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CONCEPT MAPS AS FACILITATORS OF MEANINGFUL LEARNING IN MATHEMATICS TEACHING

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ABSTRACT

This theoretical article investigates the contribution of concept maps to meaningful learning in mathematics teaching, proposing a reflection on how this tool can facilitate the interconnection of previous and acquired knowledge, promoting a deeper and more lasting understanding of mathematical concepts. Its general objective is to investigate the use of concept maps as a means of identifying signs of Meaningful Learning. The study is based on David Ausubel's theory of meaningful learning and highlights how concept maps can be used not only to organize and represent knowledge, but also as diagnostic and formative tools in the educational process. The research is based on a literature review and qualitative exploring the effectiveness of concept maps in promoting meaningful learning. It was realized that the concept map is a valuable tool to identify and address gaps in students' knowledge, promoting a more solid and integrated understanding of mathematical concepts.

Keywords: Concept Maps. Meaningful Learning. Mathematics Teaching. Theoretical Research. Learning Theory.

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INTRODUCTION

The field of learning is broad when it comes to understanding aspects related to human cognitive development. Learning is understood as the individual's ability to offer adaptive solutions in the face of the demands and challenges imposed by constant interaction with the environment. This process must be seen as continuous, dynamic, individual and cumulative. For this to occur, the subject needs to be an active agent in the processing of information, attributing meanings to what is presented to him. Otherwise, by adopting a passive posture, you run the risk of not assimilating knowledge.

Concept maps are essential tools for reviewing prior knowledge, playing a crucial role in understanding and consolidating learning.

Concept maps are graphical representations similar to diagrams, which indicate relationships between concepts linked by words. They represent a structure that ranges from the most comprehensive to the least inclusive concepts. Its use helps in the hierarchical ordering and sequencing of the concepts studied.

Ausubel's learning theory can be thought of as directed learning in the classroom, but the responsibility for the acquisition of knowledge is not exclusively the teacher's, it depends a lot on the student, as he must be predisposed to learn, in this case, the teacher assumes a role of facilitator in the learning process.

Concept maps are great allies to promote meaningful learning and can be useful as resources in the following stages of teaching from the Ausubelian point of view:

a) identify the structure of meanings accepted in the context of the teaching subject;
b) identify the subsumers necessary for meaningful learning;
c) to identify the pre-existing meanings in the learner's cognitive structure;
d) sequentially organize the content and select curricular materials, using the ideas of progressive differentiation and integrative reconciliation as programmatic principles;
e) teaching using previous organizers, to build bridges between the meanings that the student already has and those that he would need to have in order to meaningfully learn the teaching subject (Moreira, 2003).

According to Frota (2001), there is a consensus that the teaching of Mathematics should be detached from a step-by-step approach, focused only on the learning of procedures, and that little promotes the development of relational mathematical knowledge, in which the individual is encouraged to establish new connections between the various

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concepts studied (p. 91). To break with this limitation, the teacher should propose activities that encourage students to make conjectures, generalize and argue, so that they can later formalize mathematical knowledge. After all, "knowledge is built from the perceptions and actions of the subject... and through much research and exploration" (Gravina & Santarosa, 1998, p. 1-2).

The general objective of the research was to investigate the use of concept maps as a means of identifying signs of Meaningful Learning.

The specific objectives of this study were: (1) To describe the perceptions related to studies on concept maps; (2) To analyze the implications of the use of concept maps in the teaching of Mathematics; (3) Reflect on the impact of concept maps on the students' learning process.

This research is important because it proposes new ways to achieve success in the training path at various levels of education, in addition to allowing teachers to reflect on student learning. The relevance of this work covers the teaching and learning of mathematics, identifying the need for students to develop significant mathematical knowledge.

JUSTIFICATION

David Ausubel's theory of meaningful learning emphasizes the importance of the relationship between new knowledge and previous knowledge. The concept maps, developed by Novak (NOVAK; CAÑAS, 2010, p. 29), are useful tools to facilitate this interconnection in the context of mathematics teaching. This study seeks to understand how these tools can contribute to more meaningful and lasting learning.

