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MATHEMATICAL MODELING IN EDUCATION: THEORETICAL APPROACHES GUIDING PEDAGOGICAL PRACTICES

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ABSTRACT
Mathematical modeling in teaching should promote the active participation of students, establishing connections with pre-existing knowledge. This may include the application of already known models, the discussion of pertinent laws, or the analysis of variables. Thus, this article aims to address the contribution of mathematical modeling in education, considering the main theoretical approaches in force, namely, Burak's perspective, Bassanezi's constructs, and Biembengut's investigations. From the methodological point of view, this research is organized in the form of a bibliographic study that starts from content analysis and, at the same time, carries out a simultaneously descriptive and interpretative approach. The results indicate that when students can translate everyday situations, or those they conceive into mathematical language, they feel motivated to present solutions clearly, developing a more robust and effective education, which benefits them when entering the job market. It is concluded that the mathematical modeling of problem situations favors meaningful learning and contributes to the creation of environments that stimulate learning. Therefore, future investigations can address the significant learning of students in the aforementioned contexts or other educational environments, in addition to exploring how they interact with various technologies in modeling activities.

Keywords: Theoretical Approaches. Teaching. Mathematical Modeling.

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INTRODUCTION

Mathematical modeling has been one of the themes widely explored in investigations of educational environments. In this study, mathematical modeling is configured as an effective pedagogical alternative in the teaching of mathematics, highlighting the cognitive processes that students mobilize during modeling activities. The perspective that teaching and learning environments should integrate the potential of information and communication technologies has been the subject of several investigations (Borssoi; Almeida, 2015). Studies by Villarreal and Borba (2005), Ashburn and Floden (2006), and Howland, Marra, and Jonassen (2011) demonstrate how these technologies can provide interactive and enriching learning experiences for students.

It is important to recall that the movement for mathematical modeling in Basic and Higher Education began to consolidate in the 1970s, developing simultaneously in several countries, including Brazil. The first initiatives were promoted by mathematics teachers from Higher Education courses, especially in the area of Engineering, who sought to respond to the frequent questions of students about the applicability of mathematics, in addition to the criticism received from businessmen regarding the mathematical training of students (Biembengut, 2012).

In this movement of theoretical consolidation, mathematical modeling is configured as a relevant approach in Mathematics Education, attributing greater meaning to the teaching and learning process (Borssoi; Almeida, 2015). From this perspective, the analysis of problem situations transcends mathematics in its pure form, being improved by the application of mathematical concepts and tools (Ferri; Blum, 2009; Almeida; Vertuan; Silva, 2012).

Biembengut (2012) emphasizes that although recent graduates in mathematics can solve problems and possess an adequate knowledge of mathematical techniques, they often lack the necessary skills to formulate, plan, and critically evaluate the problems faced. As a response, many Higher Education professors, with mastery in applied mathematics, which involves mathematical modeling, began to develop activities that would enable students to understand the application of mathematical concepts and evaluate the results of problem situations. Therefore, in classes related to modeling, they sought to engage students in the choice of a problem of interest, ensuring that they saw themselves as an essential part of the investigative process, actively participating in the resolution of the challenge through the application of mathematics.

Biembengut (2012) also points out that, among the pioneers of this approach, David Burghes, from the United Kingdom, who collaborated with high school teachers to create materials aimed at modeling, and Aristides Camargo Barreto, from Brazil, who implemented modeling in his Mathematical Analysis and Integral Differential Calculus classes in Engineering and Mathematics Courses in the 1970s and 1980s.

In this context, the study presented in this article is justified by the existence of multiple initiatives of classroom practices, research, and extension promoted in several countries that have contributed significantly to the advancement of mathematical modeling in Basic and Higher Education, but still demand greater dissemination and effective implementation in the school environment. Lectures at educational events, in particular, have proven to be valuable sources for improving teaching, motivating many educators to adopt mathematical modeling in their classes after having contact with works that promote this practice.

Thus, in this continuous process, those who feel inspired to carry out activities, whether in the classroom or research, tend to share their experiences at events. However, even with the growing interest in modeling, there is still scant evidence of effective changes in teaching, especially about new adherents.

