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Chapter 5

SELF-EFFICACY BELIEFS OF PHYSICS TEACHERS IN THE CONTEXT OF CURRICULUM INNOVATION

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ABSTRACT

This chapter presents research on the self-efficacy beliefs of prospective teachers of physics relating to the introduction of modern and contemporary physics (MCP) content in the high school. The methodology of this research was qualitative and the main instrument used for data collection consisted of questionnaires, in addition to semi-structured interviews and video recordings, applied to eleven individuals of a physics teacher training program at the São Carlos Institute of Physics of the University of São Paulo, Brazil, in 2009. The prospective teachers' data selected for this chapter were from two undergraduates who were involved in the planning and implementation of a particle physics teaching and learning sequence for high school students. We emphasize the importance of qualitative studies relating to teachers' self-efficacy beliefs and the fact that these investigations are still rare in the literature. They have been conducted over the last two decades as case studies from different contexts relating the teachers' self-efficacy beliefs and their practices. On the other hand, it is much more common to find in the literature on teachers' self-efficacy beliefs, research using the quantitative method. Throughout this chapter, we discuss the use of cognitive maps as an analytical tool, which give a clear view of the teachers' responses. The cognitive maps were also interesting for a global understanding of prospective physics teachers' self-efficacy beliefs concerning the implementation of modern and contemporary physics in the high school. It was pointed out, in addition, that positive and vicarious experiences, as well as physiological states were plausible sources of changes in self-efficacy beliefs. A promising prospect for a research and education strategy for the training of physics teachers would be to reflect with them on their own self-efficacy beliefs relating to the implementation of these themes.

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INTRODUCTION

In recent years there has been a general trend in science education with regard to the need for innovation of classroom content, as well as of methodologies used to teach such content in schools. This movement for curriculum reform has been identified in several countries where emphasis has shifted from content-needs to learner-needs. This encourages learners to engage actively in learning situations which are potentially relevant to them, and which are also understood as useful and important to their lives.

Nevertheless, despite the proposals for curriculum reform carried out in many countries in recent decades, traditional teaching has remained resistant to new changes. This is largely due to teachers' knowledge and beliefs in respect to the nature of their subject, their personal and professional identity, as well as the teaching and learning of specific subjects.

Everyone involved in the process of education reform recognizes that teachers' knowledge, their experiences and beliefs play a crucial role in curriculum changes, particularly in physics teaching. The manner in which teachers learn how to teach, what they know, how the teachers obtain their knowledge, how they change over time, etc, are factors that cannot be neglected if our aim is to understand what causes the difficulties involved in the implementation of curriculum innovation in the classroom (Davis, 2003).

Feldman (2000, 2002) studied the ways in which a group of teachers from one school were involved in the curriculum reform movement in the United States. The author proposes a practical model of conceptual change for teaching from a socio-cultural perspective, which seeks to integrate teachers' beliefs, their thoughts, knowledge, and behavior to the context in which they are placed. The author defends a perspective of professional development in which teaching is seen as a teacher's way of being, so that accepting curricular innovation involves a personal reconstruction of what it means to be a teacher of science. He emphasizes that teachers ought to feel dissatisfied with their practices once they recognize their ineffectiveness, and as a consequence they will replace old practices with new practices that should meet the instructional objectives. Among the various actions that can support this process of change in the teacher, the author emphasizes the need for teachers to become aware of their background and belief system with regard to the manner in which the content is taught and learned in a variety of educational situations.

This author (Feldman, 2000, 2002) also highlights the importance of teachers having a deep understanding of the subject that they teach and the methodologies for teaching it, both of which are fundamental prerequisites for the delivery of a quality education. Obviously, without an adequate knowledge of the specific content, teachers can hardly acquire teaching strategies to promote student learning on the subject. In this sense, it is vitally important that teachers be aware of their beliefs and values with regard to the nature of the science and the subject they teach. In this way, they will be able to break with the distorted views of scientific endeavor and will conceive of science as a dynamic process. Finally, the author draws attention to the importance of time needed for reflection and interaction with other teachers, during their initial or in-service training, in order to incorporate new perspectives on teaching slowly and gradually.

