MATHEMATICAL MODELLING IN TEACHER EDUCATION COURSES: STYLE OF THOUGHT IN THE INTERNATIONAL COMMUNITY - ICTMA

Maria Salett Biembengut & Emília Melo Vieira

Pontifícia Universidade Católica do Rio Grande do Sul – PUC-RS,
maria.salett@pucrs

Centro Universitário Leonardo da Vinci – UNIASSELVI
emiliamv@gmail.com

This paper presents the mapping of mathematical modelling (MM) pedagogical practices in teacher education courses from publications available in the books organized by the International Conference on the Teaching of Mathematical Modelling and Applications – ICTMA. Mapping refers to the identification, survey, organization, classification, and data analysis. Forty-two papers published in the ICTMA books were identified about teacher education and the data were analysed through the lenses of style of thought in MM, according to the theory of Ludwik Fleck (1979). This study aimed at understanding how knowledge was built by society and became common part of the group, and not at analysing the quality of knowledge departing from immutable criteria. The analysed productions revealed that these researchers constitute a collective of thought indicating the concern with and the support to the official documents and to the issues related to teacher education. The collective of thought about modelling in initial and continuous teacher education courses follows institutionalized standards.

Key-words: Mathematical Modelling, ICTMA, Style of Thought, Mapping.

INTRODUCTION

Mathematical modelling (MM) refers to the process toward the elaboration or the creation of a mathematical model about a problem-situation of some knowledge area, by making use of mathematical theories not only for the solution of a particular situation, but as support to other areas. This process, applied in all sciences, has contributed extraordinarily to the evolution of human knowledge. In modelling, the procedures are basically the same employed in scientific research: problem delimitation; familiarization; hypothesis; model formulation; problem resolution; interpretation; and model validation. According to Biembengut (2003), such procedures require from the modeller: mathematical knowledge and problem-situation knowledge, skills to read, describe and refine the data obtained from the phenomenon under the light of math, and creative and critical senses in the formation,

the resolution and the evaluation of the model elaborated. Modelling is rooted in the human creative process and it encompasses scientific research.

In the last four decades in several countries, the defence for this process or method is increasing in the teaching and learning of math, in all levels of schooling. The main justification relies in offering students the opportunity to make use of math in order to comprehend a problem-situation of other knowledge area and know how to solve it. It means that teachers are able to provide students with opportunities to integrate math to other knowledge area, in particular, an area that students display interest in knowing more about. Osawa (2007) claims that the studied problem-situations give rise to knowledge learnt from experience, to comprehension reached through mathematical proofs, judgment, thought and foundation. According to Herget (2007), MM still facilitates students' comprehension of what is abstract (symbolic), by changing their perceptions in relation to the entities that surround them and in different ways, by stimulating their interests and, as a consequence, their learning.

MM for Education has emerged in the 1970s, impelled by the dissatisfaction and criticisms professors and businessmen interwoven in relation to the education of undergraduate students. The situation instigated many professors to find ways to justify math in the schools' curricular program. Among them, David Burghes in 1978, while working with high school teachers, in Cranfield University, produced papers and books about modelling, offered teachers workshops, and organized the first two International Conferences on the Teaching of Mathematical Modelling and Applications – ICTMA, in Exeter University, the United Kingdom, in 1983 and 1985. Since then, every two years, there is an expressive conference with a great number of participants and representatives worldwide (Biembengut, 2003).

This interest in the ICTMA international conferences gave rise to an organized community that, besides promoting the conferences, is part of the International Congress on Mathematical Education – ICME. In the period 1983-2011, there were 15 conferences, and also, the Study Group 14 Conference of the ICME on modelling and applications (M&A). The studies presented in these conferences are published in printed books. There are 15 books published until 2011; 443 papers on M&A with different focuses and from these, 42 were identified by being pertinent to pedagogical practices in MM in teacher education courses. In this corpus, there are applied and theoretical studies. From the applied ones, the focus is on the different schooling phases: from the early years of Elementary School to the end of graduation, and on the initial and continued education of teachers. According to Blum, Niss and Galbraith (2007), in the period 1965-1975, research suggests that M&A promoted arguments in favour of the inclusion of Mathematical Education; in the period 1975-1990, studies are characterized by the development of curricula and instructional materials to encompass the components of M&A; and from 1990 on, empirical studies on the teaching and learning of M&A have been added to the theoretical emphasis of research of the previous phases.