Therefore, there is an urgent need for comprehensive dissemination of mathematical modeling activities in education, focusing particularly on the conceptions that teachers adopt when using it and on the trends that have emerged over the forty years of mathematical modeling in Brazilian education. Thus, this study intends to discuss the contribution of mathematical modeling in the educational context, considering the different theoretical approaches in force, namely, Burak's perspective, Bassanezi's constructs, and Biembengut's investigations.

For this, this research is organized in the form of a bibliographic study that starts from the content analysis proposed by Bardin (2011), which allowed the organization, classification, and interpretation of qualitative data, facilitating the identification of patterns in the analyzed studies, in parallel the approach of Flick (2009) is adopted, which is simultaneously descriptive and interpretative. The description was used to encompass the recording, observation, analysis, classification, and understanding of the data; and interpretation was used as an expedient for the analysis of the manifestation configuration of the referential procedure evaluated.

As a result, modeling in the educational context plays a crucial role in establishing a closer connection between teachers and students, promoting a collaborative learning environment. Therefore, this dynamic facilitates the exchange of ideas and experiences, allowing the teacher to act not only as a transmitter of knowledge but also as a facilitator of active learning. Thus, understanding this process becomes essential to optimize pedagogical strategies and ensure that both educators and students benefit the most from this interaction.

METHODOLOGY

The research started, at first, from the reading and compilation of vast and diversified theoretical references on mathematical modeling and energy consumption, composing what is called bibliographic research. At the same time, the action was not dispensed with "[...] with autonomy and respect for copyright, being faithful to the bibliographic sources used in the study" (Prodanov; Freitas, 2013, p. 46).

From the methodological point of view, it is organized in the form of a bibliographic study that starts from the constructs of content analysis to support the interpretation of the data and the sources consulted. At the same time, it adopts a perspective that combines a descriptive approach, by systematizing and recording in detail the elements and information extracted, with an interpretative approach, which aims to attribute deep and contextual meanings to the observed phenomena.

Thus, the subsequent analyses and discussions developed here reflect a meticulous and integrated work, which articulates both the theoretical foundation and the practical application of the concepts addressed, contributing to a more comprehensive and critical understanding of the object of study.

MATHEMATICAL MODELING IN MATHEMATICS EDUCATION

The teaching of mathematics in Basic Education schools is still predominantly based on traditional lectures. In this model, the teacher presents the content he deems relevant on the board, while the students restrict themselves to copying this information into their notebooks and performing repetitive exercises based on what was taught (D'Ambrosio, 1989). This approach results in a mechanical practice of mathematics, in which students memorize formulas and algorithms only to ensure they perform well on assessments and get high grades.

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Therefore, the teacher needs to show how mathematics relates to everyday life, highlighting the relevance of the contents for understanding the world around them. This requires the search for new teaching methodologies that encourage students to engage with mathematical knowledge, promoting the integration between theory and practice. In this context, trends in Mathematics Education emerge that have stood out in contemporary discussions and practices, such as ethnomathematics, modeling, problem-solving, and the use of technologies.

By relating mathematical modeling to the school environment, directions emerge that guide the study and research of it. Authors of national and international literature refer to this as methodology, learning environments, and "mathematics education". According to Barbosa (2003, p. 240, apud Golin, 2011, p. 28), "modeling can be understood as a learning environment where students are invited to explore, through mathematics, situations from other areas." Meyer et al. (2013) also insert modeling into the concept of mathematics education. They highlight that:

> Modeling is a process of creating models in which the individual's action strategies on reality are defined, more specifically on *his reality*, loaded with interpretations and subjectivities specific to each modeler (Bassanezi, 2015, p. 15, emphasis added).

Thus, regardless of the approach chosen, mathematical modeling proves to be extremely valuable, as it allows teachers to combine theory and practice, allowing students to apply mathematics in their daily lives.

RESULTS

MATHEMATICAL MODELING

Mathematical modeling, according to Bassanezi (2002), consists of the art of transforming reality problems into mathematical problems and solving them by interpreting their solutions in the language of the real world. In its various aspects, it is a process that combines theory and practice, motivating its user in the search for understanding the reality that surrounds him and in the search for ways to act on it and transform it.

