Model of innovation: Process of integrating technology in Mathematics Education[1]

Celina Aparecida Almeida Pereira Abar

ABSTRACT

This article aims at discussing the process of integrating technology by Mathematics teachers according to Everett Mitchell Rogers's model of innovation. This author presents concepts and explanatory categories, which may help, understand the elements that make up the process teachers face from their initial contact with the idea of teaching with the use of information technology (IT) to their choosing or not to use this work proposal. Thus, understanding innovation and educational innovation is necessary, implying analysis of technological innovation and, ultimately, of teacher training facing a new pedagogical practice. Rogers' (2003) model proves to be an important contribution to understanding the many variables that can influence the inclusion of technologies into pedagogical practice.

Keywords: Innovation. IT. Teacher Training. Mathematics Education.

Modelo de inovação: processo de integração da tecnologia na Educação Matemática

RESUMO

Este trabalho tem como objetivo discutir o processo de integração da tecnologia pelo professor de Matemática segundo o modelo de inovação de Everett Mitchell Rogers. Esse autor apresenta conceitos e categorias explicativas que podem ajudar a compreender os elementos presentes no processo pelo qual passa o professor, desde seu contato com a ideia inicial de ensinar com o uso das Tecnologias da Informação (TI) até a sua confirmação ou não pela adoção desta proposta de trabalho. Assim, é necessária uma compreensão sobre inovação e inovação educacional, o que implica uma incursão sobre inovação tecnológica e sobre a formação do professor frente a uma nova prática pedagógica. O modelo de Rogers permite um entendimento das diversas variáveis que podem se apresentar na inclusão das tecnologias na prática pedagógica.

Palavras-chave: Inovação. TI. Formação de Professor. Educação Matemática.

INTRODUCTION

The idea of innovation may be appropriate to understand the situation teachers go through when faced with a "new" work situation in which experience accumulated in

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Celina Aparecida Almeida Pereira Abar é Doutora em Lógica Matemática. Atualmente, é professora titular do Programa de Estudos Pós-Graduados em Educação Matemática da PUCSP, Centro de Ciências Exatas e Tecnologia, Av. Dr. Altino Arantes, 958 – 04042-004. São Paulo, SP. E-mail: abarcaap@pucsp.br
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teaching is extremely important, but insufficient to meet new educational and technological demands.

Beliefs and expectations are elements that may arise in the approach to innovation, because teachers, in their own individual time, develop a special relationship with innovation and, simultaneously, while working in a team, can create a collective relationship with it, making it easier to overcome certain fears in the face of novelty.

So as to study this topic, we can be guided by the following questions: what possible relationships can be established in the process of using information technology in Mathematics Education by teachers and the stages of innovation-decision of Rogers' model (2003)? What elements can contribute to the use of these technologies in teachers' pedagogical practices?

Innovation has been the focus of research in different fields of knowledge, including in education. Rogers (2003), from the field of sociology, contributes as a theoretical framework for research in education.

In the educational context, the idea of innovation has been given denominations, such as change or even rupture from one practice to another. However, we consider that it is not necessarily a rupture, because facing the innovation that is considered as the use of IT, teachers may react seeking to suit themselves to it based on their own knowledge, skills, worldview and pedagogical beliefs, establishing new relationships with the innovative elements and adding different knowledge to them. Innovation, therefore, is established in a continuum of teaching activities.

To Saviani (1980, p.25), innovation can be understood from different points of view, depending on the philosophical conception adopted: humanist, analytical and dialectical and, according, to the author

> According to traditional "humanist" ideas, innovation is understood as accidental, as superficial changes that will never affect the essence of purposes and methods advocated by education. Innovation is therefore synonymous with retouching superficially. According to modern "humanist" ideas, innovation fundamentally changes methods, ways of educating. From the "analytical" point of view, however, innovation is not exactly changing, be it accidentally or essentially. Innovation is using other forms. [...] That is, educational innovation translates into the use of other means (or "media") which are added to conventional means, to make them up or replace them. [...] As for the "dialectic" idea, innovating, strictly speaking, is putting education at the service of new purposes, that is, at the service of the structural change of society.

We can understand innovation in the "analytical" sense presented by Saviani (1980), since teachers' practices are not changed essentially, although they incorporate new elements and other means. Faria (2012, p.12) understands that "teachers' former

experience is redefined in a new context, whilst it assigns a sense to innovation according to the relationship established with it".