MM for Education has been stimulated and sustained by the gradual establishment of math teachers' communities, as well as the study groups and research groups that followed the proposals for the teaching of math. Worries about what, how, how much, and to whom teach math have contributed to the strengthening of the studies in MM for Education. These studies lead to research whose results imply proposals for teaching and learning that, in a cyclical process, promote new studies. The studies presented in conferences bring a style of thought that when shared, make ideas circulate and produce a collective of thought.

According to Ludwik Fleck's theory, each study expresses the researcher's style of thought from the type of accomplishment and/or the collective of people that have a similar style of thought constituted by knowledge and/or shared practices. Consistent with this theory (Compared Epistemology), style of thought "consists of a determined attitude and a type of accomplishment that completes it". And it is characterized by "common problem features that interest the collective of thought, by the judgments the collective thought considers evident and by the methods employed as means to know" (Fleck, 1979, p.145).

Fleck proposed a theory about knowledge focused on heuristics. His theory allows for a historical and epistemological analysis to distinct areas of knowledge. It is centred in the analysis of academic productions, oriented by socio-historical studies to comprehend the interaction between the scientific practice and the contexts in which they occur. It is an "interactive model of the knowledge process, connected to the social, historical, anthropological and cultural presuppositions and conditionings, that as is processed, transforms reality" (Delizoicov et al., 2002, p.56).

Following Salles (2007, p.32), "throughout time, the action of researchers and the social factors that interfere with the constitution of science constructs a specific trajectory, with no determined beginning or end". It means that the most diverse historical, social and epistemological factors and entities interfere in the generation of scientific knowledge, that in turn requires reflection upon the facts and entities involved, careful and accurate historical analysis so that the common traces in the process of constitution of scientific concepts are identified.

The educational effort to provide better teaching of math culminated with the development of research on MM for education worldwide. As this defence for M&A in the ICTMAs has been on for about three decades, it is considered that styles of thought about MM for education are formed due to the idea circulation from a collective of thought and, this way, understandings change or vary permeating discussions about teacher education in several countries. It is feasible to inquire: *what are the styles of thought about mathematical modelling in courses of initial and continued teacher education in the international scene*?

In the ICTMAs there is circulation of ideas from styles of thought. Each person comes from a social and historical context (active connections) and each person perceives the reality in such a subjective way that nurtures his /her research (passive

connections). Therefore, people's interactions allow for the establishment of styles, and by recurrence, collectives of thought about M&A for Mathematical Education. This study aimed at analysing the productions published in the ICTMA's books about pedagogical practices on MM in teacher education courses. These productions, as shared by the scientific community, as ICTMA's, consolidate scientific knowledge.

METHODOLOGICAL PROCEDURES

This study is bibliographical since the data base consists of 42 papers about the pedagogical practices in MM in teacher education courses. From these, 35 were published in nine ICTMAs conferences (1995 to 2011) and 7 were published in the Study Group[1] 14 book (2007). Although the ICTMAs began in 1983, research focused in teacher education began to be presented from 1993 conferences on, whose publications were released from 1995 on. For this reason, the sources come from the period 1995-2011. This kind of scientific production brings a set of studies conducted by M&A researchers. These studies generated knowledge accepted by the scientific community. According to Biembengut (2008), studies based on bibliographical documents may offer a map about the theme of the problem or hypotheses to conduct the verification by other means.

Thus, the papers, written by whom participated in one or more ICTMAs, constitute a natural source that reveal different contexts (institutions and countries) and enable different interpretations and analyses. In this research phase, the focus resides in identifying the style of thought about modelling the authors of these papers display. We expect in the following phase, interview these authors to better understand their MM practices. This study was developed in two stages, named identification map and recognition map, as follows. These stages did not occur separately.

2.1 *Identification map*

This phase consisted of identifying the field in which the object is inserted in. The 42 papers analysed belong to 32 "first authors"[2] of 12 countries of five continents. Following, we identified the countries, the number of papers and the number of same authors(s) and different authors (d): Australia (4: 2s, 2d), Brazil (6: 2s, 3s, 1d), Canada (2d), China (1), Denmark (1), Germany (5: 2s, 3d), Mexico (2d), Portugal (1), South Africa (2s), Sweden (5s), United Kingdom (1), USA (12: 2s, 10d).

In the first moment, we opted to assemble the papers into three groups, published between the years 1995-2011: the first (1995, 1997 & 1999), the second (2001, 2003 & 2005) and the third (2007, 2009, 2010 & 2011). We hypothesized there would be some changes throughout the years. But, departing from a careful study of all papers,

[1]MM was the 14th theme for the study of the International Commission on Mathematical Instruction (ICMI), initiated in 2002 and published in 2007.