Tobin and McRobbie (1996) highlight the existence of four cultural myths that surround the beliefs of teachers with regard to the science curriculum: the myth of transmission, the myth of efficiency, the myth of rigor, and the myth of preparation of students for exams. The acceptance or not of a curriculum reform will depend on the manner in which these cultural myths are interpreted by teachers, given that most of the time such myths are a hindrance to the implementation of changes by teachers. Thus, in order to overcome obstacles in the implementation of curriculum reform in science by teachers, their cultural myths need to be identified and a critical reflection on their effectiveness needs to be undertaken, which could have profound effects on their beliefs with regard to teaching and learning, as well as on their practice in the classroom.

Pintó (2005) argues that, to some extent, curriculum innovation only becomes effective in the classroom when the teacher embraces its ideals. Thus, one of the important aspects for the success of this innovative movement is, undoubtedly, the adequacy of initial training courses for physics teachers in order to provide a solid initial knowledge with regard to this innovative content, not only from the conceptual point of view, but also from the reflection on the manner in which this content should be dealt with in the classroom.

There are certainly numerous obstacles to the adoption of curriculum innovation. However, this research emphasizes the important role played by future teachers' beliefs in this process, in particular, their self-efficacy beliefs regarding the inclusion of topics of modern and contemporary physics (MCP) in the high school curriculum. Thus, the aim of this research is to understand the difficulties, beliefs and perceptions of future physics teachers when they participate in a process of curriculum innovation during their professional development.

THEORETICAL FRAMEWORK

In general, there have been many different definitions of the concept of belief in accordance with different areas of study. Moreover, the meaning of belief has rarely been defined within a clear conceptual framework. Therefore, since studying beliefs may prove rather difficult, we consider it important initially, to establish a general definition of the beliefs which we consider to be adequate. In addition, the relationship between belief and knowledge will be briefly outlined. Finally, social cognitive theory will be partially presented, from which the prospective teachers' self-efficacy beliefs regarding the inclusion of modern and contemporary physics content in the high school will be discussed.

Beliefs are information that people accept as true. However, this information may not often be clearly articulated by individuals because they are not always aware of their beliefs in an organized, well-thought-out and ready-to-be-explained manner, or they may even be reluctant to explain themselves. Such beliefs influence their perceptions and judgments, which in turn affect their behavior (Pajares, 1992).

Moreover, beliefs can be good predictors of individual behavior. It should be noted that this chapter is based on the theory that beliefs include knowledge (Lewis, 1990). In other words, all knowledge has its origin in a belief, and ways of knowing are essentially forms of choosing values. Even if the learning process is built through personal discovery or awareness, individuals already use their beliefs in their own senses, in their intuition, in the laws of nature and in logic to know something. Thus, there is no need to study religion, politics, and personal ideologies to understand the intertwined nature of knowledge and belief.

FUTURE TEACHERS' BELIEFS

Research on initial teacher training has highlighted the fact that undergraduates embark on training programs with strongly forged beliefs about educational aspects that usually remain unchanged throughout their training. Such beliefs accompany future teachers in their teaching practice (Florio-Ruane and Lensmire, 1990; Kagan, 1992; Wilson, 1990).

Awareness of what these beliefs are is an important step in an attempt to implement strategies to pursue changes and developments of future teachers' educational beliefs with regard to proposals for curriculum innovation (in our case, the implementation of modern and contemporary physics in the high school). It is possible to say that such beliefs relate to student teachers, to their pupils, to scientific knowledge, and to their self-efficacy in different educational situations. The beliefs of future teachers in relation to students comprise the following: (i) how future teachers see their influence on student attitudes; (ii) how they understand the process of motivating their pupils; (iii) what their roles are in the process of teaching and learning; and (iv) what their beliefs are with regard to the cause of the attitudes of their pupils. With regard to the beliefs of future teachers in relation to themselves, these consist of: (i) their views on their roles as teachers; (ii) their processes of personal and professional growth; (iii) what their motivations for teaching are; and (iv) how they attribute causes for their own attitudes. The beliefs of future teachers are also constituted by their ideas with regard to the nature of a specific content or the specific content itself. Finally, a part of these beliefs are those that relate to their ability to execute certain activities, i.e. beliefs of self-efficacy in a specific task (Bejarano, and Carvalho, 2003).

