04

DIDACTIC FUNDAMENTALS

OF VISUALIZATION AS A METHOD FOR POSING AND SOLVING MATHEMATICAL PROBLEMS

FUNDAMENTOS DIDÁCTICOS DE LA VISUALIZACIÓN COMO MÉTODO PARA PLANTEAR Y RESOLVER PROBLEMAS MATEMÁTICOS

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ABSTRACT

The present research aims to determine the theoretical foundations and principles that support using visualization as a teaching method in the teaching-learning process of posing and solving mathematical problems. In this context, an exhaustive review of the existing literature on mathematics didactics was carried out, with special emphasis on the contributions of researchers who address the process of posing and solving problems, as well as on the teaching methods applied in this field and the use of visualization in mathematics. As a result, visualization is established as a fundamental teaching method in posing and solving problems, supported by principles that encourage interaction, dynamism, and the construction of mathematical knowledge.

Keywords:

Mathematical visualization, posing and solving problems, teaching methods.

RESUMEN

La presente investigación tiene como objetivo determinar los fundamentos teóricos y los principios que respaldan el uso de la visualización como método didáctico en el proceso de enseñanza-aprendizaje del planteo y la resolución de problemas matemáticos. En este contexto, se llevó a cabo una exhaustiva revisión de la literatura existente sobre la didáctica de la matemática, con especial énfasis en las contribuciones de investigadores que abordan el proceso de planteo y resolución de problemas, así como en los métodos didácticos aplicados en este ámbito y el uso de la visualización en matemática. Como resultado, se establece la visualización como un método didáctico fundamental en el proceso de planteo y resolución de problemas, sustentado en principios que fomentan la interacción, el dinamismo y la construcción del conocimiento matemático.

Palabras clave:

Visualización matemática, planteo y resolución de problemas, métodos didácticos.

INTRODUCTION

Heuristics is the set of strategies, procedures and methods used in the process of problem solving. A fundamental objective of heuristics is to investigate the methods that lead to discoveries and facilitate the search for ways to solve the problems posed. In this sense, Alhirtani (2020), states that there is no ideal method to develop the teaching-learning process of a subject in general. Therefore, teaching methods vary and their selection depends on specific educational situations and the subject to be taught. This researcher expresses that "*teaching methods are the set of techniques and strategies that the teacher uses in the teaching activity to meet the goals that have been set*". (p. 33)

Similarly, Zwęglięski (2020), manifests the importance of the teaching method in developing cognitive skills and interests and to apply the acquired knowledge in practice. Similarly, Neumann et al. (2011), highlight the contextualization of the teaching method as closely related to the content being taught. That is, what is taught determines how it is taught.

The teaching method in specific, has been the subject of study by researchers from different scientific disciplines due to its importance (Mussabekova, et al., 2018; Kjimova, 2020; Misra, 2021). Kucheruk (2013), defines it as "*a multidimensional pedagogical phenomenon, characterized by a number of aspects, considered from different positions, encompassing various relationships existing in an educational process*" (p. 11-12). Kjimova (2020), argues that "*the didactic method is a specific path of the educational process and aims at the fulfillment of planned teaching goals. Also, it promotes logical and holistic knowledge by including multiple cognitive components in the form of facts, ideas, laws and affective component, by conveying emotions and interest in adopting cognitive goals"; and asserts that a combination of new procedures can create a new method*". (p. 39)

This last author alludes to the importance of the didactic method in the sense that it allows the elaboration of logical, useful and accessible information. "*It is not enough to present information to demonstrate ideas, but it must all be in an interesting way, involving as many senses as possible, so that the information is applicable otherwise interest in its retention is lost"* (p. 39). Therefore, the objective of the research is to determine the theoretical foundations and principles that support the use of visualization as a didactic method in the teaching-learning process of posing and solving mathematical problems.

In this order of ideas, Vale et al., (2018), highlight the usefulness of the use of visualization in the process of posing and solving mathematical problems, in this regard Hitt (2003), states that the mathematical visualization of a problem "*plays an important role, and has to do with understanding a statement by bringing into play different representations of the situation in question and this allows us to perform an action that can possibly lead towards the solution of the problem"* (p. 215).

In addition, better results are obtained when using visualization, if technological resources are used in its treatment, since it allows the identification of numerical patterns; between figures; of movement and relationship behaviors (Gutiérrez et al., 2020). In this sense, Adame et al. (2019), argue that, observing a graphical representation of a mathematical object, a variety of questions can arise in students, linked to changes in semiotic representations.

In this sense, the understanding of a conceptual content "*rests on the coordination of at least two registers of representation, the apprehension of a concept will only be achieved if there are activities of conversion from one representation to another and vice versa, thus promoting the construction of mathematical concepts*" (p. 365). From an epistemic point of view, visualization in mathematics differs from the conception provided in everyday language, where it is related more to the formation of images than to the construction and manipulation of mathematical objects (Blanco et al., 2019; Marmolejo et al., 2020).

