. Interpret the solution in terms of the problem and discipline areas of the context.
9. Present decontextualized mathematics.

1.1. Purpose of study

Engineering students are often unclear about why it is necessary to study certain mathematical concepts. Actually, the topics are usually introduced in an isolated framework, which has nothing to do with the other subjects of the specialty. Students wonder … where do we use this? will we ever use it? Thus, it is essential to show the importance and usefulness of the topics presented to awaken the interest of students. But posing mathematics within the context of a problem not only fosters the student's interest but also achieves meaningful and comprehensive learning. The main objective of this work is to show a didactic proposal that allows for solving non-linear equations. It was designed to improve how numerical methods are taught by posing mathematics within the context of a problem. In the 2021 academic year, students of the Electronic and Mechanical Engineering specialties who are studying Numerical Analysis at the Facultad Regional San Nicolás, Universidad Tecnológica Nacional, Argentina will learn this way.

Additionally, rubrics were developed to evaluate the problem-solving process taking into account the expected learning outcomes of the experience; one of them will also be shown in this paper.

2. Materials and Methods

In this section, the contextualized problem that will be used as a motivator at the beginning of learning the numerical methods that allow for solving non-linear equations will be presented. That is, one of the functions that the contextualized event will fulfill is to show students the need to apply a numerical method to obtain an approximate solution to a problem.

It should be noted that the selection of the contextualized event was carried out in such a way that its presentation is not a cognitive obstacle for students. For this reason, the knowledge required to write the mathematical model that represents the contextualized event is minimal since this proposal will be solved by students of the second and third levels of the engineering career.

2.1. Procedure

2.1.1. Selected contextualized problem

The contextualized event statement is (Mathews & Fink, 2000): A sphere with a radius of 10 cm, made of a material of density $\rho = 0.638$ g cm^{-3}, is immersed in water. How deep is the south pole of the sphere submerged?

2.1.2. Stages of the contextualized event

In each of the following subsections, each of the stages of the event will be detailed according to the educational theory of Mathematics in the Context of Sciences.

2.1.3. Contextualized event identification

The contextualized event is given by determining the depth to which the south pole of the sphere is submerged, knowing that it has a radius of 10 cm and is built with a material of density $\rho = 0.638$ g cm^{-3}.

2.1.4. Posing the problem

In order to solve the posed contextualized event, first, students must appeal to the Archimedes principle. That is to say,

$$B_f = \rho_f \cdot V_s \cdot g \tag{1}$$

where B_f is the buoyant force, V_s is the volume of the submerged part of the body, ρ_f is the density of the fluid, and g is the acceleration of gravity.

On the other hand, for a body to be partially submerged, students will have to take into account that the actual weight of the body is equal to the buoyant force.

$$B_f = P_a \tag{2}$$

Considering that $P_a = mg$, where m is the mass of the body, it is possible to write the equality:

$$\rho_f \cdot V_s = m \tag{3}$$

Also, if $m = \rho_c V_c$, where ρ_c is the density of the material with which the body is built and V_c is the volume of the body, the expression (3) results:

$$\rho_f \cdot V_s = \rho_c \cdot V_c \tag{4}$$

It is known that the volume of a sphere of radius r is given by:

$$V_c = \frac{4}{3} \cdot \pi \cdot r^3 \quad (5)$$

and that the volume of a spherical cap of radius r and height h is:

$$V_s = \frac{1}{3} \cdot \pi \cdot h^2 \cdot (3r - h) \quad (6)$$

Therefore, students by substituting (5) and (6) in (4) will obtain:

$$\rho_f \cdot \frac{1}{3} \cdot \pi \cdot h^2 \cdot (3r - h) = \rho_c \cdot \frac{4}{3} \cdot \pi \cdot r^3 \quad (7)$$

