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Presentation date: September, 2021
Date of acceptance: October, 2021
Publication date: November, 2021

SUSTAINAIBILITY AND EDUCATION:

SOLVING PROBLEMS BASED ON MATHEMATICS FROM SOCIOFORMATIVE APPROACH

SOSTENIBILIDAD Y EDUCACIÓN: RESOLUCIÓN DE PROBLEMAS BASADOS EN LAS MATEMÁTICAS DESDE UN ENFOQUE SOCIOFORMATIVO

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Suggested citation (APA, 7th edition)

Valdez Rojo, E., Tobón, S., Luna Nemecio, J., Pimienta Priento, J. H., & Juárez Hernández, L. G. (2021). Sustainaibility and education: solving problems based on mathematics from socioformative approach. *Revista Universidad y Sociedad*, 13(6), 134-143.

ABSTRACT

Problem solving has a long history in mathematics, however, the concept of resolving mathematical problems based on the context has been little worked to achieve sustainable development from the socioformative approach. The goal of the study was to clarify the concept of problem solving of the context from socioformation. The research was carried out based on a documentary review, using the conceptual cartography of the eight axes that comprise it. The main results reflect that the resolution of mathematical problems favors the development of cognitive and metacognitive skills in the student, which are strengthened by incorporating the socioformative approach and the mathematical model that allow establishing a relationship between reality and its abstraction in mathematical language. From the main conclusions, it is emphasized that it will be necessary to move to a new paradigm seen from socioformation where the teacher enhances the student's ability to solve problems by applying mathematics from the context close to people's lives.

Keywords: Conceptual cartography, education, mathematical modeling, mathematical problem solving, socioformation.

RESUMEN

La resolución de problemas tiene una larga trayectoria en matemáticas, sin embargo, el concepto de resolución de problemas matemáticos con base en el contexto ha sido poco trabajado para lograr un desarrollo sostenible desde el enfoque socioformativo. El objetivo del estudio fue aclarar el concepto de resolución de problemas del contexto a partir de la socioformación. La investigación se realizó a partir de una revisión documental, utilizando la cartografía conceptual de los ocho ejes que la componen. Los principales resultados reflejan que la resolución de problemas matemáticos favorece el desarrollo de habilidades cognitivas y metacognitivas en el alumno, las cuales se fortalecen al incorporar el enfoque socioformativo y el modelo matemático que permiten establecer una relación entre la realidad y su abstracción en el lenguaje matemático. De las principales conclusiones se destaca que será necesario pasar a un nuevo paradigma visto desde la socioformación donde el docente potencia la capacidad del alumno para resolver problemas aplicando las matemáticas desde el contexto cercano a la vida de las personas.

Palabras clave: Cartografía conceptual, educación, modelo matematico, resolución de problemas matemáticos, socioformación.

INTRODUCTION

A great variety of educational plans that seek to develop the mathematical thought and attempt an approach to problems on the learning process are proposed within the framework of the Integral Reform of the Higher Secondary Education (RIEMS, in Spanish) in Mexico (Tatto, et al., 2006). The mathematic thought is proposed from a perspective of diversity, without losing sight of the fact that the teacher must imagine and propose situations to students in which they may be interested.

However, the following difficulties are presented in the approach to mathematical formation in school: a) in a cross-sectional math solving problem approach; b) there is no assessment focused on developing competencies or mathematical thinking skills so they can be organized when solving learning problems and achieve significant learning goals; c) a poor use of technologies to visualize mathematical behaviors; and d) an emphasis is placed on exercise solving to learn contents. The solution to the learning problems would help transform the pedagogical practices that make the learning and application of mathematics difficult for students (Buentello-Montoya, 2021), based on the design of mathematical problems according to the concrete realities of the students.

In addition, to be able to count on the help of socioformative technologies. Socioformative technologies are a new category of technologies available to organizations, the community and people and consist of procedures based on equipment, networks and software in order to support the identification, systematization, communication and resolution of environmental problems through Online collaboration (Chou & Chou, 2021). Although the solution of problems is a subject with a long history in mathematics, little has been worked on the concept of problem solving of the context or of the real and concrete world. This is shown by a recent study in Mexico and the United States that states that in textbooks of calculation, between 65% and 87% of the problems addressed are conventional and abstract and don´t correspond to situations in the world of real life.