From this point of view, visualization is the ability to move from one representation embodied in a semiotic system to another representation embodied in a different semiotic system, in a bidirectional way (Adame et al., 2019; Gutiérrez et al., 2020). In addition, Arcavi (2003), reveals that visualization can be analyzed as a double process, one that goes from the concrete to the abstract and another that goes from the abstract to the concrete. This Argentine author states that "*visualization offers a method to observe the invisible*" (p. 216). This "*observation*" can be mental and not related to physical objects or, it can be related to physical representations and then represent perceptible objects.

Similarly, Rojas (2009), bases mathematical visualization as a heuristic principle within the teaching-learning process of mathematics. This researcher is based on epistemic assumptions and axiological potentialities of visualization. In addition, they expose factors that make the presence of visualization as a principle, its actions and rules feasible.

Based on the above analysis, it is evident that the use of visualization is more explicit in some areas of Mathematics, as is the case of geometry. However, the fact that it is used in other predominantly analytical areas such as Algebra, Mathematical Analysis, Statistics and Probability, among others, supports the use of visualization as a general heuristic principle of Mathematics from an epistemic perspective (Reséndiz et al., 2018; Salazar, 2020; Rojas, 2021; Losada, et al., 2021).

From a didactic stance, different researchers have employed mathematical visualization as a method, however they are limited to its exemplification from a practical point of view (Sánchez, 2021). It is precisely this epistemic basis of visualization as a general heuristic principle, together with the methodological contributions of various researchers in the field of Mathematics Education, which allows us to support visualization as a didactic method.

DEVELOPMENT

The integration of the contributions of different researchers has made it possible to determine the fundamental premises that serve for the development of the didactic method. In this sense, the work of authors who deal with the process of posing and solving mathematical problems (Polya, 1962; Kilpatrick, 1987; Shoenfeld, 1985; Binyan et al., 2020; Zayas et al, 2023; Pacheco & Cáceres, 2024); on didactic methods in the teaching-learning process (Alhirtani, 2020; Casasola, 2020; Jiménez et al., 2020; Kjimova, 2020) and on the use of mathematical visualization in the process of posing and solving problems (Cruz 2020; Estrada et al., 2021; Vílchez & Ávila 2021).

Didactic methods are governed by principles and are composed of three basic elements, which are the didactic language; the auxiliary means; and the didactic materials. In addition to a correctly determined didactic action. In this sense, in the use of visualization in the teaching-learning process of problem posing and solving, the following didactic principles are identified:

1. Visualization is conceived with a well-determined purpose, which should make it possible to reveal the conceptual system needed to correctly pose a problem and integrate it, in such a way as to generate new solution strategies.

2. To achieve the objectives requires an adequate arrangement of the data presented in the problem, of the means that serve as support, of the resources available, as well as of the appropriate procedures. All this obeying a rigorous planning that allows students to appropriate the knowledge in an environment where critical reflection predominates.

3. The use of visualization should provide new challenges, as it contributes to educate new ways of thinking and acting to successfully face the resolution of problems in Mathematics.

4. Visualization in the teaching-learning process contributes to a more effective achievement of objectives. It allows a better use of time, so that this process is more comprehensible and active. In addition, technological materials and resources can be used, all in order to improve the quality of teaching and learning.

5. The use of visualization makes sense in the process of posing and solving problems of high difficulty for students. On the basis of the setting of simpler tasks that direct in a safe, simple and well-defined way the solution of the initially set tasks. The simplest tasks should be oriented towards the representation of data through symbols, graphs, figures, diagrams or any other semiotic system considered convenient and useful to develop problem posing and solving skills.

Visualization in the teaching-learning process of problem posing and solving allows the teacher to conceive tasks that promote teacher-student and student-student interaction. Its basic elements provide motivation, information and orientation to conceive and carry out their learning through the use of didactic materials that make it possible to illustrate, demonstrate, concretize, apply and record what is being studied.

Based on the above and taking into account the principles, basic elements, characteristics and ways of conducting learning that govern the didactic method postulated by researchers Mamani (2018); Kjimova (2020); and Real et al. (2021), mathematical visualization is identified as a didactic method in the teaching-learning process of problem posing and solving. In addition, it is considered that the use of this didactic method allows to dynamize the process of posing and solving problems, as well as to obtain the posing of situations that enrich the process of construction and reconstruction of new mathematical knowledge.