In addition to facilitating the interconnection between knowledge, concept maps allow students to visualize the connections and hierarchies between mathematical concepts, promoting a deeper understanding of the topics studied. This visualization not only helps identify gaps in knowledge, but also strengthens areas of weakness, which is essential for building a solid foundation of mathematical understanding.

Concept maps also serve as diagnostic and formative assessment instruments. By using them, teachers can gain valuable *insights* into student progress by identifying which concepts have been understood and which need reinforcement. This enables a more effective and personalized pedagogical intervention, adjusting teaching strategies to meet the specific needs of each student.

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Additionally, concept maps encourage active and collaborative learning. When students work together on creating these maps, they engage in discussions and exchanges of ideas that enrich understanding and promote critical thinking skills. This collaboration improves not only individual learning, but also strengthens classroom dynamics, creating a more inclusive and participatory learning environment.

Therefore, incorporating concept maps into mathematics teaching not only facilitates the construction of meaningful knowledge, but also offers a powerful tool for checking for evidence of meaningful learning. By exploring the interrelationships between concepts, assessing student progress, and promoting collaborative learning, concept maps contribute to a more meaningful mathematics education, aligned with the principles of Ausubel's theory of meaningful learning, which justifies this research.

THEORETICAL FOUNDATION

According to Gondino (2004), when analyzing student learning, the main objective is for them to understand Mathematics and develop skills and abilities in this field. To achieve this goal, it is crucial to adjust the teaching of certain concepts to the learning conditions and prior knowledge of the students, using clear and accessible language. This is due to the fact that, in order to consolidate learning, it is essential that students understand the meaning of Mathematics.

Given this perspective, the present work presents some reflections on Ausubel's Theory of Meaningful Learning and the use of concept and mental maps in the educational context. So, these theoretical contributions are fundamental to investigate how these tools can be used to improve the teaching and learning of mathematics. Concept and mind maps allow students to visualize the relationships between different concepts, facilitating a deeper and more meaningful understanding of mathematical content. In addition, they serve as valuable instruments to assess and reinforce students' prior knowledge, adjusting teaching to their specific needs.

For Ausubel (2000), this involves, above all, the construction of new meanings from the learning material presented. For this to happen, it is essential that the student adopts a meaningful learning attitude and that the material offered has significant potential.

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AUSUBEL'S THEORY OF MEANINGFUL LEARNING

Brazilian education faces numerous challenges, often characterized by mechanized teaching and an emphasis on memorization. The Theory of Meaningful Learning, developed by David Ausubel, highlights the importance of constructing new meanings from potentially meaningful materials (Ausubel, 2000, p. 25). Meaningful learning occurs when new knowledge is substantively related to the student's previous knowledge.

It is important to note that Meaningful Learning should not be confused with the mere learning of meaningful material. It is essential to highlight that the learning material has only potential for meaning. Thus, a Meaningful Learning mechanism is necessary for genuine understanding to occur. Even if the learning material contains intrinsically significant elements (such as pairs of adjectives), each element of the learning task, as well as the task as a whole (such as memorizing a list of seemingly unrelated words), is not, in and of itself, logically meaningful. Moreover, even logically significant materials can be learned merely by memorization if the student's learning method is not truly meaningful (Ausubel, 2000).

From this perspective, Meaningful Learning allows students to build new knowledge based on their previous knowledge. The integration between this knowledge is essential to achieve Meaningful Learning. Moreira (2012) justifies this by explaining that Meaningful Learning is characterized by the interconnection of previous and new knowledge. In this process, previous knowledge achieves new meanings or greater cognitive stability.

On the contrary, when addressing the constant evolution of education, we are currently faced with a worrying factor: educational inequality. Educational inequality refers to the methods used to achieve quality teaching and learning. Meaningful Learning is a means to achieve success, but, according to Ausubel (1978), "the essence of the meaningful learning process is that symbolically expressed ideas are related in a substantive (non-literal) and non-arbitrary way to what the learner already knows, that is, to some aspect of his knowledge structure" (p. 41). Meaningful learning presupposes that: a) the material to be learned is potentially meaningful for the learner, that is, relatable to his cognitive structure in a non-arbitrary and non-literal (substantive) way; b) the learner manifests a willingness to relate the new material in a substantive and non-arbitrary way to his knowledge structure.