The main purpose of this research is to determine the bases for the revitalization of the teachers didactic planning of the mathematics, from the systematic review of some theoretical considerations, such as solving problems and the socioformation teaching. From this perspective, problems on the learning process of math are: differences between acalculia and dyscalculia, difficulties related to the processes of cognitive development and the structure of the mathematical experience, difficulties in acquiring basic concepts and numerical principles, difficulties related to numbering and calculation skills, difficulties in solving problems, difficulties related to numbering skills and calculation skills and difficulties in solving math problems.

These types of problems are considered areas of opportunity for a better life and not as negative situations that prevent action, that is, when talking about a problem it is not valued as something negative but as an area of opportunity to improve. In this sense, the positive aspect of each problem in the learning process is sought through interpretation, argumentation and solution proposals, which must be flexible and consider the different elements of the context, while these are understood as challenges to solve needs, create and innovate, and thus contribute to improve what you have in everyday life (Miranda, et al., 2021).

Secondly, due to the lack of explicit and innovative proposals for the development of mathematical thinking, it is established how socioformation may enrich them through the consideration of the social context where the student interacts, the challenges of knowledge society and the mathematical modeling (Musa, et al., 2021). Socioformation doesn´t focus on the learning process or the student but on how to achieve sustainable social development and in all social actors, seeking to improve living conditions through collaboration but without depending on teamwork and in accordance with the ethical project of life. That is, work collaboratively, taking advantage of each person's abilities and knowledge according to a specific objective, which must be based on various competencies so that people can face the challenges of the context.

MATERIALS AND METHODS

Based on the main goal of the study, a conceptual analysis was carried out to clarify what is understood by solving problems in the context of socioformation. For this, the conceptual cartography technique was used (Luna-Nemecio, 2021): which consists of a systematic process of inquiry, analysis and organization of information around a concept, theory or methodology to advance its clarification, understanding, delimitation and use. The conceptual cartography consists of eight axes, which are: notion, categorization, characterization, differentiation, division, connection, methodology and exemplification.

With respect to the axis of notion, a conceptual panorama of the concept is offered, establishing its current definition and the origin of the word or words of which it is composed. About the categorization axis, the general class of concepts within which the concept in question is included is described. The axis of differentiation establishes one or

several propositions in which the difference of that concept from other similar concepts is shown. The characterization axis describes the essential characteristics of the concept. The subdivision axis builds the classes in which the concept is classified or divided. The linkage axis establishes the relations of this concept with others that are important from the semantic or contextual. The methodology axis offers an explanation of how a methodological framework should be developed from the concept. The axis of exemplification describes propositions that exemplify the concept with specific case. In this study, the suggestions of Pejic-Bach and Cerpa (2019) regarding the literature review were also taken into account in implicitly form, as it is based on the planning, implementation, and reporting of the research results. Although it is worth saying, that its methodology does not appear expressly but that elaborated by the authors for the present study.

The research included the following phases:

Phase 1. Planning: The search for articles in indexed journals using the databases: Scopus and Scielo. This review was carried out between the months of December of 2020 and July of 2021. The following keywords were used: problem solving, socioformation and mathematical modeling.

Phase 2. Conducting the Review. Selection of relevant sources according to the following criteria: 1) Articles should be dated no longer than four years back; 2) Articles should address some of the questions formulated in the axis of the conceptual cartography; 3) We use a particular semantic structure for searching specific papers in each journal for each one axis and research categories; 4) The articles were selected based on the methodology of conceptual cartography; it was not intended to review all existing articles on the subject, but only those that provided specific elements to address each of the eight axes of conceptual cartography.

Phase 3. Report the Review. In the Table 1, the axis, Research Question (RQ) and the Components are presented as part of the results of the documentary analysis. The research questions served to explore each of the axes with which the solution of learning problems from a mathematical perspective was addressed.

Table 1. Report the Review: Axis of conceptual cartography.