Hernandez et al. (2000, p.26) presented a study on innovations in schools and one of the main ideas developed is one that relates innovation with teachers' attitudes. In this sense, they say that the multiple approaches to the idea of educational innovation are located in a "continuum" in which, at one end, is the social and pedagogical meaning of innovation, which is defined as "an idea, practice or material perceived as new by the relevant unit that adopts it". At the other end, meanwhile, the authors say that innovation "implies planned change" in order to enable the organization or teacher to achieve its or his goals.

Concerning the dimensions of technological innovations in education, Teixeira (2010, p.1) states that innovation application initiatives "in educational systems in different countries gave rise to research that would define educational innovation as an object of study by experts and politicians". The author draws attention to the fact that "innovation is no magic solution that can solve all the problems of education" and that it "must be followed by questions such as: to whom does it interest? By whom was it proposed or implemented? And who could benefit from it?" (TEIXEIRA, 2010, p.2).

Just as to Hernandez et al. (2000) and Farias (2006), we also advocate that teachers' need to comply with the innovative process is key to it being consistent and effective. To these authors, innovation is understood in the context of something being built or to be built.

In this sense, these authors find that "innovations do not last if one does not count on teachers" (HERNANDEZ et al., 2000, p.23). By considering the role of teachers as important in the innovation process, Fullan (2009) is also emphatic when stating that it is the actions and ideas of teachers that bring about changes in education.

Research such as that by Motejunas (1980), Cardoso (1997), Fullan and Hargreaves (2000), Hernandez et al. (2000), Farias (2006) and Fullan (2009), among others, make reference to changes that happen in school through curriculum restructuring, through the introduction of new teaching methods or the implementation of projects. These studies resulted in important aspects of the relationship between teachers and the process of change and concern the form of inclusion, the manner in which awareness is brought about, the imposition of external agents or teachers' compliance to the process. Many of these innovation initiatives stem from government or private institutions; others are made by the school and, also, there are those that emerge from the concerns of teachers themselves.

The introduction of IT in schools or the use of new teaching methods are situations that bring about discussions concerning the entry and permanence of innovation in the educational environment. Research such as that by Cardoso (1999), Hernandez et al. (2000) and Farias (2006) reveal that, when imposed from above, these changes result in a low degree of compliance by the school community, particularly by teachers.

With regard to the inclusion of IT in the school system and its relationship with teachers and students, we must mention, among others, studies by educators such as Masetto (1998; 2003), Moran (2000), Belloni (2003, 2005) and Behrens (2007), who see in technology the potential for introducing new ideas in teaching and learning processes.

According to Teixeira (2010, p.3), "when making use of technological tools, subjects, somehow, can modify their use and by them be modified". To the author, with regard to education, "the defense of the need to use 'new' technological tools as well as in teacher training is intensified".

By bringing the focus of this discussion to innovation in the educational field referring to the practices of teachers, we refer to the pedagogical, technological and managerial aspects in this context.

INNOVATION FROM ROGERS' POINT OF VIEW

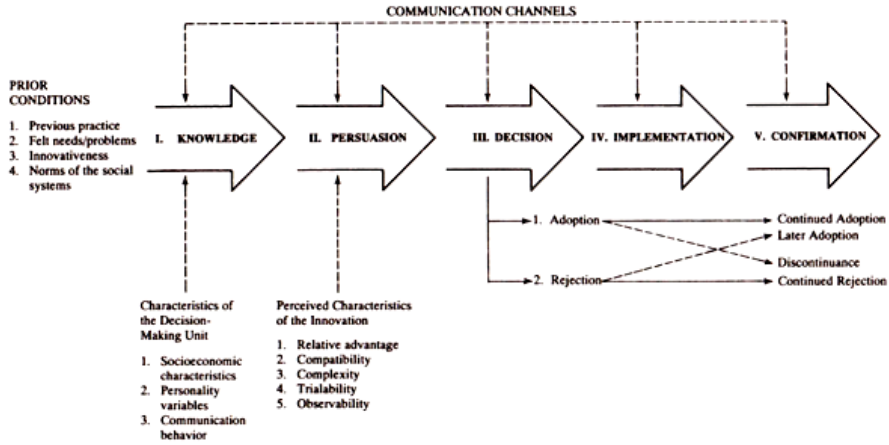
Rogers (2003) presents an innovation-*decision* model that outlines the process in which individuals go from more general knowledge on innovation, to deepening this knowledge, to forming an opinion or attitude toward it, to reaching the decision to use it or reject it, to, ultimately, in the case of using it, working on implementation and confirming this decision.