SELF-EFFICACY BELIEFS

In social cognitive theory there is a central idea: self-efficacy, which is defined as "the beliefs in individual abilities to organize and execute courses of action required to produce a specific event or outcome" (Bandura, 1986, p. 391). The sources that make up the self-efficacy beliefs, according to Bandura (1977), are the mastery experiences*,* which are characterized by instances in which the person faces a certain situation and manages to deal with it successfully, and thus obtains good information about his or her own abilities to cope with similar situations. Vicarious experiences*,* related to the observation of others in situations of success or failure in similar events, also influences the behavior of individuals. Verbal persuasion, which may be interpreted as a cluster of verbal stimuli that leads a person to become aware of what may or may not be achieved by a given action. Physiological states, which take into account an individual's physiological and emotional states, such as anxiety, stress, increased heartbeat, shortness of breath, chills that may occur during the execution of a task. Examining the self-regulatory mechanisms through which people exercise control over motivation, styles of thought and emotional life, Bandura situated successful experiences as the principal vehicle of change in behavior. Experiences of success, in addition to enabling changes in behavior, are very important for the lasting maintenance of the self-efficacy beliefs in the face of threatening situations, being indispensable even in the presence of other sources. Indeed, once a person's self-efficacy belief is well established, any experience of failure does not represent a significant threat, except on the basis of certain causal attributions for failure.

QUALITATIVE SELF-EFFICACY RESEARCH

There are very few qualitative studies dealing with teachers' self-efficacy beliefs. Below are some that relate teachers' self-efficacy beliefs to their practices.

Mcalpine and Crago (1995) followed a relatively common event in Canada in which teachers are assigned to take classes in small aboriginal communities even though often their initial training programs have not provided an educational foundation to enable them to address these various social experiences. Data collection, including observations, formal and informal interviews, documented the experiences of a teacher who began her teaching in these conditions and initially had conflicting experiences. Her lack of knowledge about this community and culture almost prevented her from developing her role as a teacher, but she gradually increased her understanding of the culture and how its characteristics affected the classroom. This teacher ended up modifying and developing her efficacy beliefs about teaching science in a classroom with a culture different from her own began to have a clearer view of how to develop strategies to take into account these differences in her practice.

Other qualitative self-efficacy research (Mulholland and Wallace, 2001) involved a two-phase (pre-service and in-service) longitudinal case study of a primary school teacher. Data were collected through semi-structured interviews at the end of the year she completed her undergraduate course, observations of her classes, interviews throughout her first year in service, and sound recordings of her classroom interactions in order to compare them with the interviews. The authors constructed an analysis of Katie's activities and interactions in a narrative form representing her experiences in these two phases as a science teacher. The narrative was also analyzed in terms of the similarities between the two phases and sought to understand how her self-efficacy beliefs were shifting along this route. The conclusion of the authors was that her experiences demonstrated both positive and negative self-efficacy beliefs, but her persistence in science education was interpreted as a strengthening of her self-efficacy in this field.

Takahashi (2011) sought to better understand how teachers' self-efficacy beliefs develop based on a model of teacher training grounded in socio-cultural theories. The participants were a group of four teachers with varying years of classroom experience in teaching English and mathematics. The group was focused on the common exchange of experiences and studying together. The semi-structured interviews were conducted in three stages: before any observation of the teachers' practice, after observations of their classes, and after discussions with the group. The results indicate that teachers can build together their efficacy beliefs relating to common classroom practices. This kind of research on the influence of group dynamics on teachers' self-efficacy has been growing and can help in corroboration and reformulation of what is known about self-efficacy beliefs.

Self-efficacy research using a hybrid methodology, quantitative and qualitative, occurs more frequently in the literature, but since this is not the main focus in this chapter, only a brief discussion is included, outlining an article that illuminates this methodology well. Ramey-Gassert, Shroyer, and Staver (1996) conducted a qualitative study to examine the factors that influence self-efficacy and expectations of science teachers concerning the results of their practices in elementary school. Data were collected from 23 elementary school teachers involved in a project to improve science and mathematics teaching and technology education. Using self-assessment tools such as the STEBI-A (Science Teaching Efficacy Belief Instrument), the PSTE (Personal Science Teaching Efficacy) and the STOE (Science Teaching Outcome Expectancy), ten teachers were selected with high, moderate and low PSTE and STOE levels to be interviewed. The interviews centered on the professional development of teachers and experiences related to teaching science. Research results indicated that there was a reasonable impact on PSTE and to a lesser degree on STOE when the teacher had the experience of acting as a teacher during undergraduate studies, participating in in-service training courses for professionals, or even having access to varied instructional resources and supportive colleagues who shared their knowledge relating to teaching science.

