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Mathematical modelling, problem solving, project and ethnomathematics: Confluent points

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This paper presents a documental study about the confluent points among mathematical modelling, problem solving, project and ethnomathematics as methods of research and mathematics teaching. As a result, the study has shown that there are elements that bind these methods structurally together as research methods. Starting from the fact that education should promote knowledge this study provides evidence for these methods. Thus in each one of them, it is required knowledge from the student about the topic of the problem-situation; method to delineate the phases to go through; technological instruments to support the solution; aesthetics for the expression; and ethics in the communication of the resulting ideas.

Keywords: Mathematical modelling, problem solving, project, ethnomathematics.

INTRODUCTION

The concepts of modelling, problem solving and project permeate the most varied contexts. It is known that concepts arise from the human mind and are developed by necessity. According to Boutinet (1990), this ability to model the 'imagined thing' is what drives people to conceive projects. As concepts guide people's daily actions, they have been at the core of educational curriculum reforms in mathematics and have nourished several thematic developments, among them three topics that are confluent with Mathematical Modelling (MM): Problem Solving, Project and Ethnomathematics. Despite being independent topics, they instigate us to identify confluent procedures in research and teaching. Two questions steered this study: (1) what are the confluences among Modelling, Problem Solving, Project and Ethnomathematics? and (2) in what circumstances can the involved phases be integrated into pedagogical practices of MM in Education?

METHODOLOGICAL PROCEDURES

In order to answer the research questions, I collected data in the literature about Modelling, Problem Solving, Project & Ethnomathematics. I sought to gather a deep understanding of the authors' propositions as well as attempted to identify the commonalities among the topics. I also subdivided the expression about each topic into two parts: scientific research method and teaching method. This study may be considered documental, since the data comes from publications of authors who are referenced in academic literature. In this context, it is essential to highlight that in the process of identifying confluences among the topics, different identifications may coexist. Additionally, it is crucial to bear in mind that the expression in this article is not neutral, since it carries along the conceptions implicit in the works analyzed.

MODELLING, PROBLEM SOLVING, PROJECT AND ETHNOMATHEMATICS

Most of the problem situations people experience require them to make use of representations to solve them. These situations are inserted in a sociocultural context and sometimes exceed the needs of subsistence. As a result, such situations prompt people to design ways to solve problems and to learn new knowledge in order to solve them. When one of such designs involves the 'desire to know' about something, a research method is required to accomplish the goal. If this 'knowledge' aims to solve a problem situation for which the available data are not sufficient for the person to use an existing model, there is the need for Modelling. However, if this 'knowledge' aims at constructing knowledge, at explaining how a person or a group from a social culture elaborates a mathematical model or makes use of this model in their activities, the method is called Ethnomathematics.

Mathematical modelling

Modelling is the process involved in the development of a model in any field of knowledge. The essence of this process emerges in a person's mind when a genuine doubt/circumstance instigates her to find the best way to solve, understand, create or improve something. The route of scientific research is delineated when someone models a problem situation using mathematical concepts. According to Biembengut (2014), this research happens through three connected phases: (F1) understand and grasp – recognize and become familiar with the subject; (F2) understand and explain – formulate the model and solve the problem situation; (F3) articulate meaning – interpret the solution, validate, explain the process and results.

As MM is in essence a research process, it has been advocated as a process for mathematics teaching. The goal of MM in Education is to teach students the contents of the curriculum departing from a topic, formulating a project with a proper design and guiding students to conduct research within the limits of the school structure. The teacher organizes the project following the modelling steps by promoting (E1) understanding and grasping (topic presentation, provoking questions, selection of adequate issues to develop the content); (E2) understanding and explaining (presentation of the data, suggestion of hypotheses, presentation of the content and examples); (E3) expressing meaning (model formulation, requiring students to solve the problem, result evaluation). The purpose consists in providing students with opportunities to research about topics of their interest while they learn the curricular contents.

Problem solving

A problem emerges when the person realizes that there is a gap between the situation she does not know how to solve and her desire to solve it. The solution may come from an idea, in a heuristic approach: a set of rules and methods that leads users to solutions and discoveries. A person may solve problems using different heuristics, and each heuristic may be more appropriate or less for each kind of problem. Authors such as Wallas (1921), Dewey (1922) and Polya (1981) are recurrently cited as references in heuristics for Mathematical Education.

