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Original article

Development of logical-mathematical thinking in the Computer Engineering career

Desarrollo del pensamiento lógico-matemático en la carrera Ingeniería Informática

Desenvolvimento do pensamento lógico-matemático na carreira de Engenharia da Computação

Claudia Permuy Díaz[1] 0000-0001-6403-2106 claupd@upr.edu.cu
Meivys Páez Paredes[1] 0000-0001-5325-1004 meivys@upr.edu.cu
Reinaldo Meléndez Ruiz[1] 0000-0003-3795-2382 reinaldo.melendez@upr.edu.cu

[1] University of Pinar del Río "Hermanos Saíz Montes de Oca". Pinar del Río, Cuba.

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ABSTRACT

In a world where technology advances rapidly, professionals are needed who are prepared to face the challenges that arise in innovative ways. For the computer engineer, having a proper development of logical-mathematical thinking makes it possible to solve the wide variety of problems that arise in today's society in a creative way. In the present research, an analysis of the development of logical-mathematical thinking was carried out in the Computer Engineering course at the University of Pinar del Río "Hermanos Saíz Montes de Oca". The theoretical methods used were: historical-logical analysis, systematization, modelling and systemic-structural; empirical methods: survey, scientific observation, documentary analysis and consultation of specialists; statistical methods, the use of statistical, descriptive and inferential techniques in the processing of information. Two

dimensions were established: teacher action and student action, with their respective dimensions for the diagnostic study, which presented evidence of the existing shortcomings in the teaching process-learning, to achieve a proper development of logical-mathematical thinking in the computer engineer, although its importance is recognized for training a professional with solid preparation.

Keywords: development; logical thinking; logical-mathematical thinking; computer engineer.

RESUMEN

En un mundo donde el avance de la tecnología es vertiginoso se necesitan profesionales preparados para enfrentar los desafíos que se impongan de manera innovadora. Para el ingeniero informático tener un adecuado desarrollo del pensamiento lógico-matemático hace posible que pueda resolver la amplia variedad de problemas que surgen en la sociedad actual de forma creativa. En la presente investigación se realizó un análisis del desarrollo del pensamiento lógico-matemático en la carrera Ingeniería Informática de la Universidad de Pinar del Río "Hermanos Saíz Montes de Oca". Los métodos teóricos utilizados fueron: el análisis histórico-lógico, la sistematización, la modelación y el sistémico-estructural; los métodos empíricos: la encuesta, la observación científica, el análisis documental y la consulta a especialistas; los métodos estadísticos-matemáticos se emplearon para el procesamiento de la información, con la utilización de técnicas estadísticas, descriptivas e inferenciales. Se establecieron dos dimensiones: accionar del profesor y accionar del estudiante, con sus respectivas dimensiones para el estudio diagnóstico, el cual presentó evidencias de las carencias existentes en el proceso de enseñanza-aprendizaje, para lograr un adecuado desarrollo del pensamiento lógico-matemático en el ingeniero informático, a pesar de que se reconoce su importancia para formar un profesional con una sólida preparación.

Palabras clave: desarrollo; pensamiento lógico; pensamiento lógico-matemático; ingeniero informático.

RESUMO

Num mundo onde o avanço da tecnologia é vertiginoso, são necessários profissionais preparados para enfrentar os desafios que surgem de forma inovadora. Para o engenheiro da computação, ter um desenvolvimento adequado do pensamento lógico-matemático possibilita resolver de forma

criativa a grande variedade de problemas que surgem na sociedade atual. Na presente pesquisa foi realizada uma análise do desenvolvimento do pensamento lógico-matemático na licenciatura em Engenharia da Computação da Universidade de Pinar del Río "Hermanos Saíz Montes de Oca". Os métodos teóricos utilizados foram: análise histórico-lógica, sistematização, modelagem e sistêmico-estrutural; métodos empíricos: levantamento, observação científica, análise documental e consulta a especialistas; para o processamento das informações foram utilizados métodos estatístico-matemáticos, com uso de técnicas estatísticas, descritivas e inferenciais. Foram estabelecidas duas dimensões: ações docentes e ações discentes, com suas respectivas dimensões para o estudo diagnóstico, que apresentaram evidências das deficiências existentes no processo de ensino-aprendizagem, para alcançar um desenvolvimento adequado do pensamento lógico-matemático no engenheiro da computação, apesar o fato de ser reconhecida sua importância para formar um profissional com sólida preparação.