Finally, in the literature on teachers' self-efficacy beliefs, it is much more common to find papers using the quantitative method. These studies, however, require a large number of participants in order to be able to carry out quantitative analysis, which clearly was not our case.

Therefore, our aim in this chapter was to identify and analyze the self-efficacy beliefs of two prospective physics teachers regarding the inclusion of modern and contemporary physics in the high school.

METHODOLOGY

Our research methodology was qualitative (Bogdan and Biklen, 1994), a case study, and our instruments for data collection consisted of a questionnaire and semi-structured interviews administered at the beginning and the end of this investigation to a group of 11 students in the physics teacher training course at the São Carlos Institute of Physics of the University of São Paulo/Brazil. Video recordings were also made at each research development stage, including the classroom activities with high school students.

The 11 prospective teachers participating took part in a course entitled: "Supervised Teaching of Physics", in the 8th semester of the physics teacher training course, with a total of 180 h (~30 weeks). The classes took place once a week lasting 4 hours. Among the activities in this discipline were study hours, classroom observations of experienced teachers, and the preparation and implementation of mini-courses for high school students attending local authority schools.

During this period, the class of prospective teachers was divided into two groups: one group participated in a short course on the subject of particle physics while the other group pursued a course on nanoscience and nanotechnology. Both courses had a total workload of 16 hours and both shared the same goal: to provide conceptual and methodological tools to enable them to handle the proposed topics in the classroom.

The particle physics mini-course developed and applied learning activities that included topics such as Rutherford's scattering technique, particle detection, conservation laws, fundamental interactions, the standard model of elementary particles, and the connection between cosmology and particle physics.

The nanoscience and nanotechnology mini-course covered the following topics: soft matter and phenomena at the nanoscale, fundamentals of atomic force microscopy, manufacture of nanostructures with molecular control, and operation of an organic device.

After participating in the mini-course, at a later stage with a workload of 20 hours, the undergraduates were given the task of analyzing the contents studied in order to adapt them and organize them into a teaching module that would be delivered to high school students, lasting 4 hours. These new teaching modules were adapted, organized, and delivered in the high school environment by 5 (nanoscience and nanotechnology) or 6 (particle physics) prospective teachers.

For the purposes of this chapter, the results of two undergraduates were selected. These two prospective teachers will be identified as Roberto and Saulo, who participated in the particle physics mini-course. Their synthetic profiles are outlined below:

Table 1. Profiles of undergraduates investigated

Teachers	Profiles
Roberto	He chose the teacher program for the following reasons: his empathy with physics, the availability of the course at night, given his need to work during the day, and the fact that teacher enjoys teaching. But he does not intend to practice immediately, since he already has a steady job as a civil servant now, but Roberto intends to be a teacher in the future.
Saulo	He always wanted to be a teacher and this teacher considers the profession to be very important, since physics is in everything around us. The fact that he had always liked mathematics, mechanical and electrical objects helped him decide to be a physics teacher. Saulo would like to pursue the profession when he graduates.

Below is the questionnaire used in this analysis as it was presented to the undergraduates.

a. I consider myself capable of implementing curricular innovations in my teaching.
b. I'm very effective in developing innovative activities in the classroom.
c. I believe I am able to select appropriate content to introduce MCP topics with my students.
d. I consider myself able to teach MCP topics to my students.
e. I consider myself able to understand MCP concepts.
f. I consider myself able to transpose to the high school MCP topics learned during the undergraduate course.
g. I am able to create MCP teaching activities for the classroom.
h. I am able to motivate my pupils by teaching and learning MCP topics.
i. I am able to answer questions from pupils relating to MCP in the classroom.
j. I consider myself able to make MCP concepts clear to my pupils.

Cognitive maps were used to interpret the information from the Likert questionnaires (Aranega, García, Muñoz, and Mellado, 2002; Da-Silva, Mellado, Ruiz, and Porlán, 2007; Porlán, 1989; Ruiz, Silva, Porlán, and Mellado, 2005). The use of cognitive maps as an analysis procedure of data obtained from the questionnaires has become a useful analytical tool in science teaching research. It makes it possible to structure a more comprehensive and less fragmented outline of the educational beliefs of each future teacher in different dimensions. Cognitive maps can be characterized as a network of ideas that reflects how the individual relates to his or her own perspective. They do not consist of an exact copy of the environment, but of a simplified representational model, or even provide a rough picture of this reality (Laszlo, Masulli, Artigiani, and Csányi, 1995).

