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Original article

The formation of logical thinking in the teaching-learning process of Geometry

La formación del pensamiento lógico en el proceso de enseñanza-aprendizaje de la Geometría

A formação do pensamento lógico no processo ensino-aprendizagem de Geometria

Yaquelin Morales Molina[1]
https://orcid.org/0000-0002-4298-1033
Raydi Teydi Rojas Angel Bello[1]
https://orcid.org/0000-0003-1668-2459
Ibrahim Arnaiz Barrios[1]
https://orcid.org/0000-0002-4394-6504

[1] University of Ciego de Avila. Cuba.
yaquelin@unica.cu, raidyteidy@unica.cu, brahima@sma.unica.cu

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ABSTRACT
Taking into account the importance of the formation of logical thinking, whose fundamental task is to raise the quality of learning, the professionals who graduate from the Bachelor of Education, Mathematics career, play an important role in fulfilling such purposes, since they contribute to the mathematical training of adolescents and young people. As the forms of logical thinking are concepts, judgments and reasoning, in the Didactics of Mathematics, logical procedures associated with these three representations have been specified and to train these professionals in logical thinking based on the ability to demonstrate content exercises geometric; This is a current need. For this reason, the present work aims to: offer a definition, actions and distinctive operations for the ability to demonstrate in the teaching-learning process of Geometry, which allow it to be associated with the three forms of logical thought. Methods of the theoretical and empirical level were used, all under a general dialectical-materialist methodological approach, whose results allowed a theoretical analysis of the formation of logical thought, as well as establishing the definition, actions and distinctive operations for the ability to demonstrate in the process. of teaching-learning of Geometry, achieving a contribution to the theory of Didactics of Mathematics, which guides students and teachers in the teaching-learning process of these mathematical contents.

Keywords: learning; geometry; ability; logical thinking.

RESUMEN

Teniendo en cuenta la importancia de la formación del pensamiento lógico, que tiene como tarea fundamental elevar la calidad del aprendizaje, los profesionales que egresan de la carrera Licenciatura en Educación, Matemática, desempeñan un papel importante en el cumplimiento de tales propósitos, ya que contribuyen a la formación matemática de adolescentes y jóvenes. Como las formas del pensamiento lógico son los conceptos, los juicios y los razonamientos, en la Didáctica de la Matemática se han precisado procedimientos lógicos asociados a estas tres representaciones y a formar en estos profesionales el pensamiento lógico a partir de la habilidad demostrar en ejercicios de contenidos geométricos; ello resulta una necesidad actual. Por eso, el presente trabajo tiene como objetivo: ofrecer una definición, acciones y operaciones distintivas para la habilidad demostrar en el proceso de enseñanza-aprendizaje de la Geometría, que permiten verla asociada a las tres formas de pensamiento lógico. Se utilizaron métodos del nivel teórico y empírico, todos bajo un enfoque metodológico general dialéctico-materialista, cuyos resultados permitieron realizar un análisis teórico de la formación del pensamiento lógico, así como establecer la definición, acciones y operaciones distintivas para la habilidad demostrar en el proceso de enseñanza-aprendizaje de la Geometría, lográndose una contribución a la teoría de la Didáctica de la Matemática, que orienta a los estudiantes y profesores en el proceso de enseñanza-aprendizaje de estos contenidos matemáticos.

Palabras clave: aprendizaje; geometría; habilidad; pensamiento lógico.