From the provided data, students know that r = 10 cm, ρ_f = 1 g cm $^{-3}$ (water density) and ρ_c = 0.638 g cm $^{-3}$. So, to calculate the depth to which the south pole of the sphere is submerged, students have to solve the equation:

$$\frac{1}{3} \cdot \pi \cdot h^2 \cdot (3 \cdot 10 - h) = 0,638 \cdot \frac{4}{3} \cdot \pi \cdot 10^3 \quad (8)$$

2.1.5. Determination of variables and constants of the problem

In the posed contextualized problem, students will indicate that the only independent variable that intervenes is h, which must be lesser than 20 (being 20 the diameter of the sphere). While the constants are the characteristics of the sphere (radius and density of the material) and the density of the fluid in which the sphere is submerged.

2.1.6. Inclusion of mathematical topics and concepts

The mathematical themes and concepts that are involved in the resolution of the contextualized event are the volume of a body, the equations classification, and the numerical methods to solve a nonlinear equation.

2.1.7. Inclusion of mathematical topics and concepts

To calculate the depth to which the south pole of the sphere is submerged, it is necessary to solve the nonlinear equation:

$$-\frac{1}{3} \cdot \pi \cdot h^3 + 10 \cdot \pi \cdot h^2 - \frac{2552}{3} \cdot \pi = 0 \quad (9)$$

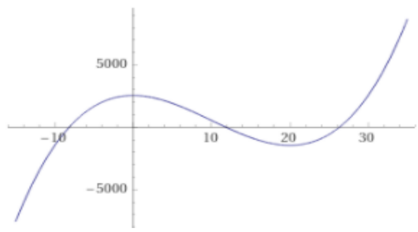
Equation (9) is a cubic equation. Although there is a formula to calculate the roots of these types of equations, its application is not simple. Therefore, an alternative to obtain an approximation of the solution of this equation is by applying some numerical method.

2.1.8. Mathematical solution of the model

To obtain an approximate solution to the proposed mathematical model, in the first place, students should graph the function associated with equation (9) and visualize the values of x where the value of the function is zero.

Figure 1

Graph of the function of the mathematical model



2.1.9. Solution required by the problem

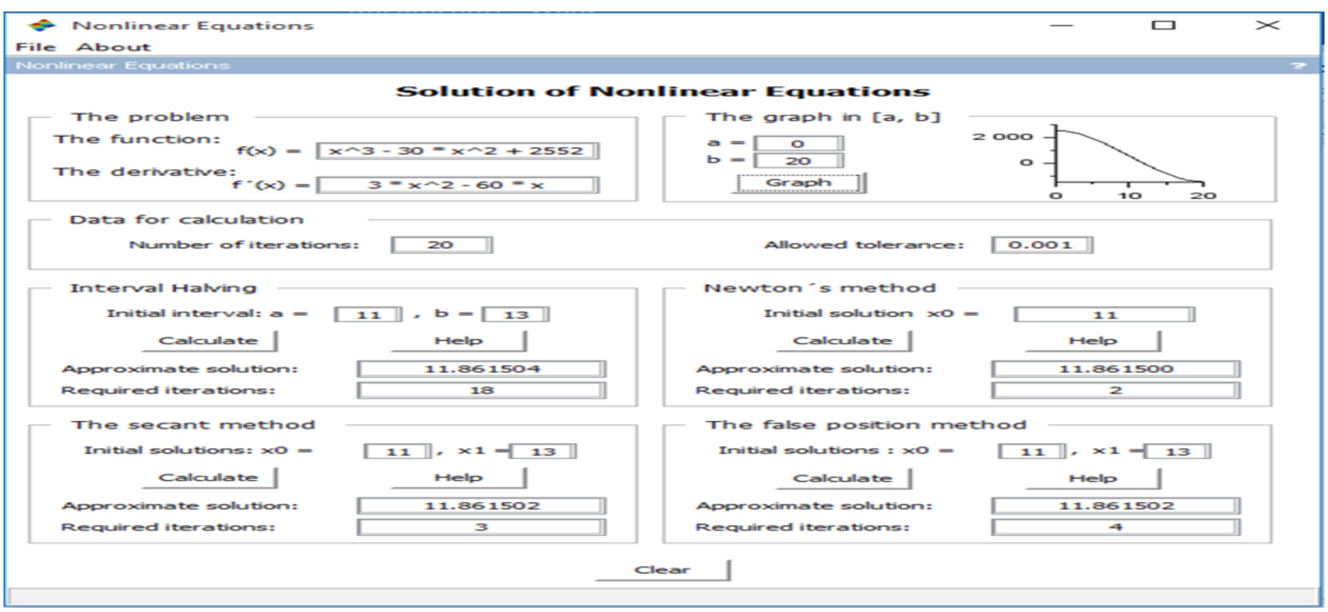
To approximate the solution of the problem, students must take into account that the solution is in the interval [0; 20]. From the observation and analysis of the graph, presented in Figure 1, students will be able to determine the initial information that is required to be able to apply each of the methods that allow obtaining an approximate solution to the nonlinear equation.