Palavras-chave: desenvolvimento; pensamento lógico; pensamento lógico-matemático; engenheiro de computação.

INTRODUCTION

Higher education's role in achieving the 2030 Agenda is essential; without it, the Sustainable Development Goals (SDGs) cannot be achieved. Higher education educates future generations, conducts research to find solutions to complex problems, supports and engages with local communities, and creates initiatives to make university campuses more sustainable. It also provides a critical voice to the issues presented in the SDGs, encourages systemic thinking and critical engagement (Mallow et al., 2019).

The Cuban Higher Education aims to increase the levels of academic demand, in order to benefit the quality of learning of university students. The E program proposed by the Ministry of Higher Education for the course in computer engineering is based on the fact that the computer engineer is a highly qualified technologist, who deals with acquisition, transmission, storage, processing, protection and presentation of information through the efficient use of computers and other means. The modes of action of the computer engineer are associated with self-management of learning. In keeping with the systematic nature of advances in computing, he must demonstrate a strong spirit of self-improvement to keep up with the latest developments in science and technology in his field. It is

associated with the design, modelling, design, development, application, integration, maintenance and testing of computer systems, taking advantage of available infrastructures for storage, processing and exchange of information, Contributes to increased efficiency and effectiveness in the operation of a wide range of organizations.

In computing, logic plays a basic role, whether in databases, computational complexity, programming languages, artificial intelligence, system design and verification, and others, and is undoubtedly one of the foundations that provide the maturity and agility necessary to assimilate concepts, languages, techniques and computer tools that arise in the future (Garrido et al., 2019).

The formation of logical thinking has been studied by several sciences, and various theories have been proposed. The results of dialectical logic, psychology, epistemology and pedagogy are known among other sciences; However, it can be said that the didactics assumes a great responsibility in the development of this type of psychological training in the new generations through the development of the teaching-educational process in school (Medina, 2017).

When it´s thought about the term logical thought, it´s started from the fact that there is a quality which is attributed to thought and it is to be logical; understanding as logical a concept which, being used in everyday life, gives an idea of natural and adequate. "Also used to qualify thought in the sense of its validity and correction, meaning that it is understood by logical a thought that is correct, i.e., a thought that ensures that the mediated knowledge it provides is in accordance with the real" (Campistrous, 1993).

Piaget (1975) argues that "the mathematical logical process is highlighted in the construction of the notion of knowledge, which decomposes itself from the relations between objects and descends from the production of the individual" (p. 20). That is, the child builds up mathematical logical knowledge by coordinating the simple relationships he has previously created between objects which, viewed from this point of view, requires that the teacher be informed of all aspects related to this subject in order to guide and enhance these processes in children and thus achieve the consolidation of a meaningful, integrative, autonomous, integral learning (Lugo Bustillos et al., 2019).

Traditionally, for engineers, mathematics was a tool to model and formulate problems precisely, with a solution adjusted to the conditions of the situation, using strong mathematical symbology. Now mathematics has become an integral part of engineering, therefore new methods are being used to solve problems related to engineering such as the contextualization of mathematics. Mathematics

has many applications for describing the static structure and dynamic behavior of a software system, and for verifying a software specification by logical statements, among others (Bueno et al., 2020).

Ramos y González (2021) deepen this relationship with the computer engineer. For the author, the study of mathematics enables computer engineers to develop skills such as: identifying, interpreting, representing and modelling problems encountered in industry, with the aim of improving the processes inherent in these. The teaching and learning process should help to make mathematics an indispensable working tool in solving problems of specialization and production, to support the student of Computer Engineering to develop a vision of the world that favors the formation of an analytical, reflexive, deductive and creative thinking.