[2]We use the expression "first authors" due to the fact that we counted 'one' for the papers that have more than one author.

we could not identify significant differences. In each paper, the researchers identified and classified the questions, sources and methods upon which the data were obtained. A summary of each paper was done and common topics were highlighted. As all the papers present: (1) justification, (2) process, (3) possibilities and (4) difficulties in making use of modelling for Education, we considered these topics as categories of analysis. These data allowed us to have a system for recognition. Due to space limits, the summaries of the papers and the resulting maps will not be presented in this article.

2.2 *Recognition map*

We sought to get acquainted with Fleck's Comparative Epistemology (1979) to have a better glimpse of the styles of thought about the pedagogical practices in MM in teacher education courses worldwide. According to him, a style of thought is understood as shared practice and knowledge. For him, when this style is shared, the group displays a collective of thought read the papers attentively and identified similarities among them and could delineate styles of thought in MM. We identified possible traces that were recognized and valued by the community. In addition to that, we sought to comprehend the studies departing from confluent and/or indicative places that suggest styles of thought in a community of modelling for Mathematical Education. In the following section of this work, we sought to make the data explicit such that an illustrative image of the studies and the results could be produced, based on Fleck's epistemological theory.

This study did not aim at analysing the quality of knowledge produced departing from immutable criteria. Instead, it aimed at comprehending how knowledge was constructed by the community and how it was integrated in the common pile of the group in the period 1995-2011. We admit the coexistence of different knowledge models and educational development so that we are able to recognize the similar points among these studies and the possible factors conditioned by the scientific communities. We assume that these processes do not express people's neutrality. We understand that scientific knowledge does not emerge in the methodological order of observation/experimentation in a distinct perspective from the empiricist conception. It is not neutral from the conception of who studies, of who prescribes results.

RESULTS & DISCUSSION

The analysed 42 papers on pedagogical practices in MM in teacher education courses bring the historical, social and educational context in which they were produced. All of them present applied research. They describe the process of modelling and use a group of students, research collaborators, future teachers or teachers in continued education as participants to collect data. These studies depart from specific experiences lived in the classroom and contribute to understand the different issues involved. The authors defend the primacy of MM in the development of Basic

Education teachers. According to Sales (2007), these activities contribute in such a way that the researcher learns to identify stable elements in the research object and, establish facts tacitly accepted by the collective of thought that permeates the international community.

Although curricular programs are similar in the 12 countries from the 5 continents that the authors of the studies analysed belong to, it is not possible to deny that the studies occurred under the cultural reference and own meaning that these curricular contents have to the respective population; ways that guide us to derive the styles of thought. Meanwhile, when organizing the text statements into categories, it was possible to identify that some occurrences and reflections are common in the publications, even considering the elapsed time between one conference and the other and the participants of different countries. These similar reflections suggest the circulation of ideas, allowing for a collective of thought.

According to item 2.1, the established categories were: (1) justification, (2) process, (3) possibilities and (4) difficulties in making use of modelling for Education. In what follows, we turn to the reflections upon each category, considering the styles of thought present in the productions and that commune with the collective of thought.

(1) The authors' *justification* is based on the understanding that MM for Education allows the student in each schooling phase: (a) to learn the mathematical concepts better; (b) to interpret the meanings of the mathematical concepts; (c) to use technological resources to solve problems; and (d) to make students aware of social and environmental issues. This justification, in the 42 papers, is endorsed by the criticism to the style of teaching still in vigour in almost all the countries. The justification of the majority of authors - departing from the criticism to the current teaching and departing from the defence for modelling - suggests a style of thought in this community. This style shows that *MM for Education allows teachers and future teachers to become aware of the various issues of society and of the results the current schooling structure produces.* This consciousness can display another style of thought about the way to teach; guiding them to commit themselves to make use of pedagogical practices that promote better formation of students in Basic Education. This understanding requires knowing how and when to approach curricular contents, but also knowing how to make the students from Basic Education, in particular, draw on this knowledge in moments beyond the school limits. It is a style of thought legitimized by the community of thought that works with modelling for Education.

(2) The *process* of MM defended by the authors is that the teacher should: (a) depart from a subject or problem-situation of any area of knowledge that is interesting to the group of students; (b) ask the group to look for data that give rise to issues and then, seek for the problem solution; (c) orient the students to formulate these data making use of any mathematical structures (concepts, definitions, properties); and (d) guide them to solve the issue and evaluate the results. This style of thought about how to do modelling in sciences is maintained in the process of school teaching; it is how students are prepared for searching. It is characterized by the common traces of the

problem-situations that the majority of papers bring as examples. The proposed problem-situations conduct students to a collective of thought about MM as a process or method that enables knowing and developing competence to deal with issues of their surrounding environment.