RESUMO

Levando-se em conta a importância da formação do pensamento lógico, cuja tarefa fundamental é elevar a qualidade do aprendizado, os profissionais egressos do Bacharelado em Educação, carreira em Matemática, desempenham um papel importante no cumprimento de tais propósitos, pois contribuem para a formação matemática de adolescentes e jovens. Como as formas de pensamento lógico são conceitos, julgamentos e raciocínios, na Didática da Matemática foram especificados procedimentos lógicos associados a essas três representações e para treinar o pensamento lógico desses profissionais a partir da capacidade de demonstração de exercícios de conteúdo. Essa é uma necessidade atual. Por esta razão, o presente trabalho tem como objetivo: oferecer uma definição, ações e operações distintivas para a capacidade de demonstrar no processo de ensino-aprendizagem da Geometria, que permitam sua associação com as três formas de pensamento lógico. Foram utilizados métodos de nível teórico e empírico, todos sob uma abordagem metodológica geral dialético-materialista, cujos resultados permitiram uma análise teórica da formação do pensamento lógico, bem como estabelecer a definição, ações e operações distintivas para a capacidade de demonstrar em o processo de ensino-aprendizagem da Geometria, alcançando uma contribuição para a teoria da Didática da Matemática, que orienta alunos e professores no processo de ensino-aprendizagem desses conteúdos matemáticos.

Palavras-chave: aprendizagem; geometria; habilidade; pensamento lógico.

INTRODUCTION

In the literature there is consensus that training is a process and a result, depending on the preparation of professionals for efficient performance. Consequently, the formation of logical thinking is necessary and possible in the education of people and different disciplines can contribute to this. Bearing in mind that Mathematics develops in students a logical, flexible, creative thought and that its theoretical construction is It is based on concepts, judgments and reasoning, so in the teaching-learning process of this science there are numerous ways to contribute to the formation of the logical thinking of students.

In the teaching of Mathematics, general objectives are set that are achievable only through an adequate treatment of the different teaching situations, and that have a direct relationship with geometry; For example, students have to perform actions such as: define, substantiate and demonstrate.

In the teaching-learning process of Geometry, potentialities are identified for the formation of logical thinking, by developing the ability to apply what has been learned; contributes significantly to logical-linguistic training and offers the possibility of transmitting important ideological notions and the theory of knowledge, as well as forming certain values and forms of behavior. However, despite the efforts made, it has been found that the results are far from the aspirations in terms of achieving solid and lasting knowledge, as well as the appropriation by students of ways of working that foster the development of general skills from the teaching of mathematics, consistent with the methodological guideline of the general approach of the Mathematics subject in Cuba, which expresses the need to exercise knowledge, skills and modes of intellectual activity, trying to integrate the knowledge of the students in different areas of Mathematics and in other subjects.

In the formation of the graduate in Education, Mathematics, the work with the ability to demonstrate plays a very important role, fundamentally in the Geometry subject, which constitutes a guideline for the organization of the Mathematics curriculum at school. Among the most important investigations that have worked with the ability to demonstrate, is geometry for life and its teaching, where the importance of learning geometry and its value in the development of thought is valued, proposed by Fernández-Nieto (2018); Yero, Cutiño , Rodríguez, Gutiérrez & Marcillo Merino (2018); Iglesias Inojosa & Ortiz Buitrago (2019); Ciccioli & Sgreccia (2020) and Monteagudo & Betancourt Almaguer (2020), based on their teaching experience, the Demonstration in Geometry from a Didactic Perspective and the teaching of geometry.

Due to the permanent way in which this topic is worked on, expressed above, various alternatives are necessary for its improvement, such as the formation of logical thinking based on the ability to demonstrate, in the teaching-learning process of Geometry.

Travieso Valdés & Hernández Díaz (2017) addresses the issue of the formation of logical thinking, which contributes to the development of logical refutation and demonstration procedures, through the teaching-learning process.

Another approach where the subject of the formation of logical thinking is addressed is that referred to the logical procedures associated with the application of the method of proof by mathematical induction to contents related to numerical sequences; where the study is carried out based on insufficiencies in the teaching-learning process of the Mathematics subject in the

twelfth grade (Nieves Pupo, Caraballo Carmona & Fernández Peña, 2019, p. 396).

Despite the work carried out in each of these investigations, there are still cognitive insufficiencies that have been verified year after year, in the systematic, partial and final evaluations. These are revealed in student performance on exercises and demonstration problems; In addition, the shortcomings in the methodologies used by teachers related to working with concepts, judgments and reasoning as forms of logical thinking in their relationships with the conceptualization of the ability to demonstrate.

