Science Teachers' Beliefs and Practices: Collaboration as a Trigger of Change

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ABSTRACT

Teachers' beliefs regarding teaching affect how they think and act and as such influence teachers' curricular decisions and how they interpret innovative ideas. The role of a facilitator is important for creating opportunities for teachers to review and explore beliefs and practices. This study explores the role that the collaborative process between a facilitator and Physics and Chemistry teachers plays in the process of professional development. More specifically, the goals of the present research are 1) to study a collaborative process between teachers and a facilitator and 2) to understand how this process contributes for changing teachers' beliefs and practices. In order to achieve these goals, a specific program of professional development (PACIR) was studied, which characteristics were sourced on literature concerning the relationship between beliefs and practices and between reflection and collaboration. Five Physics and Chemistry teachers were involved in a qualitative study. The result shows that PACIR involved a facilitator and teachers in deep collaboration, fostering the implementation of new practices, discussion and exploration of new ideas, reflection on teaching and learning experiences. The collaboration, grounded on a trusting relationship and on a constant negotiation of meanings, was essential for teachers to overcome their fears and uncertainties, to stimulate teachers to develop different practices and to leave their comfort zone and review some of their beliefs.

Keywords: Physics and Chemistry teachers' beliefs; teachers' practices; collaboration; facilitator; professional development; scientific inquiry; science teaching.

Conceções e práticas de professores de Ciências: Colaboração como Promotora da Mudança

RESUMO

As conceções de ensino afetam o modo como como os professores pensam e agem, bem como influenciam as suas decisões curriculares e a forma como interpretam ideias inovadoras. O papel de um facilitador é importante para criar oportunidades para os professores reverem as suas conceções e práticas. Este estudo visa estudar o papel do trabalho colaborativo entre um facilitador e

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professores de Física e Química para o seu desenvolvimento profissional. Mais concretamente, este trabalho tem como objetivos: (1) estudar o processo colaborativo entre professores e facilitador; (2) conhecer como é que esse processo contribui para a mudança de conceções e práticas de professores de Física e Química. Para se atingir esses objetivos, foi estudado um programa de formação de professores (PACIR), fundamentado na literatura sobre a relação entre conceções e práticas e entre reflexão e colaboração. Os participantes no estudo são cinco professores de Física e Química. Optou-se por uma investigação qualitativa. Os resultados mostram que o PACIR permitiu envolver o facilitador e os professores num estreito trabalho colaborativo, promovendo a implementação de novas práticas, a discussão e a exploração de novas ideias, e a reflexão sobre experiências de ensino e aprendizagem. A colaboração, assente numa relação de confiança e com constante negociação de significados, foi essencial para os professores ultrapassarem os seus receios e incertezas, para os estimular a desenvolver diferentes práticas e para incentivá-los a abandonar a sua zona de conforto e rever algumas das suas conceções.

Palavras-chave: Conceções de professores de Física e Química; práticas dos professores; colaboração; facilitador; desenvolvimento profissional; ensino por investigação; ensino de ciências.

INTRODUCTION

Research on teachers' professional development points out that the process of change is a difficult one. Some studies highlight that unaided teachers tend to resist to innovations, either because they do not understand it, because they do not consider it relevant or because they do not know how to enact those changes (Fullan & Hargreaves, 1992). More recent studies show that teachers use different strategies for dealing with proposed changes, most of the times undergoing encapsulated changes or changing peripheral aspects of their practice (Feyzioğlu, 2012); nevertheless sometimes teachers do get involved in deep changes questioning previous held assumptions (Corbun, 2004). Many studies focus on the external context where change is to be enacted (e.g., Corbun, 2004). Some other studies also stress the importance of teachers' personal resources (e.g., Runhaar, Sanders, & Yang, 2010). For instance, according to Spillane (1999), "teachers have to notice opportunities for learning, or stimuli for change in their environment, and such noticing is not automatic. (…). The opportunities teachers notice depend on their environment (…), but also on their personal resources, including their knowledge, beliefs and dispositions" (p. 169). Moreover, indeed, many authors have been suggesting that teachers' beliefs regarding teaching and learning influence their curricular decisions and instructional practices and how they interpret innovative ideas (Mukminin, 2019; Nespor, 1987; Pajares, 1992). Aligned with these ideas, some authors have been proposing professional development models centered on teachers' practices, on collaboration, and on reflection on teachers' experience (Capps, Crawford, & Constas, 2012).