Axis	Research Question (RQ)	Components
1. Notion	RQ1. What is the etymology of the solving problem concept applying mathematics, its historical development and the current definition?	-Etymology of the term or terms -Historical development of the concept -Epistemology -Current definition
2. Categorization	RQ2. What major category (or class) does the concept of solving problem by applying mathematics belong to?	-Immediate class: definition and characteristics -Following class: definition and characteristics
3.Characterization	RQ3. What are the central characteristics of the concept of problem solving by applying mathematics?	-Key characteristics of the concept considering notion and categorization -Explanation of each characteristic
4. Differentiation	RQ4. What other concepts that are near or in the same category differ from the concept of solving mathematical problems?	-Description of similar concepts, such as problem, exercise and solving problem by applying mathematics
5. Division	RQ5.In what subclasses or types is the concept of solving mathematical problems classified?	-Establishment of criteria to define subclasses -Description of each subclass
6. Connection	RQ6. How is the solving of mathematical problems linked to certain theories, social-cultural processes and epistemological referents that do not belong to the category?	- One or more approaches or theories that contribute to the understanding, construction and application of the concept are described - The contributions of these approaches are explained -The approaches or theories have to be different from what is stated in the categorization

7. Methodology	RQ7. What are the minimum methodological elements that imply the approach of mathematical problem solving?	-Phases or general elements to apply the concept
8.Exemplification	RQ8. What could be a relevant and an appropriate example of the application of solving mathematical problems from the socioformative perspective?	-Specific example that illustrates the application of the concept and approaches the phases of the methodology -The example provides a context

RESULTS AND DISCUSSION

In the context of this documentary analysis with conceptual cartography, the problem solving is structured considering two terms: problem and solution. The first one, according to the Real Academia Española (2015), comes from the Latin ***problem;*** likewise, this term comes from the Greek πρόβλημα which has the following meanings: A subject that is attempted to be clarified, a proposal or difficulty with a doubtful solution, a set of facts or circumstances that make difficult the achievement of a goal, and finally, a situation which unknown answer must be obtained through scientific methods.

From a scientific perspective, the term problem is considered as any portion of nature that behaves in an atypical manner; therefore, it is unknown and incomprehensible or it is presented as an exception. The progress and development of science is due to the solution -or the attempt to get a solution- problems related to the discipline or other disciplinary fields. A scientist mission is to solve such problems, but this does not make the solving problem activity the object of his research.

A different point of view related to the meaning of solving problem in Mathematics, is the one suggested by socioformation, which consists of going beyond the procedures. The latter, so that both teachers and students may be able to 'live mathematics' by creating meeting spaces between the abstract and the real thing. With this they would take over the problems as if they belonged to them and the responsibility to solve them would be accepted.

In the socioformación, the problems with the exercises or tasks in the area of mathematics are differentiated. An "exercise" or "task" consists in answering a question or solving an algorithm in a structured and closed way, without a significant context, for example: What is the value of the unknown in the equation $3x + 4 = 16$? In contrast, a "problem" refers to solving a need or achieving a challenge in the world of life, with several paths, and different analyzes that require the generation of mathematical models. From the socioformación, it is not enough that the problems are of the context; but they must also help to understand and improve situations in the world of life to achieve sustainability (Luna-Nemecio, et al., 2020).

Categorization of the solving problems of the context from the socioformación

As a result of the documentary analysis, solving problem, applied to Mathematics, is a part of the didactic socioformation strategies. Socioformation didactics require innovative training environments that go beyond the emphasis in contents, linearity in learning, fragmentation in subjects and focus on contextualized problems through collaboration. The search of new didactic strategies is required, such as those proposed: formative projects, conceptual cartography, socioformative VEE, Kolb Method, case analysis by contextualized problems, metacognition strategy, before, during and at the end of the activity (MADFA, in Spanish), synergistic collaborative work (TC-S, in Spanish), among others.

Characterization of the solving problems of the context from the socioformación

From a didactic mathematical perspective, problem solving has the following key characteristics: 1) mathematical modeling; 2) development of psychic process of higher order; 3) problem and context; 4) auxiliary subproblems as elements in Problem Solving and representation systems.

From a practical perspective, the solution of a problem of the context in mathematics from socioformation, implies the following characteristics: 1) identify the problem in the real world and in the context of the improvement of living and natural conditions; 2) select the relevant information to analyze, understand and solve the problem, establishing assumptions when information is missing; 3) express the problem with mathematical language; 4) perform the necessary operations from the mathematics and produce one or several possible or feasible results; and 5) argue the most relevant result and socialize it to make decisions that lead to better living conditions.