Rosen (2019) believes that the use of mathematical methods considerably expands the fields of action for any engineer. Mathematical methods play an important role in the treatment of results, in the ability to properly manage and store information, in drawing sound conclusions, in formulating predictions based on available statistical data, etc. It is therefore quite obvious that the demand for a specialist capable of carrying out appropriate analyses on the basis of consolidated analytical thinking is increasing considerably.

Díaz y Ortega (2022) also address the importance of problem solving and mathematical thinking in engineering education. For the author, one of the transversal aspects of engineer training is preparation for solving problems specific to the profession.

Logical-mathematical thinking is related to the ability to work and think in terms of numbers and the ability to employ logical reasoning (Tares & Fernández, 2022).

When it's told about the development of logical-mathematical thinking, it´s referred to the relationship between thought and intelligence, terms that play a fundamental role in the process of teaching and learning for the acquisition of new knowledge. That is, if a teacher manages to develop logical thinking in the students would be contributing to the development of mathematical intelligence, which goes far beyond numerical skills, since it brings important benefits such as: the ability to understand concepts and establish logical relationships in a schematic and technical way. It implies the ability to use calculation, quantifications, propositions and notions in an almost natural way. For this reason it is essential to teach, guide, instruct, illustrate, exercise the student so that by himself and through the correct use of resources, whether provided or created by himself, he analyzes, compares, values, look for, reflect on, the whole process already carried out or to be carried

out for the solution of any problem or exercise posed and, in this way, can come to conclusions that are, of course, more solid and lasting in his mind. This is closely related to the cognitive and metacognitive process of the student, since if the teacher potentiates these two processes he will demonstrate his ability to reflect and/or seek new ones for the construction of knowledge and, from this, generate an enormous pedagogical benefit, thus building a meaningful learning in students (Quizhpilema et al., 2019).

Successful development of logical-mathematical thinking ensures the students' cognitive independence, preparing them to direct their own learning; however, the fact that it is not an instructive objective that it is where teachers usually direct their interests, places this purpose at a clear disadvantage (Yero et al., 2018).

Galindo et al. (2024) the teachers who teach mathematics do not attach sufficient importance to the deepening of mathematical concepts with the use of logic to develop logical thinking in students; only superficially emphasize problem solving procedures and methods:

- The diagnosis is not always used by teachers with an integral approach, it is directed to the result.
- The activity is focused on the teacher, who often anticipates the students' reasoning, not allowing their reflection.
- The content is treated without reaching the essential features.
- Control is about the outcome, not the process of getting to knowledge or ability.
- The center of teaching is instructive rather than educational.

This leads to a tendency in the pupils to reproduce knowledge and not to reason their answers; they present few transformations at the level of their thinking and are limited when it comes to generalizing and applying knowledge.

This is where didactics plays a major role. The purpose of teaching methods is to enable pupils to learn in a dynamic way, taking into account their intellectual capacity and the conditions of their environment; furthermore, it uses materials, The methods and methods of teaching that influence the correct participation in the development of the skills and abilities of the students (Quimis et al., 2022). The success of the teaching process depends on the knowledge, ability and performance of the teacher to carry it out with different appropriate activities, which tend to achieve the same goal, which is to facilitate the learning of students (Conforme & Mendoza, 2022).

As part of the research, an initial exploratory study was carried out to find the causes that justify this research. Consequently, strengths and weaknesses are identified in the process of development of logical-mathematical thinking in the Computer Engineering career of the University of Pinar del Río "Hermanos Saíz Montes de Oca". Documents and reports of the course were analyzed, training activities observed and interviews and exchange workshops with teachers were held, which helped to obtain the required information.

As strengths, they are identified: the curriculum from the different disciplines has an appropriate scientific level and its objectives are oriented to the integral training of future professionals.

As weaknesses: students enter with deficiencies in the analysis and solution of mathematical problems; they are not aware of the use that as professionals in their working life can make of logical-thinking, the course teachers show didactic-methodological limitations in order to systematize the development of logical-mathematical thinking; the problems solved in the teaching process, consequently, the students do not have sufficient analytical, creative and independent solutions to a problem of professional profile.