3. Results

Figure 2 shows the numerical solution obtained by each of the methods using a learning object designed for this purpose. It should be noted that to facilitate the writing of both the function and its corresponding derivative, equation (9) was algebraically worked.

Figure 2

Numerical solution of the contextualized event



From the observation of the results produced by the learning object after applying the different numerical methods, students will determine that the height h measures approximately 11.86 cm.

3.1. Interpretation of the solution in terms of the problem

Students will conclude that the depth to which the south pole of the sphere is submerged, taking into account the characteristics imposed by the contextualized event, is approximately 11.861 cm.

3.2. Decontextualization of mathematical topics in the classroom

At the end of the resolution of the contextualized event, the teacher will analyze together with students the results obtained when applying the different numerical methods and the factors that influence the approximations obtained. From the information provided by students, on the blackboard, a table like Table 2 can be made.

Table 2

Information provided by students when applying different numerical methods

Method	Iterations	Order	Approximation
Bisection	18	Linear	11,861504
Newton	2	Quadratic	11,861500
Secant	3	Super linear	11,861502
Regula – Falsi	4	Linear	11,861502

After the detailed observation and analysis of Table 2, students will indicate that the most efficient method to solve the non-linear equation that models the contextualized event raised is Newton. The approximation obtained after performing two iterations has four exact decimal places. This is because the order of precision of this method is greater than that of the others. In contrast, students will say that the least efficient method is the bisection method since it took 18 iterations to obtain an approximation with the established tolerance.

Regarding the Secant and Regula - Falsi methods, although due to the order of precision and the characteristics that each one of the presents, they required more iterations than Newton's method, both gave an approximation that also presents four exact decimal places. Taking into account that, for example, in Newton's method an important question is the adequate selection of the point to start the iterative process, the teacher will ask the question: Is it possible to choose any initial point that is in the interval [0; 20] to obtain an approximate solution of the contextualized event raised?

From the results shown in Table 3, students will be able to conclude that, on the one hand, according to the selected starting point, the iterative process will converge to a certain root of the nonlinear equation. And, on the other hand, the closer the initial point is to the required root, the fewer iterations the method will need to obtain an approximate solution

Table 3

Solutions obtained by applying Newton's method using different initial points

Initial point	Iterations	Approximation
1	7	26.314571
3	6	11.861502

7	3	11.861501
11	2	11.861500
19	5	-8.1760721

It will also be possible to ask questions that have to do with the width of the initial interval considered or reflect on the number of operations that are carried out to apply a certain numerical method and how rounding errors influence the numerical solution due to computers' finite arithmetic.

4. Discussion

Learning outcomes describe what learners are expected to know and be able to do at the end of a certain learning period (Azevedo et al., 2021). In the presented didactic proposal, the following learning outcomes were posed:

- Determine the mathematical model that describes the problem to obtain its solution considering the conditions to which it is subject.
- Analyze the solutions generated by the studied numerical methods to select the most appropriate one taking into account the different factors that influence the precision of each one of them.