Moreira (2014) points out that, regardless of the importance of the content to be learned, if the learner only seeks to memorize it literally and arbitrarily, the learning process

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and result will be mechanical. Similarly, even if the student is motivated, the learning process and outcome will not be meaningful if the material does not have significant potential. Therefore, for learning to be meaningful, the material depends on at least two factors: its logical nature and the cognitive structure of the learner.

As for the nature of the material, that of being non-arbitrary and logically significant. As for the cognitive nature of the individual, the subsumptive concepts that will relate to the material to be learned must be available.

CONCEPT MAPS VS MIND MAPS

Concept maps, created by Novak (1972), are two-dimensional graphic representations that highlight the relationships between concepts, based on the Theory of Meaningful Learning. Unlike mind maps, which are more focused on organizing ideas for writing texts, concept maps help in understanding and visualizing connections between concepts. However, it is common to find situations in which there are difficulties in understanding and differentiating Mind Maps and Concept Maps.

Based on the studies of Marques (2008), Mind Maps are instruments that help in the writing of long texts, which include a variety of themes and subthemes, in addition to being pertinent in the presentation of information regarding sequential procedures. In this way, the contribution of mind maps in the area of education is highlighted mainly by providing the student with the construction of schemes that symbolize reasoning. And Dell'Isola (2012) explains that the mind map is a graphic organizer with a web structure, which develops around a central issue, represented by a symbol in the middle of the diagram.

Research developed by Santos *et al*. (2021) the Concept Maps designed by Novak (1972) were based on Ausubel's Theory of Meaningful Learning and defined them as two-dimensional graphic representations of a set of concepts, highlighting the relationships between them. It is also agreed with Moreira and Rosa (1986) that Concept Maps are characterized as graphic representations that describe the connections between different concepts. In more detailed terms, these maps can be interpreted as hierarchical representations intended to capture the conceptual structure of a field of study or a specific portion of that field.

The study of concept maps happens because in the current context, the ability to organize and understand complex concepts is essential. Then we saw Concept Maps as visual tools that represent relationships between ideas and information, they emerged as a

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powerful approach to learning, teaching, research, and organizing knowledge. These graphical representations allow us to visualize concepts, but they also help us identify patterns, highlight connections, and clarify thinking.

There is no consideration of rigorous models for the elaboration of Concept Maps, but it seeks to clearly find the hierarchies between the concepts. The most common way to present a Concept Map is to highlight the most relevant concepts at the top and the complementary ones directed to the bottom in a hierarchical way. An important criterion is to build a map with accessible reading so that it does not become a tool that the student ends up memorizing (Moreira and Rosa, 1986).

Novak and Cañas (2010) consider that Concept Maps are characterized as graphic tools for the organization and representation of knowledge. They include concepts, usually contained in ellipses or rectangles, and the relationships between those concepts, indicated by lines that connect them. The words on these lines, called linking words or phrases, specify the relationships between two concepts.

CONCEPT MAPS IN THE EDUCATIONAL CONTEXT

Concept maps reveal themselves as an educational tool of significant relevance, playing a fundamental role in facilitating learning and organizing knowledge. Developed by Joseph D. Novak in the 1970s, these visual instruments are designed to represent relationships between concepts, promoting a deeper and more structured understanding of the contents covered.

The main importance of concept maps is their ability to transform isolated information into an integrated knowledge system. By making use of concepts and the relationships that exist between these concepts, these maps allow students to clearly and systematically visualize the interconnections between different ideas. This process can facilitate memorization and promote critical and reflective understanding, which is essential for the development of cognitive skills.

In addition, concept maps are valuable tools for diagnostic and formative evaluation. They can be used to identify preconceptions and misconceptions that students may have, adjusting teaching strategies as necessary. The construction of concept maps by the students themselves serves as a metacognitive activity, encouraging them to reflect on their own learning process and to monitor the progress achieved.