In the systematic observation made by researchers to the vocational training process in the Computer Engineering degree of the University of Pinar del Río "Hermanos Saíz Montes de Oca", together with years of experience in teaching and as a graduate from a very close area, it was found that the students show inadequacies in the development of logical-thinking because teachers and students have not internalized that it is thanks to the proper development of logical-mathematical thinking that the engineer is able to broaden the field of his knowledge and the degree of understanding of problems and their causes; It also enables to propose efficient solutions.

The objective of this research is to analyze the development of logical-mathematical thinking in the Computer Engineering course at the University of Pinar del Río "Hermanos Saíz Montes de Oca".

MATERIALS AND METHODS

The research was carried out in the Computer Engineering course of the University of Pinar del Río "Hermanos Saíz Montes de Oca", between November 2023 and July 2024. Two sample groups were worked with, comprising all students from the first to fourth years (120), six teachers from the Mathematics department and ten teachers from the Informatics department.

The selection of the population and sample groups was carried out as follows (Table 1).

Table 1. Selection of the sample population and groups

Instruments	Strata	Population	Sample	*Fr* (%)
Content analysis guide	Governing documents	9	9	100
Survey of teachers	Teachers	66	16	53
Student survey	Students	120	115	95,6
Observation guide	Teaching activities	-	-	-

Legend. *Fr*: Relative frequency, in percentage

The following sources were used as guiding documents:

1. Basic document for the design of the Curricula E.
2. Study plan E for the Computer Engineering course.
3. Model of the professional for the computer engineer.
4. Program of the Higher Mathematical discipline.
5. The discipline program Computer Systems Infrastructure.
6. Program of the discipline Computational Intelligence.
7. Software engineering and management program.
8. Professional Practice Discipline Program.
9. Work plans and improvement of teachers in the departments of Mathematics and Informatics.

Two dimensions were established with their indicators, following the criteria of (Álvarez de Zayas, 2001).

Dimension 1. Teacher's action

It is characterized by the system of activities directed by the teachers of the Computer Engineering career, in order to achieve a proper development of logical-mathematical thinking in students, setting up time and space for this purpose in each academic year.

Indicators:

- Assurance of the basic knowledge system that must be possessed by the student to enhance logical-mathematical thinking.
- Intentional treatment of concepts, propositions and procedures.
- Appropriate use of mathematical language and programming languages in problem solving.
- Treatment conducive to logical reasoning in problem solving

Dimension 2. Student's action

It is characterized by those actions that the student performs both individually and in groups, which lead to develop his logical-mathematical thinking.

Indicators:

- Level of knowledge necessary for the assimilation-understanding of content, to achieve a proper development of mathematical logical thinking.
- Skills for the development of mathematical procedures in problem solving.
- Skills for the efficient development of computational algorithms in problem solving.
- Potential to generate creative solutions to problems specific to the profession.

The development of logical-mathematical thinking in students of the Computer Engineering course at the University of Pinar del Río was considered at level:

- Very Adequate (MA in Spanish), which identifies the marked trend towards a development of logical-mathematical thinking that exceeds 95% of the total.
- Fairly Adequate (BA in Spanish), which reflects the trend towards a development of logical-mathematical thinking that is between 85% and 94.9% of the total.
- Adequate (A), which identifies the propensity to develop logical-mathematical thinking that is between 75% and 84.9% of the total.
- Little Adequate (PA in Spanish), which identifies the trend towards a development of logical-mathematical thinking that is between 65% and 74.9% of the total.
- Not Adequate (NA in Spanish), which identifies a low development of logical-mathematical thinking that does not exceed 65% of the total.

RESULTS

Results of the implementation of instruments

The instruments used produced results which describe the current status of each dimension and its indicators. Its implementation linked the establishment of criteria (qualitative phase) with the measurement of the frequency of occurrence of these criteria (quantitative stage). Finally, a methodological triangulation of data in sequential designs was carried out, which revealed the main diagnostic regularities of the process.