Differentiation of the solving context problems from the socioformation of other nearby concepts

Frequently, the resolution of mathematical problems is confused with "exercises" and "problems". These terms arise from different perspectives. However, they have different meanings. First, "exercises" are routine activities

in which algorithms or learned formulas are applied with a practical purpose to reinforce knowledge, and generally encourage memorization and mechanism (Lee-Cultura, et al., 2021). The "exercises" are highly structured because they present all the necessary information to be analyzed and solved, in which skills of little complexity are learned such as memorization, work with equations, etc., which can be transferred to other problems that are similar, but Little trouble with life. On the other hand, the term "problem" is used to address a situation involving a mathematical problem, whose method of resolution isn´t immediately available to the person who is trying to solve it. This person doesn´t have an algorithm that connects data and questions or data and conclusions; therefore, it requires searching, researching, generating representations and establishing relationships, among others; pretends to face a new situation.

Finally, "problem solving" is understood as the different paths or strategies that students can use, the skills that make up those strategies and how they can be refined to detect alternative learning paths (He, et al., 2021). Resolution of mathematical problems favors the development of cognitive and metacognitive skills in the student, which are strengthened by incorporating the socioformative approach and the mathematical model that allow establishing a relationship between reality and its abstraction in mathematical language. Mathematical problems that are based on context problems, make it more feasible for students to generate better and greater results in the cognitive process. In addition, students must introduce variables and techniques that aren´t in the problem considering how they can improve their environment; and they focus on learning complex thinking skills such as critical analysis, systemic thinking, metacognition, creativity and co-creation of knowledge that can be applied to other environmental problems in various fields (Table 2).

Table 2. Differences between solving context problems from socioformationand other nearby concepts in mathematics.

Aspect	Conventional problems (exercises or tasks)	Contextualized problems	Problems of the context from the socioformación
Structure	They are highly structured because they present all the necessary information to be analyzed and resolved.	The problems are unstructured. Students must introduce variables and techniques that are not in the problem.	Little structured Students must introduce variables and techniques that are not in the problem considering how they can improve their environment.
Context	The context the disciplinary field of mathematics.	Any external context, regardless of the purpose. The essential thing is that there is a relationship with the world of life in some way.	Students are expected to learn to understand and improve living conditions and environmental sustainability.
Complexity	Few variables and relationships are addressed.	Variables and relationships are addressed regarding the mathematical part and its link with reality.	Variables and relationships are addressed regarding the mathematical component, the relationship with reality and the impact on the improvement of living conditions and environmental sustainability.
Solution	The solution may be correct or incorrect.	Problem solving may be appropriate or not appropriate, depending on the relationships between variables, information and context.	The solution may be appropriate or not appropriate, depending on how it helps to understand and intervene in reality to improve it.
Transfer	They learn skills of little complexity such as memorization, work with equations, etc., which can be transferred to other problems that are similar, but little to problems of life.	They learn skills such as analysis, comparison, criticism, creativity and approach to problems that can be used in other situations in the context.	Complex thinking skills are learned, such as critical analysis, systemic thinking, metacognition, creativity and co-creation of knowledge that can be applied to other environmental problems in various fields.
Collaboration	They are usually addressed individually. Sometimes they are made as a group.	The problems are worked individually and as a team.	They are approached collaboratively, with individual and team work, with continuous support among the students themselves and other people.

Division of solving problems from a mathematical approach

Considering the socioformative approach, problem solving based on mathematics can be classified according to their area of impact and the way that educational practices are addressed (Sun, et al., 2021). Classification according to the teaching context of students is as follows, a) work in context as a backbone element in diverse activities; b) work in context and motivation; c) work in context and transference; d) work in context and scientific vocation; and e) work in context and modeling.

Connection of solving problem applying mathematics

Problem solving, applying mathematics, is linked to the knowledge society since on it we visualize continuous education and the development of competencies for problem solving in a complex and volatile society.

Knowledge society can only be referred to when innovation in all productive processes is dominant before task reproduction. Within knowledge society, one applies for the assimilation of a rigorous knowledge base and efficient strategies, as it happens when reflexive, critic, creative and complex thoughts are developed. Social changes, within this kind of societies, also promote transformations in sustainability and education (Linnér & Wibeck, 2020).