In order to build the cognitive maps, geometric figures and different grayscales were used for the future teachers' responses: dark grey squares to represent "fully agree"; light grey squares to represent "agree".

Semi-structured interviews were also carried out with some prospective teachers individually focused on the one hand, on general aspects relating to career choice and on the other, aspects directly relating to their beliefs about the nature of modern and contemporary physics, as well as its teaching and learning, including their self-efficacy to present it in classroom. The interview protocols were developed with the help of two experienced researchers and designed to clarify and supplement certain information present in the answers to the questionnaires regarding the insertion of modern and contemporary physics in the high school.

A fully pooled data analysis from all these instruments will not be the aim of this chapter, so the data analyzed is limited mainly to the questionnaires with extracts from the interviews quoted in order to support the results.

RESULTS

The cognitive maps contained in figures 01 and 02 demonstrate that Roberto's self-efficacy beliefs increased from "agree" to "fully agree" in the case of seven different aspects of the inclusion of MCP in high school: 1) Selection of appropriate content, 2) Teaching these topics, 3) Implementation in the high school of what has been learned during undergraduate course, 4) Creation of activities, 5) Student motivation; 6) Answers to student questions; 7) Clarity in the presentation of concepts. What may explain this change, according to Bandura's (1977) concept, is that, in addition to the experience that Roberto and the entire group gained during the preparation and implementation of a new particle physics mini-course for high school students, this future teacher, specifically, was highly motivated in this endeavor, taking a lead in the design, coordination, and implementation not only of the part that he was to apply in the mini-course, but supporting his colleagues in their own parts, including Saulo. It is possible to say that the effort he exerted, added to the positive experience of preparing and implementing the mini-course and thereby increased his self-efficacy beliefs relating to the inclusion of MCP topics in the high school.

This perception is evident in the following paragraph transcribed from Roberto's response during one of the interviews performed to compare and better understand his responses to the initial and final questionnaires: *"I can even understand these answers, I still did not have sufficient knowledge. (...) I was confident that if I tried, I could, but I did not know how, right? That's why it couldn't be* 'fully agree' *(referring to the beginning of the research)"*.

Moreover Roberto's self-efficacy beliefs regarding the implementation of curricular innovations and understanding MCP concepts remained at "agree". On the implementation of curricular innovations, it is reasonable to maintain his high belief, since particle physics is an innovative classroom topic.