Despite great advances on teachers' professional development models, some studies still indicate that teachers tend to reflect on external aspects of their practice, that reflection is seldom intentional or structured and that, as a result, assumptions guiding teachers' practice remain mostly unchanged (Day, 1999; Eekelen, Boshuizen, & Vermunt, 2005). Knight (2002) mentions the need to develop guided and sustained opportunities

for teachers to reflect on their own and on alternative practices. Collaborative processes focused on teachers' practices can work as such a guided and sustained opportunity for enacting teacher intentional reflection. However, collaboration often leads to superficial reflection and to confirmation of teachers' practices and beliefs instead of questioning it (e.g., Day, 1999; Kuusisaari, 2013). So one important dimension for enacting change is to make teachers recognize their own beliefs and to create classroom situations where they can challenge it (Bryan & Atwater, 2002). Consistently, some studies point out the essential role of a facilitator for challenging teachers' frameworks, for providing them with conceptual instruments to reflect critically on their practice and for creating a safe environment where teachers feel comfortable to develop new practices and to test and revise old beliefs (Butler & Schnellert, 2012; Peeters, & Robinson, 2015, Postholm, 2011).

Considering that many studies still focus on the collaborative processes among teachers, the goals of the present research are 1) to study a collaborative process between teachers and a facilitator and 2) to understand how this process contributes for changing teachers' beliefs and practices. In order to achieve these goals, a specific program of professional development was studied, which characteristics were sourced on literature concerning the relationship between beliefs and practices and between reflection and collaboration. The study was developed with science teachers and the focus of the program was inquiry in sciences classes, which is aligned with the Portuguese curriculum and with Portuguese guidelines for teachers' education.

RELATIONSHIP BETWEEN BELIEFS AND PRACTICES

Beliefs are ideas and representations of the existing reality, they are personal truths about how the individual sees himself and others, they have an affective and evaluative component and they are formed from different sources of information, namely the personal experience (Nespor, 1987). Pajares (1992) mentions that beliefs influence the acquisition and interpretation of knowledge, and within the specific classroom context, beliefs determine how teachers will design learning and teaching tasks and which contents they will choose to teach and how. According to Llinares (2002), beliefs influence teachers' practices as they work as systems that organize thinking, and as they influence teachers' perception of reality and their expectations from others and from their actions. In order to change beliefs teachers have to recognize their initial ones and they have to be confronted with new ways to represent and to make sense of experience.

Hoy, Davis and Pape (2006) propose that teachers change their beliefs when they are confronted with other more meaningful beliefs and they start questioning their own beliefs. According to Guskey (2002), teachers have to acknowledge that some of their beliefs are not well suited for interpreting experience; and simultaneously they have to be provided with guidance aligned with their personal goals. However, firstly, defends Guskey (2002), teachers have to be encouraged to try out new practices and afterwards