In this same perspective, it also consists of a process to obtain a model, by formulating, solving, and elaborating expressions that are valid not only for the solution of the problem under study, but that later serve as support for other applications and theories (Biembengut; Hein, 2004, p. 19).

Mathematical modeling is a set of procedures, whose objective is to build a parallel to try to mathematically explain the phenomena that man experiences in his daily life, helping to make predictions and decisions (Burak, 2012).

Thus, the strategy to solve phenomena to be modeled is based on a set of models that is not limited only to the studies of pure mathematics but has its applicability in several areas of knowledge such as chemistry, physics, biology, and biomathematics, among others.

MODELING STEPS

In the Brazilian literature, renowned authors cite that the stages of mathematical modeling constitute an orderly process that contributes to educational learning in Basic Education. Thus, it is possible to analyze the phases or stages of mathematical modeling and its conceptions, building a model that values the knowledge of each student involved in the research. In this way, the construction of a mathematical model that transcends the simple creation of a mathematical formula is sought.

Therefore, the publications of Burak (2012), Biembengut and Hein (2018), and Bassanezi (2019) are taken as a basis. Mathematical modeling has produced hopeful results in both mathematics and science education. However, the authors describe different styles of thinking that result in different modeling cycles to organize didactic activities in the school environment.

A modeling cycle can start in the classroom with the presentation of a problem in the student's reality, stimulating the search for solutions that involve the application of mathematical concepts. This is followed by a sequence of logical thoughts to motivate the resolution of the problem. The discussions generated can improve students' ability to interpret as they take a critical stance when trying to solve the real problem and realize that there may be more than one solution, and multiple paths to reach resolution. The modeling cycle is essential to analyze situations that are experienced by everyone daily.

The Basic Education student, when inserted in a modeling cycle, must occupy a central place in the learning scenario, being able to discuss, exemplify, and know how to solve the real problem proposed in the teaching of mathematics. The proposal here is that when facing this challenge, the student can face the difficulties by offering possible solutions that signal the development of their learning in the real world in which they live.

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Thus, in Brazilian education, different authors describe the way to organize didactic actions for the development of mathematical modeling in Basic Education. The three authors to whom this research intends to align are presented below. However, along the way, other equally important authors may be highlighted, serving as a support for knowledge and contributing to the development of the work.

Stages by Dionízio Burak

This author assumes the conception of mathematical modeling in the context of education from a social understanding of mathematics by considering that "[...] all-natural scientific knowledge is social knowledge" (Burak, 2012, p. 54). It also assumes modeling as a teaching methodology, by presupposing premises originating in philosophy. From this perspective, for the author:

> Mathematical modeling is a set of procedures whose objective is to build a parallel to try to explain, mathematically, the phenomena present in the daily life of human beings, helping them to make predictions and decisions, and which is also based on two premises: 1) the interest of the group of people involved; 2) data are collected where the interest of the group of people involved is present (Burak, 2012, p. 88).

The author suggests that the modeling process in the classroom should be carried out in five stages, as shown in Chart 1: i) Choice of Theme; ii) Exploratory Research, iii) Survey of Problems; iv) Problem-Solving and Content Development in the Context of the Theme, and v) Critical Analysis of the Solution.

Chart 1 – Stages of mathematical modeling by Dionízio Burak

STEPS	MEANING
Choice of Theme	Stage in which the theme is chosen for the development of mathematical modeling, based on the interest of the group or groups of students involved.
Exploratory Research	Stage in which students are encouraged to seek data on the chosen theme, which can be bibliographic or field.
Problem Raising	This is a stage in which students are encouraged to make a relationship between what they research and mathematics, supported by data collection, they can propose simple or complex problems, allowing the use of knowledge.
Problem Solving and Content Development in the Context of the Theme	Stage in which the problem is solved, the development of content that will be relevant and significant to the knowledge of mathematics, prioritizing the student's action in the context of the theme and its elaboration.
Critical Analysis of the Solution	A stage in which debates will always take place in the sense of a different look, allowing the student to reflect on his intention and discovery that will help in the formation of citizenship. Strong point of modeling.