This situation makes it possible to identify the scientific contradiction that arises between the need to achieve a satisfactory level in the development of the ability to demonstrate, and the limitations for the formation of logical thinking from the ability to demonstrate, in the teaching-learning process. of geometry. For all the above, the need to form logical thinking from the ability to demonstrate is justified, as one of the ways for the teacher of education to achieve the systematic improvement of the teaching of Geometry.

That is why this article pursues the objective of offering a definition, actions and distinctive operations for the ability to demonstrate in the teaching-learning process of Geometry, which allow it to be associated with the three forms of logical thought.

MATERIALS AND METHODS

This descriptive research was carried out in the Bachelor's degree in Education, Mathematics, of the Faculty of Computer Science and Exact Sciences, of the University of Ciego de Ávila "Máximo Gómez Báez", in the period between September 2018 and December of 2021. A population of 19 students was used, from first to fifth years of said career and five professors from the department of Applied Mathematics.

The investigative process was produced following the dialectical conception of research, which has the dialectical-materialist method as its methodological basis, and theoretical and empirical methods were used.

The theoretical methods used were:

The historical-logical allowed the study of the theoretical-conceptual framework on the formation of logical thinking from the ability to demonstrate, in the teaching-learning process of Geometry, from different theoretical positions.

The inductive-deductive facilitated the analysis of the subject, moving from the general to the particular and the singular, determining what is essential in the formation of logical thought, from the ability to demonstrate, in the teaching-learning process of Geometry.

Empirical level methods were also used, as well as mathematical and statistical methods, essential to assess the intervention of the results in practice.

The observation made it possible to verify the level of development of the ability to demonstrate, in the teaching-learning process of Geometry, in the students of the Degree in Education, Mathematics.

The pedagogical test determined the regularities and trends of the current state of the level of development of the students of the Bachelor of Education, Mathematics career.

Documentary analysis, including subject programs, textbooks, methodological guidelines, master's and doctoral theses; all in order to analyze the formation of logical

thinking in students, from the ability to demonstrate, in the teaching-learning process of Geometry.

The interview allowed us to verify the insufficiencies and strengths in the formation of logical thinking from the ability to demonstrate in the teaching-learning process of Geometry in the students of the Bachelor of Education, Mathematics.

Tables and bar graphs were used as a statistical-mathematical method of descriptive statistics, and percentage analysis as a technique, which allowed the comparison of data for the analysis of the change observed between an initial and a final test.

Within the framework of the search for the solution to the problem, a study of scientific results related to the subject is carried out, following the method of systematizing experiences, specifying as an object: the formation of logical thinking, from the ability to demonstrate, in the process of teaching-learning of Geometry or topics related to mathematical skills. We reflected on the approaches used, the theoretical and methodological aspects applied for its transformation, the means of diagnosis and confirmation of results used, as well as the strengths and weaknesses evidenced. Addressing these issues from the ideas and proposals referred to in the reviewed works and the considerations of the authors of this, the main results presented in the article were achieved.

The results were applied in the Bachelor of Education, Mathematics career, from the implementation of the didactic requirements and the structure of the ability and it was possible to verify, through the review of final oriented tasks, that the students raised the level of development of the ability to demonstrate in the teaching-learning process of Geometry.

RESULTS

"The term training, in Cuban higher education, is used to characterize the substantive process developed in universities with the aim of preparing the student for a certain university career" (Horruitiner Silva, 2014, p. 20).

According to Álvarez de Zayas (1999) "The process in which man acquires his fullness, both from an educational, instructive and developer point of view is the so-called training process" (p. 7).

There is consensus that in the training process there is a dialectical relationship between the three dimensions: instruction (associated with thought, knowledge and skills); education (associated with feelings and values) and development (associated with the link between study and work).

Consistent with the aforementioned, the formation of logical thinking, essential for students of the Education, Mathematics career, is associated with the three aforementioned dimensions, an element that should be taken into account to conceptualize the term. In addition, it is known that according to Kopnin (1983), the forms of logical thought are concepts, judgments and reasoning, and in the Didactics of Mathematics (Campistrous, 1993) logical procedures (skills) associated with these forms have been specified. of logical thinking.