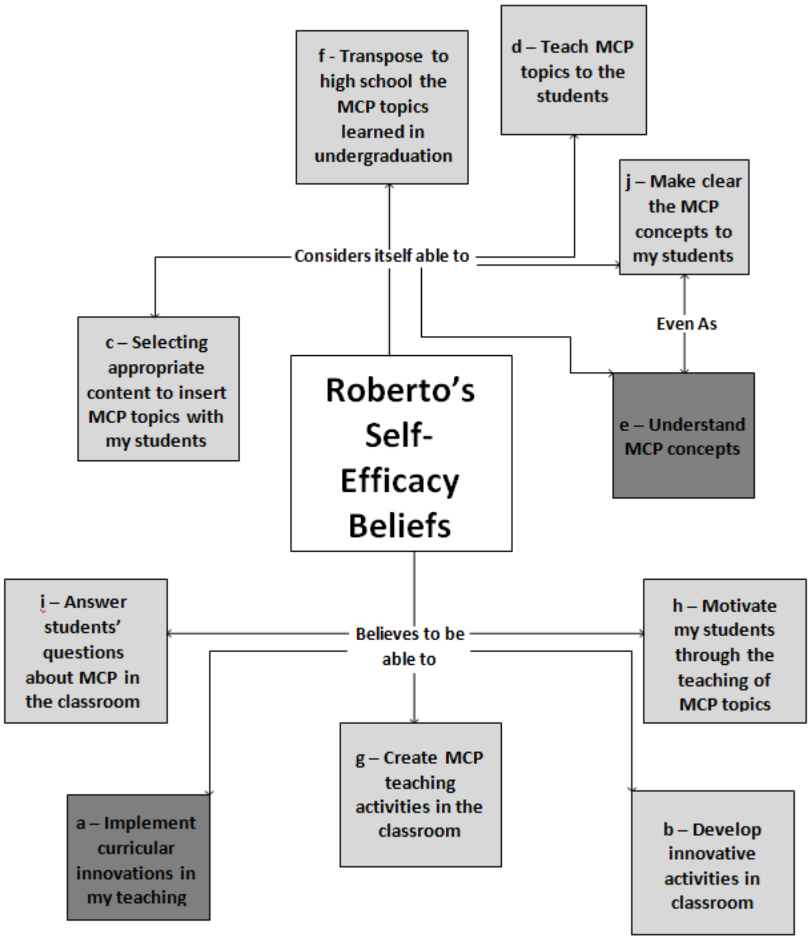

Figure 1. Roberto's initial cognitive map.

The understanding of MCP concepts can be explained in terms of his attitude of always being conceptually rigorous in his questioning. This result also reflects the possible effect of the particle physics mini-course taught to him and his colleagues or even the effect of disciplines which deal with modern physics topics. When it came to his belief in his ability to develop innovative activities in the classroom, Roberto's final response continued to be "agree".

In this sense, he and his colleagues only adapted particle physics activities and therefore they did not develop innovative activities in the classroom. Instead, they only mixed readings with activities that had already been developed during the particle physics mini-course.

Saulo, in turn, according to the cognitive maps in figures 03 and 04, also stuck to "agree" with regard to his self-efficacy beliefs concerning the development of innovative activities in the classroom. The explanation that supports this behavior is the same as that proposed for Roberto, that is, they didn't develop innovative activities in the classroom.

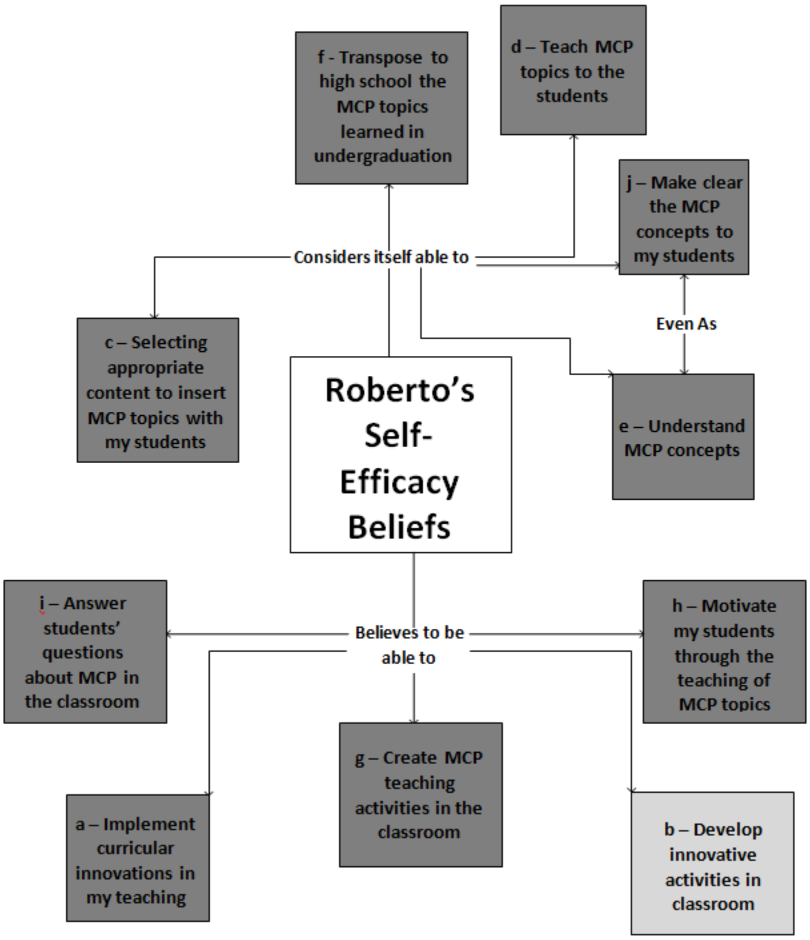

Figure 2. Roberto's final cognitive map.