This didactic method is structured on the basis of means, resources and procedures that facilitate its implementation in educational practice. In addition, taking into account what Arcavi (2003) stated, regarding the double character of visualization, in agreement with Duval (1999), who sustains the need to move from one semiotic representation system to another in a bidirectional way, the following procedures are associated to it: ***Abstract representation*** of the objects, relations and operations that are revealed in the problem statement and ***concrete representation*** through symbols, graphs, figures, diagrams or other forms that allow revealing the interdependence that is established between the objects, relations and operations associated with the problem statement. That is, the representation of the conceptual system that appears in the problem and its relationships, in a certain semiotic system.

Different authors have identified a series of didactic requirements that must be taken into account when employing a didactic method (González & Suárez, 2018; López et al., 2021). These are emphasized below:

1. Consider individual and group characteristics in the approach of the tasks.
2. Take into account the motivations and interests of the students.

3. Incorporate the progressive use of information and communication technologies, prioritizing the use of educational and mathematical application software.
4. To consider an adequate treatment so that mistakes do not turn into failures, but become a starting point to achieve new learning.
5. To develop in students meta-cognitive and self-control strategies.
6. To propose collective learning activities, but keeping in mind that learning is individual.

The objectives of these didactic requirements are, in general, the construction and improvement of mathematical knowledge in students. In addition, in particular, the aim is to develop students' problem-solving and problem-posing skills. Also, to train future professionals in Mathematics Education didactically in the use of visualization as a dynamizer of the teaching-learning process. In some aspects, these requirements respond to the need to identify and interpret concepts and to reveal the relationship of these concepts with the process of problem posing and solving.

In the research, it is essential to clarify the meaning of the term dynamize. In this regard, according to the dictionary of the Royal Spanish Academy (RAE) dynamize means to give speed and intensity to a process and some of its synonyms are agilizar, activar, energizar, intensificar, fortalecer, afanar and apurar. In this direction, there is research in which the meaning of the term dinamizar is not clarified (Rubio and Montiel, 2017; Blanco et al., 2019). Therefore, it can be assumed that in these contexts dinamizar refers to the definition of the term given by the RAE.

In similar contrast, there is evidence of works where synonyms are used to define the term: "*dynamize is characterized by intensifying or strengthening the development of an activity by showing interest in what is being done or what is going to be done in the shortest possible time*" (Alvarado, 2016). Therefore, in this research the possibility of evaluating dynamization is confusing.

Regarding the dynamization of the teaching-learning process through the use of Information and Communication Technologies (ICT), the authors Vargas & Polo (2021), state that "*dynamizing the learning environment mediated by ICT requires various strategies that help the student to understand and assume the new role in which he/she must now play*" (p. 29). In addition, these authors relate the dynamization of the process with the formation of competencies and the protagonist development of the students.

Taking into account the results obtained on the meaning of the term "*dynamizing*" in the scientific literature, as well as the specificities of this research related to the teaching-learning process of problem posing and solving in the context of the initial training of the mathematics teacher, it is possible to establish a way to evaluate the dynamization of the process of problem posing and solving in the context of the initial training of the mathematics teacher. It is possible to establish a way of evaluating dynamization in this specific framework, if the dialectic unity between the process of posing and the process of solving problems is considered essential and, in addition, the psycho-pedagogical, heuristic and mathematical components related to the teaching-learning process of problem posing and solving are valued.

Defining concepts precisely in a scientific research allows establishing a common framework and ensures the understanding of the meaning of the terms used. Thus, in the research, dynamizing the teaching-learning process of problem posing and solving comprises three fundamental features in the framework of the training of the graduate in Mathematics Education:

1. To stimulate developmental learning, providing knowledge with meaning and sense, oriented towards the integral formation of the future Mathematics teacher.
2. To form modes of action that allow acting on the zone of proximal development, as an expression of heuristic reasoning when posing and solving problems.
3. To promote a critical conception of mathematical and didactic knowledge, under a close dialectic unity between problem posing and solving.

These characteristic features allow determining the degree of dynamization of the teaching-learning process of problem posing and solving, by evaluating whether they are manifested or not during the development of the process.

CONCLUSIONS

Visualization is established as a didactic method in the process of posing and solving mathematical problems. In this direction, its use allows students to access a conceptual system that facilitates understanding and the integration of new solution strategies.

Visualization has a specific purpose, which is to reveal the conceptual system necessary to approach mathematical problems. And in this specific context visualization should challenge students, encouraging new ways of thinking and acting in problem solving.

The use of visualization as a method promotes interaction between students and teachers, thus creating a favorable learning environment for interaction that facilitates the exchange of ideas and strategies.

Visualization can be implemented through various resources and didactic materials that illustrate and concretize mathematical concepts. This includes the use of

graphs, diagrams and technology, which enriches the teaching-learning process.

The visualization method should be developed as a bidirectional process that allows the transition between different semiotic representation systems. This includes both abstract and concrete representations, facilitating the understanding of the mathematical relationships and operations involved in the problems.

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