These are some of the contributions to knowledge society development:

- Moving on from giving emphasis to information, as it happens nowadays, to working with knowledge. It is necessary to critically analyze information, understand it, systematically organize it, and search for its relevance.
- Focusing on knowledge requires making it accessible through different media, mainly through technological means, which makes access easier.
- Raising people with a solid ethical life project, with a clear purpose in life, and whose actions are based on universal values; people who commits to the solution of problems in the local and global context.

Solving problems through the application of mathematics contributes to building the knowledge society, since it provides innovation, management, production and socialization of the acquired knowledge.

Methodology for solving problem through mathematics

Problem solving is applied through a wide variety of strategies and procedures. However, there are some phases, steps, and actions that are -implicitly or explicitly- followed in most of the strategies. As follows, each one of the phases related to the problem-solving steps applying mathematics, and actions of the considered strategies are described (Losenno, et al., 2020): 1) present a real-life problem; 2) make assumptions and define variables; 3) formulate the mathematic problem; 4) solve the mathematic problem; 5) interpret the solution; 6) verify the solution; 7) report and explain the solution; 8) close the cycle by asking new questions to be solved from the mathematic point of view.

Exemplification of a learning situation from a socioformation approach

The exemplification axis refers to the axis of the conceptual cartography that describes the propositions that exemplify the concept with specific cases. To this end, it is not intended to supervise a detailed discussion of documents prior to cartography, but what is sought is to show an example of what could be the problem-solving mate from the socioformation. According to the concepts defined on the methodology, an example is presented as follows regarding the application of a solution of mathematical problems from a socioformation approach within a course of integral calculus. The subject was a high school group of 5th semester, group A, morning session, from the Electronics career. It lasted 8 hours. Table 3 summarizes and illustrates the practice of the different concepts.

Table 3. Application of mathematic problem solving from socioformation.

Context	Students from the 5th semester of the B.S. in Electronics from the Centro de Estudios Industrial y de Servicios No. 18, in the city of Mexicali, B. C., are part of the lower middle socioeconomic class. When reviewing their academic reports, it was found that 92% of them use a cell phone, and that the mostly contracted plan costs approximately $ 400 MXN PESOS per month. However, it can be observed that they use their plan inadequately, which calls for an optimized payment plan.
Problem	The mobile phone company "CELMEX" offers a really innovative price scheme. When using Internet, the marginal cost by the -nth minute would be c(t)=20/((t+100)) MXN per minute. You have some doubts about pricing and you want to answer this problem by asking the following question: How much would you pay for the first 60 minutes?

Need(s)	That the student analyzes and interprets the relation between the variables of real life problems related to areas, volumes, etc., that imply variations in infinite processes; and they are solved by applying the fundamental theorem of calculus.	
Goal(s)	-Formulate and solve mathematical problems, based on different approaches. -Explain and interpret the obtained results by using mathematical procedures and contrasting them with the established models or real situations. -Argue the solution from a problem using numerical, graphic, analytical or variational methods with the help of spoken and mathematical language, as well as the use of information technologies. -Analyze the relationship between two or more variables in a social or natural process to determine or estimate its behavior.	
Subject covered in the integrating topic	Science, technology, society and values	
Methodology		
Horizontal mathematization	Step 1. Real life problem	It begins with the above mentioned problem.
	Prior knowledge analysis	To elaborate a mind map about mathematical optimization and share the information with your class. In order to broaden it, search the Internet so that the group can answer it during class.
	Step 2. Make assumptions and define variables	The following questions may be asked during this step: Did you understand the problem? Which variables take part in the problem? What information does it provide? What information it is asking for? What is marginal cost? During the service, is the minute price decreasing, staying the same or increasing? Why? If its monthly use lasts only a minute, how much will you be charged for using the Internet service? If the cost per minute is equally paid, how much would you pay for 60 minutes?
	Step 3. Formulate the mathematical problem	It should be solve based on the following mathematical expression: c (t) =20/((t+100))when t=60 minutes but considering the fundamental theorem of calculus.
Vertical Mathematics Application	Step 4. Solve the mathematical problem	After creating some tabular, geometric and graphic representations, some questions can be asked, for example: What does the area of rectangle A represent? What does the addition of the areas of all rectangles represent? According to the cellphone problem, how much would you pay in each of the following cases? For the first 10 minutes; for the first 20 minutes; for the first hour
	Step 5. Interpret the solution	The following questions can be made during this step: What does the area of rectangle A represent? What does the sum of the areas of all rectangles represent? According to the cellphone problem, how much would you pay on each of the following cases? For the second minute; For the first two minutes; For the first 10 minutes. Did you get the same result for the first 10 minutes in Chart No. 1 as in Chart No. 2? How much did you get for the first 10 minutes? Will the first minute and the minute 20 cost the same? How much will the minute 20 cost? How many minutes of internet do you approximately use per month? Estimate how much would you pay per month with the new pricing scheme. Represent it in a chart and a graphic. Use GeoGebra online.