Source: Adapted by the author.

The Choice of Theme, according to the author, is based on the interest of the group or groups of students involved in the teaching and learning process. Initially, the teachers propose the themes or the students themselves suggest topics, either out of curiosity or to solve some problem, and then the students are invited to contribute with their opinions.

Once the theme is chosen, Exploratory Research is carried out to deepen the knowledge about the context, identify relevant information, and support the development of the activities. For this, students must organize themselves, and know how to enunciate questions that produce satisfactory answers. Therefore, the "[...] exploratory research has the purpose of inserting students in activities that form and develop attitudes and postures of an investigator" (Burak, 2012, p. 98).

The data collected during the exploration of the research serve as the basis for the Survey of Problems carried out by the students. At this stage, the development of the student's autonomy goes through the choices to make conjectures, build hypotheses, analyze situations, and make decisions. The ability to articulate data and formulate questions originating from the investigated situation has formative and attitudinal value and great educational significance. It is an important step towards citizenship education, aiming to translate and transform situations of the world/life into mathematical problems.

For Problem Solving, students must make use of mathematics. The teacher can present new content or resume content that has already been studied and that is necessary to solve the problem. Mathematical models are built when you want to elaborate a mathematical expression to solve the problem.

After solving the problem, a Critical Analysis of the Solution found by the students is made. This stage "[...] it enables both the deepening of mathematical and non-mathematical aspects, such as environmental, social, cultural and anthropological, involved in the theme" (Burak, 2012, p. 100).

Burak assumes a style of thinking in modeling based on a social understanding of mathematics, considering that mathematical knowledge is social. In this sense, he conceives modeling as a teaching methodology that consists of a set of procedures, which aims to build a parallel to explain the phenomena present in people's daily lives through mathematics, helping them to make predictions and decisions. To this end, this author proposes two basic guidelines: the first is that the interest of the group of students should be taken into account, and the second is that the data should be collected where the interest of the group of people involved in the modeling process occurs.

Thus, it is observed that mathematical modeling is a set of procedures or methods whose purpose is to obtain a mathematical model that allows the elaboration of mathematical explanations for the phenomena that human beings encounter in everyday life, leading them to make predictions and decisions. Although this set of procedures aims at the elaboration of a mathematical model, this author reflects that the production of a model may not occur effectively in the modeling stages, in this case, the process becomes important to favor critical vision and decision-making.

Stages by Maria Salett Biembengut

Biembengut and Hein (2018), call modeling mathematical modeling applied to education.

> Mathematical modeling is, therefore, an art, when formulating, solving, and elaborating expressions that are valid not only for a particular solution but also serve, later, as a support for other applications and theories. Generically, it can be said that mathematics and reality are two disjoint sets and modeling is a means of making them interact (Biembengut; Hein, 2018, p. 12)

According to the authors Biembengut and Hein (2018), the objective of those who do mathematical modeling is to establish a mathematical model of a problem situation to be able to solve, understand, or modify it. The objective of the modeling is to promote knowledge to the student in any period of schooling, doing research in front of the curricular structure, that is, in the physical space and in the time allocated to this purpose. For this, modeling appropriates the process of mathematical modeling.

This process, as shown in Figure 1 and described in Chart 2, can be developed in three stages, subdivided into six sub-stages, namely: I - Interaction: a) recognition of the problem-situation; b) familiarization with the subject to be modeled and the theoretical framework. II - Mathematization: a) formulation of the problem that leads to the hypothesis; b) solving the problem in terms of the model. III - Mathematical Model: a) interpretation of the solution; b) validation of the model that leads to the evaluation (Biembengut; Hein, 2018, p. 13).