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As cognitive strategies for the organization of knowledge, concept maps enable numerous gains of a metacognitive nature, since they mobilize the student in the planning, monitoring and regulation of their own thinking and actions (BORU-CHOVITCH, 1999).

In the context of collaborative teaching, concept maps promote interaction and cooperation among students. By working together in the elaboration of a concept map, students discuss, argue and negotiate meanings, which enriches collective learning. This collaborative aspect is particularly important in active learning environments, where student engagement is a determining factor for educational success.

Technology has also expanded the use of concept maps. The available digital tools allow the creation, editing, and sharing of maps in a dynamic and interactive way, facilitating the integration of multimedia resources and collaboration at a distance. These technological platforms make the process more accessible, stimulate creativity and innovation in the use of concept maps.

In this way, concept maps constitute a pedagogical methodology that promotes the organization of knowledge, metacognition, continuous assessment and collaborative learning. The application in the educational context contributes significantly to the integral development of students, preparing them to face complex challenges with a solid base of interrelated knowledge. Thus, the incorporation of concept maps in the planning and execution of teaching can be seen as a highly recommended practice, aligned with the best contemporary educational strategies.

METHODOLOGY

This work is based on a bibliographic research, that is, it seeks to identify, review and analyze the existing literature on a given topic. A fundamental stage in social research, according to Gil (2008), which provides a solid basis for carrying out more in-depth studies. The author emphasizes the need to approach this stage with rigor and care, ensuring a well-founded and contextualized research.

This study adopts the qualitative research method, being the one that plays a crucial role in advancing understanding in various disciplines, providing a deeper and contextualized understanding. Qualitative research involves specific methods, often associated with other researchers, such as in-depth interviews, content analysis, case studies, and ethnographic research. These methods have their own characteristics and approaches that aim to obtain a deep understanding of social phenomena, in contrast to

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data quantification, which is more characteristic of quantitative research, as highlighted by (Lakatos and Marconi, 2019).

The procedure used in this research falls into the category of case study, this approach allows an in-depth investigation of the phenomenon in the natural context. According to Yin (2015), the case study is an empirical investigation that analyzes in detail a phenomenon in its natural context, especially when the boundaries between the phenomenon and the context are not clearly defined.

The research begins with a survey of published scientific papers, including dissertations, theses and articles. The search was carried out in the Capes Periodicals Platform and in the Brazilian Digital Library of Theses and Dissertations, BDTD. To search for the works, the following descriptors were used using the Boolean operators "AND" and "OR": (MATHEMATICS TEACHING) AND (MATHEMATICS LEARNING) AND (CONCEPT MAPS) AND (MEANINGFUL LEARNING), during the period from 2019 to 2023 and 58 works were located.

After the theoretical foundation, the research proceeds to a case study with a qualitative approach. Through this study, we seek to describe concepts related to concept maps; conceptualize Meaningful Learning and highlight the use of concept maps as a tool to achieve Meaningful Learning. From the analysis of the abstract of these studies, 5 studies were selected that were in accordance with the objective of this study, described in Chart 1, named P1 to P9:

Chart 1: Studies that include Concept Maps and Meaningful Learning

	Author(s) and Year	Title	Objective of the research
P1	João Carlos Krause, Charline Da Silva Andreola, Rozelaine Contri. 2020.	Using Concept Maps for Meaningful Geometry Learning	To analyze whether the construction of concept maps using the CmapTools software can help in the process of teaching and learning geometry, and the study is based on David Ausubel's theory of meaningful learning.
P2	Fernando Guimarães da Silva, Rogério de Aguiar, Ivanete Zuchi Siple. 2021	Quadratic Function Learning: An Experience with Mathematical Modeling in Youth and Adult Education	Propose a mathematical model to describe a horizontal launch of a certain object from an aircraft in mid-flight, aiming to contribute to meaningful learning for students.
P3	André Ricardo Lucas Vieira. 2020.	Concept maps in mathematics teaching: experience in youth and adult education	To understand how the students of a class, in the High School modality of Youth and Adult Education, achieve polygon learning from the use that the teacher makes of the concept map as a didactic teaching strategy.
P4	Cristiano da Conceição Barreto. 2019.	Concept Maps in Mathematics classes	To encourage an intelligent use of concept maps as support instruments in the process of evaluating student learning.