He also stuck with "agree" in regard to three different aspects of the inclusion of MCP in the high school: 1) Creation of activities, 2) Implementation in the high school of what has been learned during undergraduate course, 3) Clarity in the presentation of concepts. Saulo continued to "agree fully" with two other items that represent beliefs associated with the introduction of MCP in the high school: 1) Teaching these topics, 2) Understanding of MCP concepts. Furthermore, Saulo stuck to "agree" with regard to his belief about his ability to implement curricular innovations. Finally, some of Saulo's self-efficacy beliefs decreased from "fully agree" to "agree" with regard to three aspects of implementation of MCP in the high school: 1) Selection of appropriate content, 5) Student motivation; 6) Answering student questions.

Studying Saulo's responses to the initial and final questionnaire, during an interview, the prospective teacher revealed important ideas in agreement with the questionnaire data: *"I really agree, but not fully, because at first I was more optimistic and in the end I was seeing* *the reality (...) I think it was too strong to put "fully" here (with regard to selecting appropriate content to introduce modern and contemporary physics topics to his students) because of the difficulty I had with it. I can't just put it down to the difficulties of everyday life, or that there wasn't time (...) when I had time, I had difficulty".*

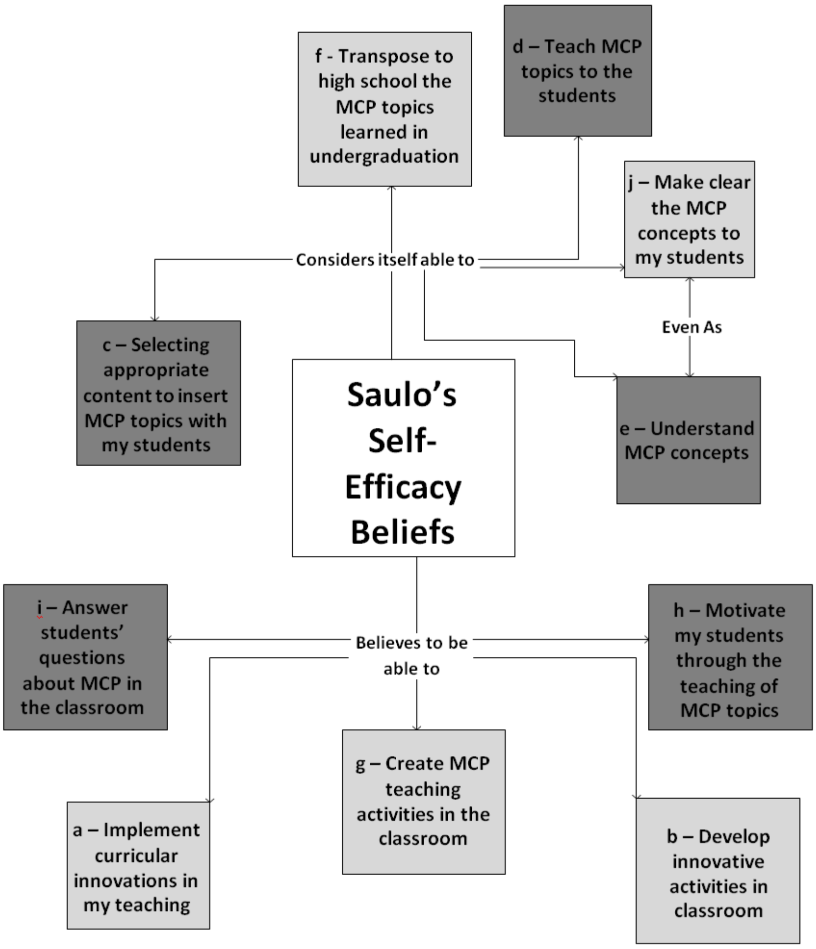

Figure 3. Saulo's initial cognitive map.

It is important to remember that, unlike Roberto, Saulo at no time during the mini-course worked on any topic of particle physics or even MCP. This happened because his role in the mini-course was only the exposition of the thoughts of ancient Greek philosophers on the topic under study. Also during the preparation, Saulo displayed a great deal of insecurity and anxiety so that his physiological state was affected in this process. Moreover, his performance in previous classes presented to the teacher trainer and fellow students was very weak and much criticized, during the preparation period for the mini-course, which shook him visibly. In the activities during mini-course days, Saulo's meager collaboration was already noticeably hesitant. So, in the light of so many obstacles and faced with a performance that should have been bolder, it would only be reasonable to expect that his overall pattern of responses to the questionnaire indicates a decrease in self-efficacy beliefs compared to the others observed.