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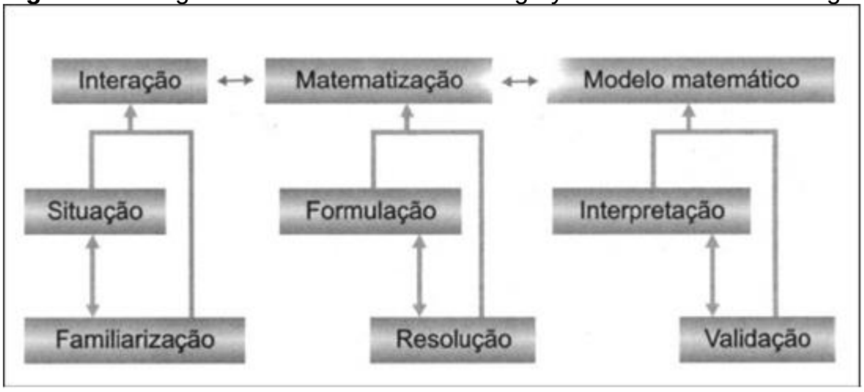
Figure 1 – Stages of mathematical modeling by Maria Salett Biembengut



Source: Biembengut; Hein (2018).

In Stage I - Interaction, once the situation to be studied has been outlined, a study on the subject must be carried out indirectly (through books and specialized journals, among others) or directly, in loco (through field experience, experimental data obtained from specialists in the area). The theme should make it possible to redo or build a model by analogy.

For this, symbols are used that identify a sign, a word, or a particular meaning. This stage requires the following sub-steps: to explain the theme, raise questions or suggestions, select questions that favor the development of the curricular content, and raise or present data on the theme.

Chart 2 – Stages of mathematical modeling by Maria Salett Biembengut

STEPS	MEANING
Interaction: Recognition of the Problem-Situation; Familiarization with the Theme; and Theoretical Framework.	Comment on the theme, raise questions, select questions to develop the content, and collect data. Seek information on the subject through books, magazines, field experience, and professionals in the area.
Mathematization: Formulation of the Problem that leads to Hypotheses; Problem Solving in terms of the Model.	Raise hypotheses. Express data, develop content, exemplify, and formulate. Transform the problem situation into mathematical language. Arrive at arithmetic expressions, formulas, algebraic equations, graphs, and computer programs that show a solution or allow the deduction of a solution.
Mathematical Model: Interpretation of the Solution; Validation of the Model that leads to Evaluation.	Resolution of questions, interpret, evaluate, validate. Evaluate what confirms the level of approximation of the model with the situation under study. Procedure through interpretation of the model concerning the implications generated by the solution and validation. If the model does not meet the objectives of the study, it will return to the mathematization stage and make the necessary adjustments.

Source: Adapted by the author.

Stage II - Mathematization is the most complex and "challenging", in general, it is subdivided into problem formulation and resolution. It is here that the "translation" of the problem situation into mathematical language takes place. Intuition, creativity, and accumulated experience are indispensable elements in this process. In the formulation of the problem, hypotheses are especially important. At this point, the information (relevant and non-relevant) must be classified, identifying facts involved; deciding which factors to pursue, raising hypotheses; selecting relevant variables and constants involved; selecting appropriate symbols for these variables, and describing these relationships in mathematical terms. The main goal, at this point in the process, is to come up with a set of arithmetic expressions or formulas, algebraic equations, graphs, representations, or computer programs, that represent the model and lead to the solution, or allow the deduction of a solution.

In solving the model, the analysis of the mathematical "tools" available is carried out, this requires a keen knowledge of the mathematical entities used in the formulation. The computer can be an indispensable instrument: especially in situations in which it is not possible to solve them through continuous processes, then approximate results are obtained by discrete processes. It should be noted here that many unsolved mathematical models in the last century have led to the development of other branches of mathematics.

In Stage III - Mathematical Model, the conclusion of a mathematical model requires an evaluation to determine how close it is to the problem situation originally represented and, consequently, also to evaluate the degree of reliability of its use. Initially, it is necessary to interpret the model, analyzing the implications of the solution derived from what is being investigated. In a second moment, its adequacy must be verified, returning to the problem situation to assess the significance and relevance of the solution and validation process.

In this way, Biembengut and Hein (2018) call "mathematical modeling" the essence of mathematical modeling applied to education and which aims predominantly at the school curriculum. Although it is important and often necessary to know the modeling steps, to help in the didactic organization of teaching tasks, the teacher, however, can also propose sets of steps or phases to be followed. Here the phases proposed by the authors previously commented are not denied, but it is ratified that, starting simply from the idea of mathematical modeling as the construction of mathematical models of real problems, the modeler can use or not such phases, adding other steps or can create his modeling cycle.