In the content of the Geometry discipline of the Education, Mathematics career, potentialities for the development of logical thinking and the creative activity of students are manifested, due to the integrative character and developer of knowledge, skills, habits and values. According to the experience of the authors and consultation with other specialists, the necessary and possible results in taking advantage of these potentialities have not yet been achieved. In

particular, the existence of insufficiencies in the formation of logical thinking has been identified as problematic, from the ability to demonstrate, in the teaching-learning process of Geometry, because the relationships between the demonstration process and the teaching-learning process are not sufficiently identified and applied. the other procedures associated with the forms of logical thought: concepts, judgments and reasoning. In particular, in exercise systems the conceptual structures that are implicit in the proposition to be proved are not identified.

Based on the above background, the authors consider that the formation of logical thinking in the students of the Education, Mathematics career, is a process and a result, in order to achieve the conscious preparation of future graduates for the mastery of associated logical procedures. to the concepts, judgments and reasoning, as a necessary condition for learning the contents of the different disciplines of the career and for their performance in work practice.

The skills or procedures of logical thinking, although they transcend the work in the Mathematics subject, find in it numerous potentialities for their development, for which they are part of the mathematical content. Campistrous (1993) has specified the skills or procedures associated with the three forms of logical thought: concepts, judgments and reasoning.

- For concepts: associate properties, recognize properties, identify, distinguish properties, compare, describe, characterize, define, classify, systematize, exemplify, limit the concept. The authors of this article consider that another logical procedure that should be included in these is the identification of the logical structure of the definition of a concept.
- For judgments: identify truth value of simple judgments, identify truth value of compound judgments, transform judgments, deny judgments, particularize universal judgments, generalize. It is also considered that another logical procedure that should be included in these is the identification of the logical structure of a judgment.
- For reasoning: immediate inferences, basic deductions (separation, hypothetical, syllogistic, justification and refutation), argumentation, reductive inferences, direct demonstrations and indirect demonstrations.

Concepts are fundamental units of all forms of knowledge, through which the experiences that emerge from the interaction with our environment are understood.

The term judgment has various uses. It is, for example, to distinguish between what is true and what is false. The judgment is, on the other hand, an opinion, an opinion or an opinion.

Mathematical reasoning can refer to both formal reasoning and non-strictly formal reasoning used to prove mathematical propositions and theorems.

These logical procedures are closely linked to the development of skills, particularly generalized mathematical skills, which are formed during the execution of actions and operations, which are essentially mathematical in nature. They refer not only to the preparation of the student to apply algorithmic action systems inherent to a certain mathematical activity (calculate, evaluate, simplify, solve equations, decompose into factors and relate graphs and properties of functions). These skills also include the preparation of the student to apply action systems of a heuristic nature to solve mathematical proofs.

From the didactic point of view, proving is a generalized mathematical ability, which consists in identifying that a demand to the mathematical theory or practice requires the application of a concept or a theorem already studied. The way to achieve this is unknown.

From the logical point of view, proving is a finite chain of logical inferences, leading from a known situation to an unknown one, using an unknown method or path.

A detailed study of the relationships of the assumed definitions of proving and of the previous actions and operations with the procedures associated with the three forms of logical thought, allows us to affirm that the generalized mathematical ability to prove is a logical procedure associated with the three forms of thought. logical (concepts, judgments and reasoning) and not just one of them, as is currently considered in the literature. This vision reveals potentialities not explicitly declared about the contribution to the formation of logical thinking from the ability to demonstrate in the teaching-learning process of Geometry.

A proof is written in natural language, this being a rigorous argument, with the purpose of convincing the audience of the truth of a statement or definition. The standard stringency is not absolute and has varied throughout history. A demonstration can be presented in different ways depending on the expected audience. In order to gain acceptance, a proof has to meet common standards of rigor; an argument considered vague or incomplete must be rejected.