Results of the content analysis of guidance documents through a guide

In order to characterize the current state of development of logical-mathematical thinking in the Computer Engineering career, an analysis of guiding documents was carried out. In the basic document for the design of Curricula E, there is a clear need to train integral professionals who are able to provide efficient and effective solutions to problems in the profession, where mathematics education plays a primary role, since it helps future graduates to acquire a scientific conception of the world, to develop logical and algorithmic thinking and provides the basic foundations for the contents of the profession, The fact that every professional in these branches considers technical and scientific representations in mathematical terms, reflecting the quantitative and qualitative features of the phenomena they study. From the methodological point of view, it provides organized work methods by stimulating algorithmic thinking, develops communication skills in oral, written and graphic form, enabling the defense of its criteria.

Among the objectives of the discipline Higher Mathematics is: to develop the ability of reasoning and forms of logical thinking by assimilating elements of mathematical logic, understanding the demonstration of properties and theorems, Work with mathematical concepts, identification and interpretation of these, logical argumentation of properties of mathematical objects and demonstration of simple theoretical results, using analytical, graphical and/or numerical methods.

Between the objectives of the discipline Computational Intelligence is: to develop the capacity for reasoning, logical thinking and the level of abstraction through active and collaborative participation in the teaching-learning process.

Obviously, the curriculum contains lines directed towards the development of logical thinking and abstraction in the computer engineer from the teaching-learning process, although it is mainly focused on the higher mathematics discipline, and at no time are they directly oriented towards the development of logical-mathematical thinking.

Results of the survey of Mathematics and Computer science teachers

Six professors from the Mathematics department and 10 professors from the Informatics department were interviewed. The questionnaire was aimed at finding criteria on how to contribute to the development of logical-mathematical thinking in the career Computer Engineering from Dimension 1, and its impact on the professional training of this engineer

The results reflect poor compliance of the indicators corresponding to the teacher's action dimension, as shown in the category Not Adequate, with an arithmetic mean value of 0.56, which represents 56.2% of the total number of subjects investigated (Table 2).

Table 2. Results of the survey of mathematics and computer science teachers

Dimensions	Indicators	Evaluation scale					Evaluation (%)		
		MA	BA	A	PA	NA	Indicators	Dimensions	Variable
Teacher's action	1.1	0	0	3	3	10	NA (62.5 %)	Not adequate (56.2 %)	Rated not adequate (57.1 %)
	1.2	1	2	2	2	9	NA (56.2 %)		
	1.3	0	1	3	3	9	NA (56.2 %)		
	1.4	2	2	1	3	8	NA (50 %)		
Arithmetic mean (%)		0.05	0.08	0.14	0.17	0.56	NA		

Results of the survey of computer engineering students

The survey was conducted by 115 students from all over the course of their studies (43 from year 1, 26 from year 2, 25 from year 3 and 21 from year 4). The questionnaire assessed criteria on how they considered their development of logical-mathematical thinking and the current state of their mathematical and algorithmic skills as computer science.

The results reflect poor compliance of the indicators corresponding to the student's action dimension, as shown in the Not Adequate category, with an arithmetic mean value of 0.62, which represents 62.2% of the total number of subjects investigated (Table 3).

Table 3. Results of the interview with students in computer engineering

Dimensions	Indicators	Evaluation scale					Evaluation (%)		
		MA	BA	A	PA	NA	Indicators	Dimensions	Variable
Student's action	1.1	0	3	18	21	73	NA (63.4 %)	Not adequate (62.2 %)	Rated not adequate (64.9 %)
	1.2	1	3	17	25	69	NA (60 %)		
	1.3	2	4	14	23	72	NA (62.5 %)		
	1.4	0	2	12	27	74	NA (64.1 %)		
Arithmetic mean (%)		0.007	0.075	0.132	0.208	0.626	NA		

Results of observation in vocational training activities

Twenty-four activities were observed, covering the two defined dimensions, with the purpose of verifying the level of achievement of the indicators for each dimension in the process of development of logical-mathematical thinking in the Computer Engineering career, there are implications in all dimensions and indicators, reflected in the category of Not Suitable, as shown below:

- Dimension I. Teacher's action (56.2%).
- Dimension II. Student´s action (62.2%).