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P5	Vanice Pasinato da Trindade. 2019.	Evaluation of learning: analysis of conceptions of future Mathematics teachers from the perspective of the theory of meaningful learning	To identify conceptions about learning assessment in the context of the initial training of mathematics teachers and to analyze how these conceptions can contribute to teaching practices that foster meaningful learning.

Source: authors, 2024.

REFLECTIONS ON THE CONTRIBUTION OF CONCEPT MAPS IN THE CONSTRUCTION OF MATHEMATICAL CONCEPTS

In the P1 research, the author highlights that concept maps allow students to be the main agent in the construction of knowledge. Therefore, the authors identify that this resource enables the student to construct concepts and not just memorize. The use of concept maps promotes educational experiences that stimulate reflection, understanding and connection between concepts. In this process, error is a valuable indicator to guide both teachers and students in overcoming difficulties during learning.

In the P2 research, the authors proposed, along with the elaboration of the Mind Maps, to use Mathematical Modeling, since it was seen as a facilitator in the construction of learning about the Quadratic Function. In the activity, evidence of significant learning was observed in the students' concept maps. Mathematical modeling allowed them to establish relationships between the quadratic function and the horizontal throw, evidencing significant learning in the classroom, according to the results presented by the CEJA high school students.

In the P3 research, the author states that students do not always express their learning automatically, without the opportunity to demonstrate how meanings are formed in a positive way to ensure that learning has a significant value. In this context, maps influence both learning outcomes and the way each student perceives and attributes meaning to what they study, as is the case of polygons in this research.

In the P4 research, the authors consider that concept maps can be used as a study or evaluation strategy, allowing students to organize their understanding. They can transform the way we teach, evaluate and learn. Students were challenged to create concept maps on paper and with the *miMind* application, realizing the pedagogical potential of the cell phone. This strategy facilitates meaningful learning, especially in the (re)construction of mathematical concepts. Teachers and future mathematics teachers are invited to use concept maps and the *miMind app* in their educational practices.

In the P5 research, the research revealed indications that teachers in initial training may be going through a transition phase in their conceptions and practices, according to

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the adopted framework. This is evidenced by the fact that many did not maintain the same impressions presented in the questionnaires and concept maps in their reports of practical activities. This transition phase is crucial for the formation of subsumptive concepts, essential for connecting theory and practice in order to assess meaningful learning.

CONCLUSION

When analyzing the researches found, it was noticed that they offer an overview of the use of concept maps in mathematics teaching, from basic education to teacher training. Each study contributes significantly to the understanding of the benefits and challenges associated with this pedagogical tool. The combination of qualitative and quantitative methods strengthens the evidence on the efficiency of concept maps, and the relevance of the research found suggests that this practice can be positive for mathematics education.

Concept maps, by facilitating the visualization of the relationships between different mathematical concepts, allow the identification of the areas in which students have the greatest difficulties. By using concept maps, it is possible to diagnose which fundamental concepts have not been completely understood, enabling a more targeted pedagogical intervention. In this way, teachers can adapt their teaching strategies to address knowledge gaps, promoting more meaningful learning. In addition, concept maps encourage students to reflect on their own understanding, promoting an active and participatory attitude towards learning.

Thus, it is considered that the use of concept maps proved to be adequate to verify signs of significant learning. Concept maps not only help students build a solid understanding of mathematical concepts, but they also prove to be a valuable assessment strategy. Thus, it is perceived that concept maps play a positive role in promoting the learning of mathematical concepts, directly benefiting the students' learning process.

To strengthen future research, we intend to conduct studies using longitudinal methods to assess long-term impacts, in addition to integrating quantitative data to complement the research.

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