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Stages by Rodney Bassanezi

For this author, mathematical modeling is a process that aims to create models. In this process, the individual's action strategies on his or her reality are defined, and loaded with interpretations and subjectivities specific to each modeler. For him, "[...] mathematical modeling is simply a strategy used to obtain some explanation or understanding of certain real situations" (Bassanezi, 2015, p. 15).

The author points out that in the process of reflecting on the portion of reality, arguments considered essential are selected so that a formalization can be obtained, that is, the mathematical model. To do this, the first step is to find experimental data or expert inferences on the topic investigated, that is:

> The process begins with the choice of the topic of study (at this point, there is still no idea of the mathematical content that will be used to solve the questions posed by it). From there, we say to beginners: when you have an idea of what to do to deal with the topic, start by "counting" or "measuring", because, with this procedure, it is fatal to come up with a table of data. The arrangement of data in a Cartesian system and a good adjustment of its values will facilitate the visualization of the phenomenon under study, providing the elaboration of questions, the proposals of problems, and the development of conjectures that can lead to the elaboration of laws of formation. The formulation of mathematical models is simply a consequence of the transposition of this process (Bassanezi, 2019, p. 43).

To obtain a model, Bassanezi (2019) proposes a simplified scheme designating four stages, as shown in Figure 2 and described in Chart 3, namely: I) Non-Mathematical Problem (choice of themes); II) Experimental Data (data collection); III) Mathematical Model (data analysis and model formulation); and IV) Solutions (validation). To move from one stage to another, intellectual activities are necessary, which are the actions performed by the modeler, called: experimentation, abstraction, resolution, validation, and modification. The continuous arrows in Figure 2 indicate the first approximation, on the other hand, the search for a mathematical model is a dynamic process, indicated by the dotted arrows.

In this context, the path of mathematical modeling proposed by Bassanezi (2019) starts from Stage I - Non-Mathematical Problem. It is observed that the choice of the theme will also depend on the orientation of the teacher, who will evaluate the feasibility of the subject to be modeled and the sources of information. Next, the first action is the experimentation phase, that is, from the choice of the theme, laboratory activities are carried out to obtain data. Therefore, the modeler has an important role, being able to direct the research by guiding the calculations and obtaining the parameters of the models,

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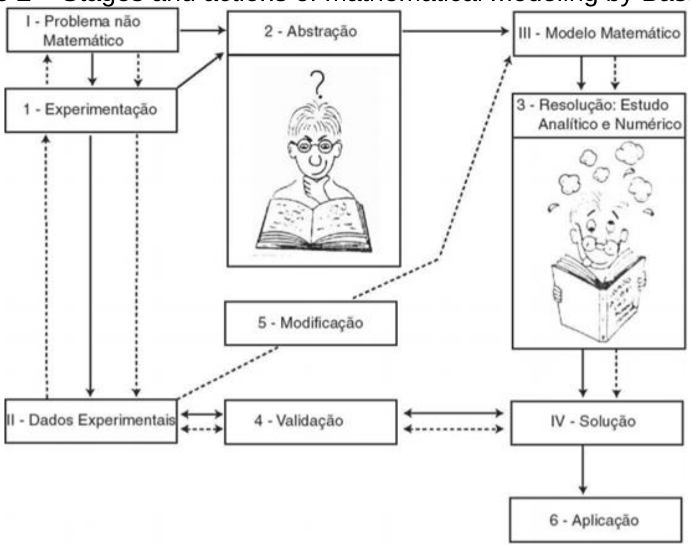
his technique, and the statistical methods involved in the research can give a greater degree of reliability to the data obtained (Bassanezi, 2019). It is also observed that this collection can be carried out through interviews and surveys carried out with random sampling methods; through bibliographic or field research, using data already available in books or specialized journals; and through experiences planned by the students themselves.

Figure 2 – Stages and actions of mathematical modeling by Bassanezi



Source: (Bassanezi, 2019).