Results of the methodological triangulation carried out

As a result of the application of methodological triangulation, the following regularities were obtained in the initial diagnosis for the computer engineering degree:

- The teacher's didactic action lacks an interdisciplinary handling of concepts, propositions and procedures and their application to problems specific to the profession, which is necessary for the integral training of the computer engineer.

- The professional approach of the student does not have an adequate application of concepts, propositions and procedures in solving problems of the profession, necessary for the professional training of the computer engineer.
- Insufficient development of activities linked to the profession, which lead to a proper development of logical-mathematical thinking of the computer engineer, not conceiving the relationship science, teaching and profession in the interdisciplinary treatment of content.

DISCUSSION

In the literature, approaches have been made to how logical-mathematical thinking can be developed in engineering and, in particular, in computer engineering. These are mainly concerned with the importance of mathematics in engineering and the influence of logical reasoning and abstraction on the training of engineers.

Engineers require a solid training and understanding of logic and abstraction, so that ambiguities and unsubstantiated interpretations of natural phenomena are avoided. Engineering deals with the processes necessary to build things, usually with a preconceived purpose, and that in practice the professional must apply his ingenuity to achieve it. Abstraction is a mental process to eliminate details, with the aim of focusing on what is really important in the problem to generate an abstract model of the solution. On the other hand, logic focuses on the sphere of a formal a priori truth, it encompasses mathematics and is crucial for engineering because it is the basis on which the construction and exploitation of abstract or mathematical models are based (Serna & Polo, 2014).

Among many other skills, engineers must achieve a deep understanding of abstract concepts; develop the ability to algorithmic thinking and adequate logical reasoning. Several studies indicate that logical reasoning is not independent of the general intellectual ability, and that students who reason logically and solve problems properly tend to have better results in any subject. Therefore, engineering education as a scientific area should include logic, abstraction, mathematics and problem solving at all levels because as professionals they must master and apply logical thinking (Serna & Flórez, 2013).

Garrido y Hernández (2019) argue that:

> In this age where social evolution has brought humanity into the Information and Knowledge Society, the work of computer engineers is essentially to detect, recognize

> and solve problems by finding increasingly effective computer solutions. The training of engineers in this sense has a basic characteristic: the need to create a very solid logical-mathematical basis, so that their performance will be largely governed by an adequate interpretation of the problem and the subsequent search for the solution (p. 1).

For mathematics, the methods of demonstration and testing are of great importance, and even more so for computer science, since tests are used to verify that programs produce the correct output for all possible input values, to demonstrate that algorithms always produce the correct result, to ensure and guarantee the security of a system and to create computer products that can be considered part of artificial intelligence techniques (Rosen, 2019)

Logical-mathematical thinking in the computer engineer provides skills of analysis and synthesis, planning and programming skills, oral and written communication, information management skills, problem solving, decision making, teamwork, critical reasoning, autonomous learning, adaptation to new situations and creativity, motivation for quality and continuous improvement and ability to apply knowledge to practice (ACM Computing Curricula Task Force, 2013)

In the opinion of the authors, the development of logical-mathematical thinking in the Computer Engineering career shows a lack of intentionality and personalized treatment from the teaching departments and the pedagogical collective, so that it can be promoted in an interdisciplinary way and stimulates the improvement of the professional performance of the pedagogical and student community.

The diagnostic study presents evidence of the shortcomings during the teaching-learning process to achieve a proper development of logical-mathematical thinking in the computer engineer at the University of Pinar del Río, although all the social actors involved in the process (teachers and students) recognize that it is essential for the vocational training of future computer engineers.

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Conflict of interest

Authors declare no conflict of interests.

Authors' contribution

The authors participated in the design and writing of the article, in the search and analysis of the information contained in the consulted bibliography.