Dewey (1922) proposed five phases: identification, definition, plan, execution and survey; Wallas (1921), four stages: preparation, incubation, illumination

and verification; Polya (1981), four: understanding, plan, execution and retrospection. As these heuristics are related, four non-linear phases may be proposed: (F1) identify the problem situation: become familiar, collect data, identify relationships – preparation; (F2) establish procedures: look for similar problem situations, map, identify the knowledge required; (F3) solve the problem: implement strategies for a plausible solution – illumination; (F4) evaluate results and validate them: check the validity of the result – retrospection.

As these procedures are requirements for any type of activity, they are part of the pedagogical proposals in Mathematical Education. Researchers such as Schoenfeld (1985), Gage and Berliner (1992) consider that helping students to solve problem situations is the reason why we should teach Mathematics. Problem situations should require students to review basic facts, identify unknowns, look for meanings in the unknowns, (re)learn math operations, understand relationships between operations and their implications, formulate, solve and argue whether solutions are compatible.

In light of the exposed, it is possible to prescribe a three-step method for Problem Solving in pedagogical practices: (E1) proposition – proposing a problem situation to students that require them to decompose the data, identify the unknowns; (E2) ideation – guiding them to perceive mathematical relationships and formulate a plan; (E3) synthesis – guiding them to apply and evaluate the resulting data. These steps allow students to combine their ideas to the extent that they are encouraged to learn about issues of their interest.

Project

A large number of people have needs that exceed the solution of practical problems. Anything may inspire people to know, do or have something, an impulse that leads one to design ways to achieve solutions. People may delineate a project to solve a problem related to physical survival as well as when they are interested in learning about something. Boutinet (1990) suggested essential steps in this process: (F1) diagnosis – setting the purpose and learning about the available resources; (F2) outline – describing means to obtain data and evaluating; (F3) strategy – identifying how to organize and classify the data; (F4) execution – performing actions and evaluations; (F5) analysis – judging the results and evaluating the situation.

Similarly, the project heuristics is a proposal for Education. Izard (1997) states that school projects encourage active participation from students; provide them with motivation and challenges; encourage them to ask questions, to learn about some topic, to observe their context. Projects also reveal students' interests in the formulation and description of the data as well as their skills in interpreting and evaluating the results. Three steps are proposed as a method to include projects in pedagogical practices: (E1) preparation – instigating students to know about a topic/issue, look for data and learn about the topic; (E2) development – guiding students to ask questions about the topic/issue, describe the data encountered, identify concepts, formulate and understand the circumstances; (E3) projection – guiding students to interpret results, analyze them and identify other facts. I believe that one of the purposes of education is achieved when students are offered with projects that enable them to expand their knowledge, to learn about their surroundings, making them feel valued.

Ethnomathematics

D'Ambrosio (2001) sustains that all social cultures have a legacy of knowledge, behavior and rules that they seek to convey to generations, making it possible to perpetuate cultures. Many social cultures have created and developed instruments to explain, understand, and learn about things. Each culture has developed unique mathematical techniques arising from their needs. D'Ambrosio calls Ethnomathematics the art or technique to explain, know or understand how a person or a group generates mathematical knowledge, makes use of it in their business, and organizes and transmits knowledge to others. It is the study of concepts, traditions and mathematical practices of a person or a sociocultural group. The researcher goes deep into the person/community's culture by observing, asking questions, among other means.

Research on Ethnomathematics, for D'Ambrosio (2001), consists of three phases: (1) develop methods from practices and solutions; (2) develop theories from methods; (3) innovate from theories. Ethnomathematics procedures involve the need to: (F1) explicit the fact – recognize the fact, become familiar with the practices and the solutions presented by a person/group; (F2) present the explanatory assumption – analyze facts, methods, practices and solutions, establish conceptual principles and formulate explanations; (F3) indicate other facts – interpret,

validate the pragmatic model from the perspective of the person/group, describe and check whether theory resulted from the method; (F4) complement the fact – identify whether innovation resulted from theory ↔ method ↔ practices and solutions.

In Ethnomathematics, the focus lies on recognizing the mathematical actions and knowledge of people, resultant from the needs and experiences these people have. Using people's activities and knowledge in pedagogical practices may best contribute to the students' learning process, since they may interact with problems and solutions, and experience the culture. The Ethnomathematics method for pedagogical practices consists of three stages: (E1) interaction – help students to get acquainted with the facts from the activities, to interact with the person/group and to recognize practices and solutions; (E2) explanation – encourage students to understand practices and solutions, to identify mathematical concepts, to stipulate phases, to learn and make explanatory assumptions; (E3) indication – guide students to interpret the assumptions, to describe or verify whether the method or theory used resulted in innovation.