By defining his understanding of innovation, Rogers (2003, p.12) states that it is "an idea, practice or object that is perceived as new by the individual". To him, it is not important whether such an idea is new in the sense that it is a recent discovery, but what matters is how a person perceives this new idea. A person who has just come into contact with a new idea may even have received, previously, some knowledge of it, however, what matters is the relationship that will be established between this person and the new idea from then on.

Thus, a teacher can know about the use of IT in education and have already formed an opinion about it, or the use of IT in education may not represent anything new. When this teacher, however, is faced with the possibility or need to relate to this type of education, either as a manager or as a teacher, ultimately carrying out some role in this context, he then sees the use of IT in education as a new idea, as a novelty, because his relationship is also re-signified.

This relationship requires stages the teacher will cover when searching for information, motivation and certainty; when formulating opinions and making decisions as to accepting or rejecting the innovation, particularly given the specific requirements of the language of Mathematics.

FIGURE 1 – Model of the innovation-decision process.



Source: Rogers (2003, p.170).

The model of Rogers' *innovation-decision* process involves five stages: knowledge, persuasion, decision, implementation and confirmation, which are represented in Figure 1.

We can see that, in the *innovation-decision* process, a person goes through stages and, although linearly represented in Figure 1, the relationship that may be established between the person and the new idea will determine his route. In this context, the media are constantly present, indicating a high degree of interference in this relationship.

Based on the individual's previous conditions, his initial motivation, i.e., his knowledge about the new idea also interferes, as well as the need to seek information and more thorough knowledge of the same.

When researching components that appear in the new practices of Mathematics teachers who are starting this experiment, it is important to try to identify elements that may facilitate the establishment of this relationship.

Throughout the process, some elements will be decisive in determining a positive or negative attitude towards innovation: the perception of the advantages and disadvantages with respect to innovation; its level of complexity; and to what extent it meets, or not, specific needs and desires. These elements are shown in Figure 1, in the identified characteristics of innovation.

In the *persuasion* stage, we can further include the observation of innovation and its handling as key elements for the person to form his own opinion about the idea that is being presented as a solution, or a possible solution to his needs.

Relating this to teachers' activities, we refer to this stage as the one in which teachers receive specific training for carrying out their activities; discuss with peers what will be

developed and planned activities; observe the progress of activities; and carry out author functions. From there on, they gather conditions to assess the experience they are going through and to formulate their opinions with regard to working with the use of IT.

In the case of teaching mathematical content, inserting abstract entities requires resources that ease the visualization of ideas that are going be transmitted. It is thus an important advantage, since teachers will make an extra effort to implement these resources and to create new ways of easing the understanding of graphic schemes, of formulas and of examples that teachers often provide in their daily explanations.

So, situations in which teachers face the challenge of creating courses with the use of IT are very complex, especially when the pedagogical, methodological, technological, educational and management specificities require of them more than they bring from previous experience.

The characteristics of innovation, as listed by Rogers (2003) are part of the mental process and are perceived by teachers in two ways: individually, since each member formulates his own opinions about innovation; and collectively, since the team negotiates its ideas so that the work offers convergence, taking a common path, i.e. one in which a member, even if not strongly persuaded about what will be done, knows that he is supported by the other members.

When coming into contact with innovation, teachers seek to gain new knowledge, establishing associations with their previous luggage and making information exchanges with their peers, in order to state their views, answer their questions and carry out their working activities. Thus, teachers will, little by little, adjust their performance and improve their working conditions along the way, based on the strategies they personally and collectively establish with innovation, i.e. with the use of IT.

The *Persuasion* stage can also present itself in various topics and sub-topics: in interpretations referring to prior knowledge, when teachers seek to establish connections between their knowledge and that required to work with the use of IT; in training for work and during work and in supporting the institution. The perception and the development of opinions through a subjective approach to innovation are very important, especially for teachers to take on a positive attitude towards innovation, since it does not survive if it does not count on the compliance of teachers and if they have not apprehended its meaning.

Regarding the *Decision* stage, as Rogers himself warns us, it does not occur only at the end of the *innovation-decision* process, but continuously, because at every moment the use of innovation is questioned by some situation or event.

We can identify moments referring to the decision stage when teachers express the desire to seek more specific training on issues referring to the use of IT, when they mentioning plans for the preparation of their discipline and when they feel the need to assess what they had done up to then.