Rubrics are assessment instruments that articulate essential criteria for each learning outcome, with performance descriptors that demonstrate progressively more sophisticated levels of achievement (Curcio, 2018). To analyze the degree of specificity of the learning outcomes posed in the didactic proposal, two analytical rubrics were made.

As an example, the rubric developed for the second learning outcome is shown as well as the evaluation criteria considered. These evaluation criteria are:

- Criterion 1: Selects the numerical methods that can be applied, taking into account the characteristics of the problem to be solved.
- Criterion 2: Applies the selected numerical methods following appropriate steps.
- Criterion 3: Compares the obtained numerical solutions to determine the precision of each one of them.
- Criterion 4: Identifies the different factors that influence the precision of the numerical solution.
- Criterion 5: Analyzes the precision of each of the numerical solutions obtained, taking into account the different influencing factors.

Table 4 shows the analytical rubric developed for the second learning outcome, taking into account the criteria detailed above. The colored cells indicate the required achievement levels to overcome the corresponding criterion.

Table 4

Analytical rubric of the second learning outcome

	Begginer (2pts)	Basic (6 pts)	Proficient (8 pts)	Advanced (10 pts)
E.C. 1 10%	Does not indicate the numerical methods that can be applied because the characteristics of the problem are not analyzed.	Indicates few of the methods that can be used because the characteristics of the problem are analyzed in a very incomplete way.	Indicates almost all the methods that can be used because the characteristics of the problem are not completely analyzed.	Indicates all the numerical methods that can be used because the characteristics of the problem are completely analyzed.
E.C. 2 30%	Does not adequately apply the steps of the	Applies the steps of the selected methods with	Properly applies the steps of the selected	Properly applies the steps of the selected

	selected methods and does not obtain the solutions.	errors and does not obtain each of the solutions.	methods but some of the solutions have numerical errors.	methods and correctly obtains each of the numerical solutions.
E.C. 3 20%	Does not explain which of the obtained solutions is the most accurate.	Elementary explains which of the obtained solutions is the most accurate.	Explains with errors which of the obtained solutions is the most accurate.	Adequately explains which of the obtained solutions is the most accurate.
E.C. 4 20%	Does not indicate the factors that influence the precision of the solution.	Lists some of the factors that influence the accuracy of the numerical solution.	Lists almost all the factors that influence the precision of the numerical solution.	Lists all the factors that influence the precision of the numerical solution.
E.C. 5 20%	Does not study the increased precision of the solution considering all factors.	Incompletely studies the increased precision of the solution taking into account all factors.	Studies almost completely the increased precision of the solution taking into account all factors.	Thoroughly studies the increased precision of the numerical solution taking into account all factors.

5. Conclusions

Mathematics in the context of science allows students to integrate their knowledge as well as transfer it to other disciplines. It also helps students to be motivated by making sense of the different mathematical concepts learned since they can understand why they are taught, and how and where they can be applied.

Taking this into account, the authors of this work consider that proposing the teaching of numerical methods under the approach of mathematics in the context of science, is an alternative not only for students to build meaningful learning but also for developing or strengthening different mathematical competencies. The authors will continue working in this line, designing didactic proposals where students can see the importance of learning numerical methods to solve engineering problems.

References

Azevedo, J. P., Hasan, A., Goldemberg, D., Geven, K., & Iqbal, S. A. (2021). Simulating the potential impacts of COVID-19 school closures on schooling and learning outcomes: A set of global estimates. *The World Bank Research Observer*, *36*(1), 1-40. https://academic.oup.com/wbro/article-abstract/36/1/1/6174606

Caligaris, M. G., Rodriguez, G. B., Schivo, M. E., Romiti, M. R., & Laugero, L. F. Herramientas que sitúan la matemática en contexto. *JEIN 2012*, 60.http://www.usfx.bo/nueva/vicerrectorado/citas/TECNOLOGICAS_20/Ingenieria%20Sistemas/4.pdf#page=60

Caligaris, M., Rodríguez, G., & Laugero, L. (2012c). La enseñanza del Análisis Numérico en el contexto de las ciencias. I CADI, Facultad de Ingeniería de la Universidad FASTA – Facultad de Ingeniería de la Universidad Nacional de Mar del Plata, Mar del Plata, Argentina.