The main argument is that modelling provides students with opportunities to make connections between the language present in their surroundings and the mathematical language. During this process, students improve their conceptual structures, their understandings of the mathematical concepts, and more, their critical and creative senses are improved in the formulation of data and in the evaluation of results. This argument indicates a style of thought that considers *MM for Education a way to surpass the linear process of teaching that is decontextualized from students' experience.* It is considered that each student has his/her own cultural spectrum that is revealed in his/her doings, outside the school context. When s/he experiences the modelling process in a triad: research-school-reality, the student can perceive his/her talent, his/her interests and even the importance of the school in this process of literacy to scientific and professional issues or issues related to companionship.

(3) About *possibilities*, the authors argue for MM as a means so that students may (a) construct their knowledge by understanding the concepts involved; (b) choose significant problems to the context; (c) become capable of explaining their reasoning with the correct use of mathematical language; (d) have better performance in mathematical modelling activities; and (e) know how to use it in their pedagogical practices, since these students are future math teachers. This defence, present in all papers, suggests that when doing, people get to know and when people get to know, they do. It is a cyclical process. Going from the simplest to the most complex issues and continuously revising can make modelling a more effective process to deal with the various issues that involve the living context. *MM for Education is a dynamic process: it can be modified whenever necessary so that students' knowledge can be improved.* This instance reveals another style of thought.

(4) The *difficulties* in the implementation of MM reside in the current educational structure: available timings and schedules, curricular programs divided into various subjects. Difficulties emerge for future teachers and in-service teachers. For future teachers the difficulties reside in knowing how to use the mathematical language to describe the problem-situations and, thus, resist to changes. And for in-service teachers, difficulties reside in the available time they have to get acquainted with the themes chose by the students to orient them.

The curricular model in teacher education courses is similar in the various countries. It consists of several disciplines, each one under the responsibility of a teacher and with a restricted number of class hours. Math, although present in all schooling years of Basic Education, follows, in general, the same process of teaching, without connection to the other disciplines of the curricular structure. This model contributes to the fact that the students from these teacher education courses, who experienced a 'traditional' way of teaching for more than 12 years, have difficulty in interpreting

the context and data from a subject of any knowledge area; in recognizing the math required to interpret data; in formulating mathematically and in analysing it.

This difficulty, a consequence of the experienced education by these teachers, emerges when these students or even teachers become aware of MM. They learn about it in a single subject in an initial or continued teacher education course, with a limited number of hours if compared to the time experienced in 'traditional teaching'. As a result, obtaining effective results depends on the interest the participants involved have in following the modelling pathway; that advances gradually departing from practical and conscious activities about the importance of learning.

The current educational structure in various countries does not lead to the integration among math and the other disciplines of the course, neither the diverse areas of knowledge. As a consequence, *there are difficulties students and also teachers have in making use of modelling in the classroom practices, particularly in the initial and continued education, due to the time spent in this educational structure.* Paraphrasing Salles (2007), MM will only reach a status of legitimized knowledge if it resists to the tests imposed by the group that 'maintains' the traditional process in the teaching of math. The incorporation of MM for education can establish a dynamic relation between the 'traditional' and the 'innovations'. Allowing for a change in the conception of math teaching departs from reactive interactions among the teachers in the group. This kind of argument present in many these 42 papers suggests another style of thought.

Departing from the categories: *justification*, *process*, *possibilities* and *difficulties*, it may be claimed that the styles of thought displayed by these 42 paper, of the 32 'first authors' converge in the understanding that modelling can contribute not only to improve mathematical teaching and learning, but also to provoke reaction and interaction between the body of teachers and the body of students involved in the on-going and necessary production of knowledge. It is a mutual share of acquired experiences. These authors, participants of the ICTMAs, make explicit their knowledge gained in the interactions among the theories of MM for Education and their practices of modelling in classrooms. As Wenger (1998, p.45) points out, "this collective learning results in practices that reflect both the pursuit of our enterprises and the attendant social relations". These interactions conduct to a style of thought.

According to Fleck (1979), so that a style of thought can be constituted, it passes through the phases of instauration, extension and transformation that occur by means of interactions of distinct groups in the circulation of ideas intercollectively and intracollectively. This circulation of intracollective ideas occurs among experts and the circulation of intercollective ideas among non-experts. This process implies seeking for knowledge that brings increment to the existing data and yet, creates a collective a thought. It is worth highlighting that these styles of thought, that come since the teachers-researchers of the first phase (1965-1975) in the classification proposed by Blum, Niss and Galbraith (2007), are present in the community, independently of the country, the geographical distance, the educational system.