Chart 3 – Stages of mathematical modeling by Rodney Bassanezi

STEPS	MEANING
Non-Mathematical Problem: Choice of Theme.	Survey of possible study situations, to enable questions. The theme is chosen by the students or according to the needs of the majority. The final choice of the theme will also depend on the guidance of the teacher, who will evaluate the feasibility of the subject that will be modeled and the sources of information.
Experimental Data: Data Collection.	This collection can be carried out through interviews and surveys carried out with the sampling methods consulted; through bibliographic research, using data from the literature; and through experiences carried out by students.
Mathematical Model: Data Analysis and Model Formulation	After collecting the data and performing its tabulation, the mathematical model is formulated, which represents the situation using variables.
Solution: Validation	A process that is accessible or blocked. The analysis is conditioned to several factors, the most common being the confrontation of real data with the data simulated by the model. In this phase of demonstrating the model in the graph, the variations that show the reality that the research shows should appear.

Source: Adapted by the author.

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Once the data collection is carried out, Stage II - Experimental Data is reached and the second action, called abstraction, is carried out. It is in this phase that the formulation of the model must occur, subdivided into small actions. Initially, the variables that describe the evolution and the control variables of the system are selected. Then, the problematization or formulation of theoretical problems in a language specific to mathematics is sought. It is observed that the statement of the problem must be clear, understandable, and operational, because, at this stage, the formulation of the problem indicates what is intended to be solved. Thus, hypotheses must incorporate mathematical theories that can be tested. The last action within this phase is simplification and, at this point, the model that gives rise to a mathematical problem must go through this process, according to the degree of complexity of the problem in question (Bassanezi, 2019).

In Stage III, the mathematical model that represents the studied situation is obtained, it is observed that many mathematical models are obtained by the solution of variational systems, so it is essential to understand how the variation of the variables involved in the investigated phenomenon occurs. Next, the third action is carried out, which is the resolution of the mathematical model, which can be analytical or numerical. This phase is always linked to the degree of complexity in the formulation of the model, and can often only be made feasible through computational methods, resulting in an approximate numerical solution.

With the model solution, Step IV is reached, and the validation action is carried out, where the acceptance, or not, of the proposed model occurs. This analysis is conditioned to several factors, the most common being the confrontation of real data with the data simulated by the model. For the author "[..] a good model must serve to explain the results and can predict new results or unsuspected relationships" (Bassanezi, 2019, p. 22).

The empirical data must be confronted with the hypotheses, comparing the solutions and predictions with the values obtained in the real system. At a minimum, the model should predict the values that originated it. The interpretation of the results obtained can be done with the help of graphs of the solutions, which can facilitate evaluation and predictions, or even suggest an improvement of the model (Bassanezi, 2019). Finally, considering that some factors related to the original problem can cause the rejection of the model, in the face of a refusal, the modification action is taken. In this, the solution is to go back to the initial data of the experiment and resume the path of mathematical modeling.

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CONCLUSION

In the present research, mathematical modeling was analyzed as a teaching and learning methodology, focusing on its different theoretical approaches and its implications in the educational context. The study showed that mathematical modeling enables the connection between theory and practice, favoring more meaningful and contextualized learning. The perspectives of Burak, Bassanezi, and Biembengut reinforce that modeling not only contributes to the cognitive development of students but also expands their ability to analyze and solve problems critically and autonomously.

The results suggest that mathematical modeling can strengthen collaborative work, stimulating interaction between students, teachers, and technologies. In addition, continuous problematization proved to be a fundamental element in the teaching and learning process, promoting reflection on the everyday phenomena studied, and encouraging the search for grounded mathematical solutions.

Thus, this research reaffirms the relevance of mathematical modeling as a methodological resource for the teaching of mathematics, providing a more dynamic and investigative learning environment. However, its implementation still requires efforts to overcome pedagogical challenges and expand its presence in teaching practices.

In future works, it is suggested to deepen the investigation of the impact of mathematical modeling in different educational contexts, analyzing how students interact with various technologies in this process, and how modeling can be adapted to enhance the teaching of different mathematical contents. Thus, it is hoped that this study will contribute to strengthening the use of mathematical modeling in education, promoting more engaging and effective approaches to learning.

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