The *Implementation* stage of the *innovation-decision* process model refers directly to making use of innovation. From the moment which teachers begin to use IT on, there is progression to this stage of the process described by Rogers.

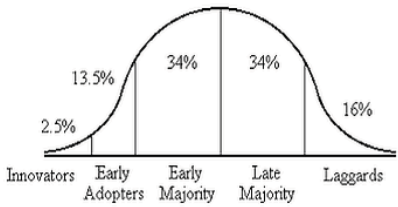
When confronted with practice, they realize that this stage is actually continued training that supplements initial training and draws attention to specific features concerning the use of IT in the context of Mathematics that had not yet been noticed.

The *Confirmation* stage is the last one to be presented in Rogers' *innovation-decision* process model, as shown in Figure 1, however, it is not necessarily the last to occur in the process, since it is considered continuous over time. Moreover, since the decision to accept or reject an innovation is established in a continuum, an individual can change or enhance the decision made earlier as receives new information.

The establishment of different categories of users is considered the most significant contribution of the theory of Rogers. According to this author, individuals not adopted innovation at the same time.

According to the time needed for this purpose, are established five categories: innovators, early adopters, early majority, most laggard and traditional (Figure 2)

FIGURE 2 – Categories of users.



Source: Rogers (2003, p.281).

The *Innovators* imported the idea from outside and incorporated it into the system.

Early adopters traditionally accept innovation and strategies used for release earlier than most. They maintain leadership positions among the colleagues and have a certain weight in local decision making.

Early majority plays an important role in broadcasting since they are expert in keeping channels informal communication, but differs from the above categories when needed more time to adopt an innovation.

Late majority adopts new ideas by pressures of the environment, so they need greater motivation.

Laggards have the reference point in the past and act with reservations about the adoption and the role of intermediaries.

THE MATHEMATICS PROFESSOR: NEW ROLES AND SKILLS

Teacher education is an ongoing effort that transforms itself according to the needs of teachers in the classroom, in the production of materials, in management of academic activities, in political activities and in professional issues that concern them.

Ponte, Oliveira and Varandas (2003, p.160), when discussing IT contributions to the development of teachers' knowledge and to their professional identity, consider that learning to work with IT can help teachers "develop a professional identity", "stimulating the adoption of the perspective and the values of a Mathematics teacher".

According to Ponte, Oliveira and Varandas (2003, p.162), IT, when they become part of teachers' working environments, change the former, also changing the way teachers relate to other teachers. This provides an "important impact on the nature of teachers' work and, thus, on their professional identity", as noted by the authors.

To instigate teachers to develop themselves in order to achieve the goals mentioned by Ponte, Oliveira and Varandas (2003) requires from the former an effort toward the changes that they take on concerning new possibilities in teaching, as well as mobilization of knowledge, beliefs and ideas.

Regardless of whether work is focused on education and of the type of technological tool being used, the idea presented by Penteado (2000) establishes a relationship between a situation in which teachers have full control, i.e. the *comfort zone*, and another in which they launch themselves into a "new" situation marked by uncertainties and discoveries, in the *risk zone*.

What the author calls a "risk zone" corresponds to the "encounter" with innovation, in the sense that it is in new space that relationships are established with the uncertainties, beliefs and expectations inherent to this work.

Discourses concerning training needs converge in the development and improvement of the activities of Mathematics teachers, due to various factors, such as media, research as a means of encouraging the production of knowledge, and the ability to work cooperatively. This discourse expands the possibilities of the use of technology in education.

When describing teachers' work in education, Belloni (2003, p.79) notes that the role to be played consists of multiple functions, due to the use of technological means, and states that "the increased use of technological communication and information media makes teaching more complex and requires segmentation of the act of teaching into multiple tasks".

In his definition of the role of teachers, Belloni (2003, p.81) points out the "transformation of teachers from individual entities into collective entities" as its main feature.

When mentioning the challenges inherent to resizing teachers' roles facing the task of moving from traditional teaching to teaching that is increasingly *mediated*, (BELLONI,

2003) considers the need for these teachers to "learn to work in teams and to move with ease between various disciplines. It will be crucial to break the isolation of the conventional classroom and to take on new and different roles" (BELLONI, 2003, p.29).