These styles may be considered the scientific knowledge of the ICTMA. This knowledge was consolidated by facts, theories and interpretations shared by the community of practice. Perceiving that the process involved in MM for education is even more relevant when dealing with issues that allow having a particular set of data that can be better studied using specific methods and as consequence, become charmed with the solution and the validity of this solution.

FINAL REMARKS

The papers analysed reveal that these researchers who circulate in the conferences organized by ICTMA constitute a collective of thought, indicating the concern and support to the official documents and to the issues related to teacher education. The collective of thought about modelling in math teacher education courses follows institutionalized standards. It means that the events in the modelling process in courses for teachers or future teachers enunciate necessary changes in the educational structure, based on values, goals and other inspiring stimuli that come from the different people within the system.

To Fleck (1979), the researcher's style of thought designates the formal aspects of his/her research that comprises all ways of expressing the units associated in the process and in the results. The style comes from shared practices and shared knowledge. When a certain style is shared by a group of people, a collective of thought is established. It may be claimed that in the ICTMA conferences we encounter groups that share the same style of thought that is composed by collectives of thought. This sharing occurs when the researcher identifies in his/her research object traces that are recognized and valued by the community, that are present in other studies about similar themes. There are hues of this style of thought that arrange facts and fit in the MM theory for education dominant in the discussions of mathematical education. These various elements coalesce around different conceptions of knowledge production, but when confronted, as pointed out by Salles (2007), constitute an extension of the established style of thought.

This fact indicates that the style of thought about MM for Education that circulates in the ICTMAs is established in the knowledge of different groups of researchers. And according to Fleck's theory (1979), the changes in this area will become noticeable as a collective process, in which the transformations will be construed by the community of thought, when the ideas circulate in the ICTMA conferences. The importance of analysing scientific productions throughout time in MM in the international scene is justified by the panorama that this type of research results, providing a map of the contributions, needs and challenges related to MM. According to Witter (1996), it is by means of this type of research that a basis of scientific data may be formed. This basis consolidates certain knowledge and thus, allows for scientific advancement.

Investigating how each style of thought a group adopts or how it is incorporated by the style of the community of thought, how styles are established and transmitted is the beginning of another study. Diverse presuppositions may be formulated. Some may direct the researcher's steps to the origins of M&A in the teaching practices of the school system. It is relatively simple to identify how the ideas and proposals are disseminated. These proposals and ideas, written or verbalized, carry styles of thought, express attitudes or ideals that deal with experiences, beliefs, values and casual sequences, whose order is diverse.

REFERENCES

Biembengut, M.S. (2003). *Modelagem Matemática: Mapeamento das Ações Pedagógicas dos Educadores de Matemática*. Post-Doctoral Dissertation. São Paulo: Universidade de São Paulo.

Biembengut, M. S. (2008). *Mapeamento na Pesquisa Educacional*. Rio de Janeiro: Ciência Moderna.

Blum, W.; Niss, M. & Galbraith, P. (2007). Introduction. In: *Modelling and Applications in Mathematics Education* (pp.32). New York: Springer.

Delizoicov, D.; et al (2002). Sociogenese do Conhecimento e Pesquisa em Ensino: contribuições a partir do referencial fleckiano. *Caderno Brasileiro de Física*, 19, pp.52-69.

Fleck, L. (1979). *Genesis and development of a scientific fact.* Chicago & Londres: The University of Chicago Press.

Herget, W. (2007). Picture (im)perfect Mathematics! In: Blum, W., et al (Eds.), *Modelling and Applications in Mathematics Education* (pp.153-181). New York: Springer.

Osawa, H. (2007). Development of Applications and Modelling by Ation Re-Search in Japanese Secondary School. In: Blum, W.; Haines, C.; Galbraith, P.; Khan, S. (Eds.), *Modelling and Applications in Mathematics Education* (pp. 285-294). New York: Springer.

Salles, A. C. (2007). *Nem de Gênios, nem de Heróis: a história da ciência em Ludwik Fleck*. Master's Thesis. Belo Horizonte: Universidade Federal de Minas Gerais.

Wenger. H. (1998). *Communities of Practice*: learning, meaning and identity. New York: Cambridge University Press.

Witter, C. (1996). *Psicologia Escolar: Produção Científica, Formação e Atuação (1990-1994)*. Doctoral dissertation. São Paulo: IPUSP.