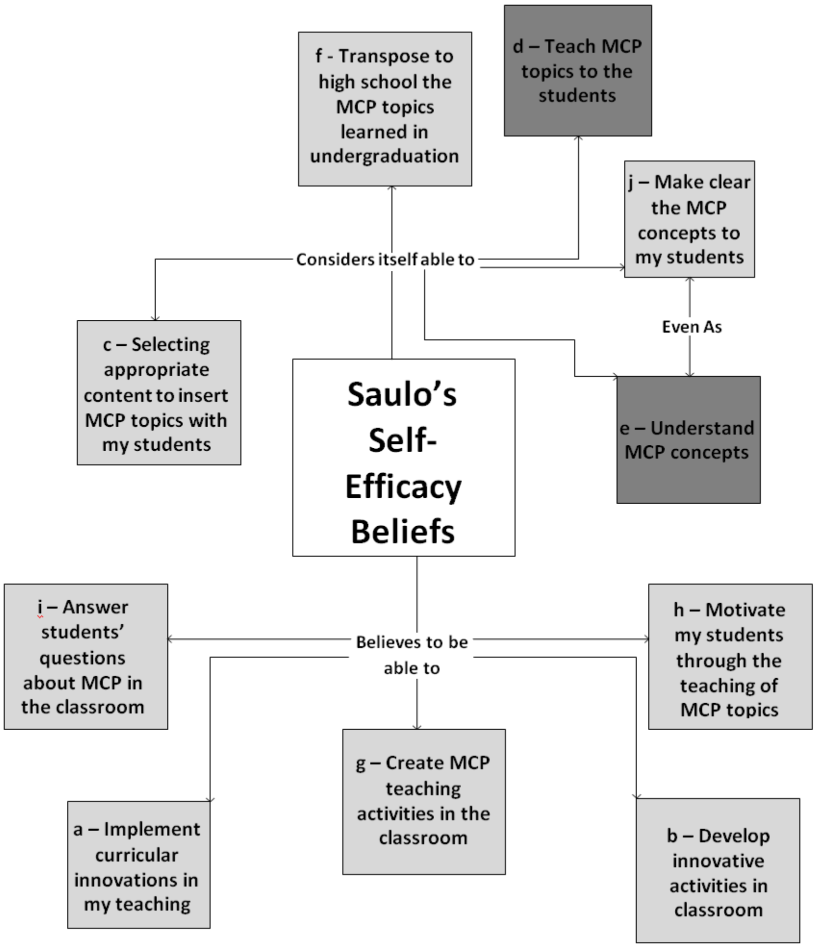

Figure 4. Saulo's final cognitive map.

However, Saulo seems to have offset the perception of his limitations and difficulties thanks to productive vicarious experiences of the teaching of MCP reported by some of his colleagues, especially Roberto, which helped him to maintain his self-efficacy beliefs unchanged.

CONCLUSIONS

The concept of self-efficacy created by Bandura (1977) enabled us to propose an interesting perspective which explains the possible causes of the changes in self-efficacy beliefs of the prospective teachers Roberto and Saulo in relation to the inclusion of MCP in the high school curriculum. In other words, the mastery experiences, vicarious and physiological states proved to be plausible sources of change in the self-efficacy beliefs of future teachers surveyed during their experience of the process of curriculum innovation. Thus, it is reasonable to assert that self-efficacy beliefs offer a good explanatory concept and, in this sense generally, it is important to undertake more qualitative research to study self-efficacy and contextual implications in physics education in order to better understand their predictive and explanatory limits.

A promising perspective for research and education strategy for training physics teachers would be to encourage them to reflect on their own self-efficacy beliefs regarding the implementation of MCP in the high school. In order to do this, it would be interesting, for example, to use cognitive maps as a support element for this process of reflection, focusing on the questionnaire used in this investigation.

In this sense, cognitive maps, as an analysis tool, provided us with a clear view of the restructuring of future teachers' responses and proved to be an interesting tool for a comprehensive understanding of prospective physics teachers' self-efficacy beliefs regarding the implementation of MCP in the high school.

Thus, when teacher trainers seek to evaluate and discuss the self-efficacy beliefs of prospective physics teachers regarding the implementation of MCP in high school, they will benefit their students and encourage the development of strategies to foster these beliefs throughout their initial or in-service training courses.

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