Validation and reflection	Step 6. Verify the solution	In joint project, students - guided by the professor, working in collaboration and using technological tools - compare, contrast and discuss their solutions from the subject of Science, technology, society and values.
	Step 7. Report and explain the solution	Students should come up with a solution, in this case, close to this one: According to what is observed in the previous examples, if we make the intervals of our partition smaller and smaller, the sum of the areas of the rectangles will approximate to a limit; we can use that limit to define the area under the curve. If we increase the number of rectangles we will approach (intuitively) to the value of the definite integral. When solving the definite integral as a simple operation, it can be positive, negative or zero. But when solving the definite integral, applied to the calculation of the area, its value must be only positive, or zero. In general, the region between the curve y = f (x) and the x-axis in the interval [a,b] will be represented as:
Application in context	Step 8. Socialization of the learning process and problem solving	Each group of collaborative work prepared a report to be reviewed to present a conference before the school community where the main findings and proposals on the theme of optimization will be punctuated. Each student presented a conceptual V-model on the new payment plans. Evidence was co-evaluated between the teams and finally evaluated by the professor.

Although there are still no published results or experiences regarding the approach and solution of mathematical problems posed since the socioformación, there are research that have measured the impact of socioformación in the general process of learning and resolving problems; whether using formative projects, conceptual cartography (Luna-Nemecio, 2021), Socioformative rubrics and case analysis for context problems. Concrete examples of formative projects in mathematics are the research of Chen, et al. (2020)

In the case of mathematics, it has been possible to document the impact of socioformation on the learning process through the socioformative research strategy as an experience in the application of action research in the improvement of pedagogical practice related to the development and use of assessment instruments in the mathematics subject.

The documentary analysis, conducted throughout this work, provides an integral vision of problem solving through the application of mathematics, with the purpose of providing associations of mathematics professors, institutions and researchers in the field of educational mathematics and the curriculum of higher education, the elements that will enable them to determine more viable and innovative strategies (Guo, et al., 2020), allowing them to design more realistic didactic planning according to the context in which students work. Likewise, planning will be conducted considering the diversity in which each of them can contribute to their peers, based on dialogue from equality and symmetry (Abad-Segura & González-Zamar, 2021).

The research could establish the theoretical bases that are required for the didactic planning of the mathematics teachers from the design and resolution of problems based on the principles of socioformation. The socioformative approach allows to solve the problems related to the teaching of mathematics, establishing a direct relationship with mathematical problems that start from concrete and daily situations. In this way, socioformation makes it possible not to focus on the student but on the whole context. The socioformative approach proposes strategies and instruments to develop complex thinking.

The bases for the revitalization of the teaching didactic planning of mathematics were determined, starting from the systematic review of some theoretical considerations, such as the resolution of problems and the teaching of socioformation (Valdez-Rojo & Tobón, 2018). Socioformation was established as an explicit and innovative proposal for the development of mathematical thought. It is considered that socioformation can enrich the pedagogical practices

of teaching mathematics, through the consideration of the social context where the student interacts, the challenges of the knowledge society and the mathematical model. Socioformación allows to focus on the learning process or the student, but on how to achieve sustainable social development and all social actors, seeking to improve living conditions through collaboration but without depending on teamwork and agreement with the ethical project of life.

CONCLUSIONS

Finally, we may conclude, and as a limitation of what is presented herein, that a didactic model with an inter, multi, pluri and transdisciplinary character experimentally proven, is required from a social formation teaching point of view. The latter should provide a solid methodology that brings together all the phases, stages, actions and strategies related to solving problems applying mathematics. Adding a new approach – like socioformation - to solving problems from mathematics opens the possibility of innovation in the classroom, which leads to the exploration of new levels of sequential development of solving problem processes for mathematical and variational thinking.

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