Ethnomathematics has as its source the activities that a person/group performs and the knowledge they have resulting from the needs of their daily lives. It assumes dynamic sharing between activities and knowledge; values popular knowledge as a means of contributing to knowledge production; and proposes education as a process in which knowledge is transmitted across generations.

CONFLUENT POINTS

Modelling has elements that converge with Problem Solving, Project and Ethnomathematics, depending on the desire to know. As Education should promote knowledge, instigate the desire to know, I believe one of these methods should relate to the desire to teach.

Confluent points in the 'desire to know' as a research method

Modelling is used when we need to solve a problem situation for which the available data are not sufficient to apply an existing model to obtain the solution, or when we need to (re)create, improve something. To confront the MM procedures with those of Problem Solving, Project and Ethnomathematics, for research purposes, the similar points consist of: delimitation

of the problem situation, theoretical framework, hypotheses/assumptions, development, implementation, interpretation and evaluation of the solution.

MM is the area of research for the development/creation of a model for the solution of a particular problem situation or to support other applications and theories. Ethnomathematics is the area of research that seeks to understand a person/group's knowledge related to their activities. When someone intends to conduct research, a project with a proper design is required to accomplish such a goal. In light of these definitions about the desire to know, I may conclude that in all these areas, the researcher is guided by the scientific methodology following common steps to produce knowledge; be it something original, be it a complement to what already exists.

It can be stated that a research design, be it in Modelling or Ethnomathematics, has as its source a problem situation, a desire to know. To solve a problem, we direct our steps through other areas of knowledge, fact that allows the researcher to expose events, enunciate models of relationships between things and facts. As they are part of the scientific research pathway, they cannot be denied in the school context as methods of teaching and research, since they give students the chance to design projects, be them in Modelling, Problem Solving or Ethnomathematics.

Confluent points in the 'desire to teach' – teaching method

Modelling in Education is a method for teaching research in Basic Education. To confront the procedures of Modelling with those of Problem Solving, Project and Ethnomathematics, for teaching purposes, the 'desire to teach' point is similar: proposition of a topic or problem situation, review or presentation of data, procedures for resolution and evaluation of results. For instance, the teacher may use the context of an apple plantation to teach modelling. She may begin the class by talking about the context in the Brazilian state of Santa Catarina. She may present some data, such as the fact that apple trees are planted in line and that for that reason, there is a particular spacing among them. She may ask students: what is the ideal distance between one tree and the next one if we aim at producing more apples? To help them answer the question, the teacher models the data by teaching the students the required mathematical contents. At the same time, the students study the ethno-mathe-

matic aspect of the problem and start a project. They seek to understand how the producer uses farming "models" (his knowledge might possibly have been acquired through experience, or inherited from his ancestors). Students can research about the topic by talking directly to the producer and observing his work. Drawing on the data collected, students can attempt to verify whether or not the producer received technical orientation (help from specialists), whether he modified his practice, and hence, his mathematical conceptions.

I conclude that the essence of the four themes resides primarily in involving each student in the interaction among real elements present in the environment in relation to the topic in question. Be it in Modelling for Education, be it in Ethnomathematics, students will have a problem situation as a starting point, and to solve the problem they will delineate a project to guide them. Moreover, to outline a project, they ought to have knowledge beyond the traditional school topics. I believe that when students feel themselves capable of solving a problem situation that requires going through the steps of Modeling or Ethnomathematics they learn the curricular contents along the process, and teachers will feel encouraged in their desire to teach.

FINAL REMARKS

As a researcher, I hope I have not committed any kind of improbity by articulating the principles of each of the themes. I hope this work can be improved and contribute to teaching and research in education. This study had as its main guiding question the confluent points among Modelling, Problem Solving, Project, Ethnomathematics and the desire to know research method and the desire to teach teaching method. The art of these themes lies in guiding students to understand the environment in which they live as well as in the potential to put these topics into practice: by translating results into suitable language for general comprehension. The procedures, even when implemented as extracurricular activity and only by a few group of teachers and students, can contribute to improve the knowledge of those who are involved in the process. Taking the real value of Education into account, it is worth considering one of the themes, or all combined in the classroom, since they offer students the opportunity to ask questions, identify and learn about facts, accumulate experiences, become more

attentive to events, become enchanted with solutions to problems, and feel free to express their knowledge.

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