A formal proof is written in formal language, rather than natural language. A formal proof is defined as a sequence of formulas in a formal language, in which each formula is a logical consequence of the preceding ones. Having a formal definition of proof makes the concept of proof enjoyable to study.

Although in general there is no single thesis proof procedure, there are different types of proofs that are commonly used in mathematics:

- Demonstration direct.
- Demonstration by principle of mathematical induction.
- Demonstration by contraposition.
- Proof by contradiction.
- Constructive demonstration or by construction.
- Visual demonstration.

Taking into account everything explained above about the ability to demonstrate, it can be inferred that it is a category that transcends the borders of Mathematics as a subject, as Mathematical Logic practically becomes a discipline of this and put the demonstrations in a preferential place of its study. ; This determines that the teaching of Mathematics is assigned a leading role in the development of said capacity. Therefore, it is not possible to neglect the work in the field of demonstrations.

In evaluations made to a sample of 15 students, none is evaluated as excellent or good; 11, which represents 73.33%, are disapproved and four students, which represents 26.66%, are approved.

In addition, it was found that eight students had problems with analyzing and specifying the demonstration exercise. To the skills associated with geometric concepts, four students presented problems. Regarding the search for the idea of the demonstration: 10 students had difficulties and 14 did not carry out adequate reasoning. Regarding the learning they achieve when performing demonstration exercises in the teaching-learning process of Geometry, 10 students showed difficulty.

This low level of development of the ability to demonstrate is observed, both in the demonstrations that are oriented to be

carried out through independent work and those that must be done through the participation of the students in the classes, as well as in those that appear to be executed in the different evaluation exercises.

On many occasions, students master the specific knowledge they require, but do not know how to link it. Therefore, it is important that the teacher helps them to have a global perception of the solution path to be used, and take different steps to achieve the objective.

Proofs in Geometry generally have several ways of solving, which is why it encourages the analysis of the most rational ones. The adequate selection of demonstration exercises is an essential element to ensure that learning stimulates a systematic intellectual activity in students, but many times in the available bibliography there are not the necessary ones or they are not sufficient; this makes it necessary to rework some of the existing ones or elaborate others.

In this sense, it must be taken into account that the complexity of the demonstration exercises must be in correspondence with the real level of development of the students, at the same time that these must be a means to promote it, for which their selection or elaboration constitutes creative work of the teacher.

Then, knowing how to determine the way to solve the demonstration safely and effectively is not an easy task. It is required to have obtained a broad mastery of the content, namely knowledge, skills and abilities, expressed in the degree of intuition, flexibility and logic of thought, which allows for a good level of development of creativity; therefore, working on the formation of logical thinking in students from the ability to demonstrate, in the teaching-learning process of Geometry, is an important aspect to solve existing problems.

In the investigation, a system of geometric demonstrations is presented that consists of 20; in them the different types of demonstrations are worked. Next, we present three demonstration exercises where you can work on the logical procedures associated with concepts, judgments and reasoning as a necessary condition for learning and working on it from the actions and operations that are proposed.

1. Prove that an exterior angle of a triangle is equal to the sum of the two interior angles that are not adjacent to it (formal proof to fix a property of triangles that can serve as a premise for carrying out other proofs).

2. Prove that, if a triangle has two equal sides, the angles opposite these sides are also equal (proof by the direct method where the given situation reveals the solution path).

3. Show that, through every point of a straight line, a straight line can be drawn perpendicular to it (proof by contradiction where the given situation does not reveal the path of solution).

This example, which illustrates a system of three demonstration exercises, constitutes, based on proper planning, an important way to develop learning in this content of Mathematics.

Working with these types of exercises, in the Geometry subject, favors the systematic integration of mathematical content, since it is a perfect space to establish in students the properties of plane figures, making it possible to work with those who still have difficulties in it, and also with the most advantaged, by applying more complex procedures to deepen the study of Geometry.

To solve the problem exposed in this research, the authors consider that the didactic demands are requirements, which must be taken into account by teachers and students and that are related to the way of

proceeding in different components of the aforementioned process.