Caligaris, M., Rodríguez, G., Liria, L., & Laugero, L. (2012a) La resolución numérica de ecuaciones diferenciales en el contexto de los circuitos eléctricos. Congreso Latinoamericano de Ingeniería y Ciencias Aplicadas, Facultad de Ciencias Aplicadas a la Industria - Universidad Nacional de Cuyo, San Rafael, Argentina.

Camarena Gallardo, P. (1987). Diseño de un curso de ecuaciones diferenciales en el contexto de los circuitos eléctricos. Tesis de maestría en Matemática Educativa. México, CINVESTAV-IPN. http://www.revistas.usb.edu.co/index.php/Ingenium/article/view/1370

Camarena, G. P. (1995). El contexto de las Ecuaciones Diferenciales Lin eales. 6o Coloquio Académico. *ESIME-IPN, México*.

Capote León, G. E., Rizo Rabelo, N., & Bravo López, G. (2016). La formación de ingenieros en la actualidad. Una explicación necesaria. *Revista Universidad y Sociedad*, *8*(1), 21-28. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2218-36202016000100004

Curcio, A. A. (2018). A simple low-cost institutional learning-outcomes assessment process. *Journal of Legal Education*, *67*(2), 489-530. https://www.jstor.org/stable/26890950

Gallardo, P. C. (2009). La matemática en el contexto de las ciencias. *Innovación educativa*, *9*(46), 15-25. https://www.redalyc.org/pdf/1794/179414894003.pdf

Gallardo, P. C. (2015). Teoría de las ciencias en contexto y su relación con las competencias. *Ingenium Revista de la facultad de ingeniería*, *16*(31), 108-127. https://scholar.archive.org/work/wwbmkx3o25badbe72a3bfieoxa/access/wayback/http://revistas.usb.edu.co/index.php/Ingenium/article/viewFile/1370/1160

Giordano L, & Compilador R.,. (2016). Competencias y perfil del Ingeniero Iberoamericano, formación de profesores y desarrollo tecnológico e innovación. ASIBEI. https://docplayer.es/19610256-Competencias-y-perfil-del-ingeniero-iberoamericano-formacion-de-profesores-y-desarrollo-tecnologico-e-innovacion-documentos-plan-estrategico-asibei.html

Mathews, J., & Fink, K. (2000). *Métodos Numéricos con Matlab*. España: Pretence Hall.

Muro, U. C., & Camarena, G. P. (2002). La serie de Fourier en el contexto del proceso de transferencia de masa. *Revista Científica: The Mexican Journal of Electromechanical Engineering*, *6*(4), 159-163.

Niss, M. (2003, January). Mathematical competencies and the learning of mathematics: The Danish KOM project. In *3rd Mediterranean conference on mathematical education* (pp. 115-124). http://www.math.chalmers.se/Math/Grundutb/CTH/mve375/1213/docs/KOMkompetenser.pdf

Suárez, B. V., & Camarena, G. P. (2000). La transformada de La place en el contexto de la ingeniería. *Acta Latinoamericana de Matemática Educativa*, *13*, 124-130.

Trejo, E. T., Gallardo, P. C., & Trejo, N. T. (2013). Las matemáticas en la formación de un ingeniero: una propuesta metodológica. *REDU: Revista de Docencia Universitaria*, *11*(1), 397. https://dialnet.unirioja.es/descarga/articulo/4522470.pdf