There is a strong tendency to train students to perform duties that are as yet unknown or undefined, enabling them to acquire autonomy to learn enough to continue their own training over their personal and professional lives. This trend must accompany the training of teachers following the same logic, that is, receiving proper training, teachers are no exception to the general rule of social development needs required of other professions, accepting innovation and, hence, evolving in their profession.

Kamau (2014) examined the factors related to technology adoption by secondary mathematics teachers in Nyandarua and Nairobi counties in the Republic of Kenya. It was collected qualitative data from interviews and classroom observations of six teachers to better understand statistical results from the quantitative survey of 135 teachers, and drew on Rogers' (2003) diffusion of innovations theory. In the qualitative phase, the participants described how technology training, technology resources, and demographics influenced their decisions to adopt technology in their teaching. The findings revealed that secondary mathematics teachers in Kenya are *late adopters'*, had negative views about technology in learning environments and where technology was available the teachers were not using technology for teaching mathematics.

The author concludes that technology training programs for teachers need to be reevaluated to consider committing technology trainers who understand technology, training teachers on specific mathematical software, establishing training centers near teachers' localities, and encouraging collaboration efforts. In-service training is the most significant factor in technology adoption process over and above the availability of technology resources.

The author concludes that in-service training is the most significant factor in technology adoption process over and above the availability of technology resources.

Technology training programs for teachers need to be reevaluated to consider: identify technology trainers who understand technology; training teachers on specific mathematical software; establishing training centers near teachers' localities and encouraging collaboration efforts.

Regarding skills teachers need, Belloni (2003, p.87) gives us some clues concerning education professionals. The first refers to acquiring indispensable techniques in educational situations that are increasingly *mediated.* Next are communication skills, *mediated* or otherwise, that allow teachers to work as a team. The third clue refers to the ability to systemize and formalize procedures and methods to carry out pedagogical activities, and the fourth clue refers to the ability to transmit knowledge and experiences so that others can use them in their own needs.

With this reasoning, it is understood that Mathematics teachers' training to teach with the use of IT is a field to be explored, mainly by seeking to understand the phenomena that occur referring to teaching. Currently, teachers in general and Mathematics teachers, in

particular, are challenged by the process of innovating educational activities, represented by technological mediation and by the pedagogical and management specificities that are inherent to this type of education.

These proposed training needs add new elements to professional development and, thus, contribute to the strengthening of teachers' professional identities.

CONCLUSION

Some research refers to changes that happen in school through curriculum restructuring, through the introduction of new teaching methods or the implementation of projects.

These studies resulted in important aspects of the relationship between teachers and the process of change and concern the form of inclusion, the manner in which awareness is brought about, the imposition of external agents or teachers' compliance to the process.

Many of these innovation initiatives stem from government or private institutions; others are made by the school and there are those that emerge from the concerns of teachers themselves.

The discussion of innovation in educational field, refers to the practice of teachers and pedagogical, technological aspects and management in this context.

The stages of Rogers' (2003) innovation model allow us to identify the elements necessary to helping teachers to relate to the use of IT, in order to accept this novelty and to develop skills for new temporalities.

Teaching with the use of technology requires pedagogical activities to be rethought. New skills, attitudes and values are required of teachers, observing educational, technological and management aspects that are specific to this new way of teaching and learning.

Facing innovation through the use of IT, teachers react by trying to adapt based on their knowledge, skills, worldview and pedagogical beliefs, establishing new relationships with the innovative elements and adding others knowledge to them. Innovation, therefore, is established in a continuum of teaching activities.

With this reasoning, we can conclude that teachers' activities with the use of IT are a result of a process between their professional knowledge and experiences and what they acquire by relating to this new situation, as well as their decision to accept.

In short, the skills of teachers who will work with IT need to be reconfigured towards the incorporation of innovation. However, these skills are not acquired in defined periods of time or spaces: they are the result of a personal identity building and persuasion effort, characteristic of Rogers' (2003) *innovation-decision* process, as already described.

Thus, as discussed by Hernandez et al. (2000), innovation is interpreted differently by each person exposed to it. It is up to the person to establish his own relationship with the new idea, which, consequently, may determine different ways of dealing with its peculiarities

Research concerning training Mathematics teachers for teaching with the use of IT can contribute to discussions about this reality, which is, expanding reflection on the teaching of Mathematics through the use of IT, especially seeking to identify elements that contribute to the effort to overcome the difficulties and specifics of this field of knowledge, as well as language and abstraction that are inherent to Mathematics in a technological environment.

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