When thinking about the need to promote the formation of logical thinking from the ability to demonstrate in students, it is pertinent to consider the didactic requirements that must be taken into account for its conception. Based on theoretical foundations and the experience of the authors, as Mathematics teachers in Cuba, the following are identified:

Didactic requirement No. 1. Mastery of logical procedures associated with concepts, judgments and reasoning.

Didactic requirement No. 2. Master the references that support the need for the integrated application of mathematical skills in the solution of exercises and problems.

Didactic requirement No. 3. Master the theoretical references on the generalized mathematical ability to demonstrate.

Didactic requirement No. 4. Develop the ability to demonstrate from a procedure made up of actions and operations.

From the analysis of the literature related to the subject, the definitions of demonstrating previously assumed and the experience of the authors, as Mathematics and Mathematics Didactics teachers, the distinctive actions and operations for the ability to demonstrate in the teaching-learning process of Geometry. They constitute a guiding base for the actions of teachers and students, in the teaching-learning process of Mathematics, and a contribution to the theory of Didactics of Mathematics.

Actions and Operations

1. Reflect on the given proposition:

- Substitute the denominations of the concepts for their meanings.
- Identify the logical structure of the proposition (premises, thesis).
- Replace, if necessary, the proposition with an equivalent one.
- Establish relationships with other propositions that have similar premises and theses.
- Identify the concept or theorem in which the situation required in the demonstration must be framed.

2. Find the demo path:

- Determine the starting situation.
- Use mathematical symbols to represent the given situation.
- Construct an analysis figure.
- Select which elements of the premise are necessary to arrive at the thesis.
- Prepare a demonstration plan (direct, indirect, by opposition, constructive or by construction, by principle of mathematical induction), where the necessary logical inferences are specified.

3. Reflect on the demonstration pathway:

- Reflect on whether the solution path is unique.
- Look for other ways of solution, if possible.
- Identify which of the routes is the most rational.

4. Demo rendering:

- Represent in writing the chain of inferences and the foundations.
- Review each step to see if the given relationships and rationales are correct.

5. Critically evaluate the proof:

- Analyze what mistakes were made during the demo and how they were fixed.
- Assess the possibility of using the route used in other demonstrations.

DISCUSSION

The results obtained with the application of the exposed methods and the bibliographical search on the subject show the need to deepen it, due to the contribution to the formation of logical thinking in students, from the ability to demonstrate, in the teaching-learning process. of geometry.

The research was implemented to 19 students of the Degree in Education, Mathematics, which are developed at the University of Ciego de Ávila "Máximo Gómez Báez", where the authors of this research carry out their teaching work. Five professors from the Department of Mathematics of the University of Ciego de Ávila "Máximo Gómez Báez" with teaching experience in the aforementioned career are declared as study units.

From the qualitative point of view, the following transformations were achieved in the formation of logical thinking, based on the ability to demonstrate in the teaching-learning process of Geometry.

1. Students are able to arrive at a logical exposition of the procedures to carry out a geometric proof.

2. Students know the different types of demonstration and their relationship with the concept to be treated.

3. Necessary tools are applied to argue reasoning in geometric demonstrations, as one of the forms of development of logical thinking.

4. A better job is achieved in writing the proof using their own ideas, which allow the development of their logical ability to apply knowledge by reasoning as one of the forms of development of logical thinking.

5. Teachers apply the procedure presented to work with concepts, judgments and reasoning as forms of logical thought in their relationships with the conceptualization of the ability to demonstrate.

6. Greater motivation of students to move from one level of development to another.

7. The learning was more significant and lasting.

8. It makes it easier for the teacher to evaluate the level of development reached by the students and the differentiated work with them.

Although progress has been made in the formation of logical thinking, based on the ability to demonstrate in the teaching-learning process of Geometry, this topic must continue to be perfected; the foundations are laid to move forward in the medium and long term so that the learning results of the students of the career in these contents are superior.

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Authors contribution:

The authors have participated in the design and writing of the work, and analysis of the documents.