they have to be provided with feedback regarding the impact of their new practices on students' learning. Aligned with this perspective, Loucks-Horsley et al. (2003) mention that beliefs are restructured when teachers develop new behaviors and when they develop new understandings about their experience. However, involving teachers in new practices or behaviors might be a difficult process, as they tend to hold on to their initial ways of interpreting experience. In addition, it may prove difficult to make teachers interpret experience according to a different perspective as their original beliefs filter how they interpret the new information (Llinares, 2002). Nevertheless, the study of Bryan (2003) focused on a process of professional development of a novice teacher reveals that the analysis of beliefs in the context of practice was essential for helping the teacher reappraise her initial beliefs and explore her practice in the light of the initial beliefs. This process was essential to initiate a process of change. In the same line, Crawford (2007) emphasizes the importance of stimulating change of practices and beliefs in the context of authentic practice, in which teachers are able to appreciate how things work, to gain awareness that new practices might work in actual classrooms and to assess their beliefs based on their actual experience. Bryan (2003) and Crawford (2007) stress the role of facilitators in creating opportunities for teachers to review and explore their implicit beliefs and to observe how it affects their practices.

COLLABORATION AND REFLECTION

Collaboration implies several participants working together in order to achieve the same goals and it involves communication and joint decision-making (McCotter, 2001). Several authors emphasise its benefits for professional development. Collaborative work promotes learning and it motivates teachers for solving problems arising from their everyday work (Penuel, Fishman, Yamaguchi, & Gallagher, 2007). In a collaborative process, teachers analyse critically their beliefs and discuss new strategies for teaching and learning (Loucks-Horsley et al., 2003). Collaboration encourages reflection and shared critical examination of practice and of promotes co-construction of knowledge (Butler & Schnellert, 2012). Yet, mention should be made that collaboration will be most efficient in promoting teacher learning, if teachers' beliefs and practices are questioned and challenged by the other teachers (Kuusisaari, 2014).

However, studies suggest that sometimes collaboration leads to superficial reflection and often serves to confirm previous teachers' practices and beliefs instead of questioning and challenging it. Day (1999) highlights how difficult it is for the teachers to move beyond "comfortable collaboration" (p. 80). This aspect has been revealed in other studies. For instance, Meirink, Meijer and Verloop (2007) observed that teachers in a collaborative context become involved in a number of learning activities, often with the goal to know each other's methods. Notwithstanding, teachers ended up postponing their experience with other methods, and in addition, they tended to confirm their own teaching method keeping their practices unchanged. Similarly, Kuusisaari (2013) observed that teachers' discussion groups about learning theories and modes of implementation facilitated the

establishment of a link between theory and practice and the emergence of new ideas among teachers. Simultaneously, the author points out a few episodes in which teachers applied the new theories in a non-reflective way, supporting uncritically each other's ideas.

Other studies illuminate other difficulties. For instance, in their study with three groups of educational professionals, Tillema and Westhuizen (2006) concluded that being involved in a collaborative group increases the likelihood that its elements will examine and teste their beliefs. However, the collaborative construction of knowledge can also be equally inhibited by "mismatched beliefs, lack of individual commitment, absence of conceptual change and substitution of hands-on activity for discussion" (p. 65). In the same sense, the work of Levine and Marcus (2010) reveals that the structure and focus of the collaborative work influence which practices teachers are willing to make public and the type of information and ideas that they decide to share with others, which affects the degree of joint learning. Thus, although the collaborative work may facilitate teachers' professional development, the intervention of someone external can play a crucial role in moving teachers from their comfort zone. Kuusisaari (2013) stresses the importance of a facilitator in situations where the elements of the group are not able or are not willing to question or to challenge each other.

METHODOLOGY

Context of the study

As stated, the goals of the present research are 1) to study a collaborative process between teachers and a facilitator and 2) to understand how this process contributes for changing teachers' beliefs and practices. In order to achieve these goals, a program of professional development directed to science teachers and focused on inquiry was studied. The decision to focus on inquiry is due to Portuguese curricular context and closely related to recent guidelines for teachers' education.

The Portuguese science curriculum of basic education (DEB, 2001) emphasizes a constructivist approach to teaching and learning and values inquiry learning, based on problem solving and decision-making. A number of new strategies were described and teachers are expected to involve students in observing the surrounding world, in collecting and analyzing different types of materials, in planning researches and implementing experimental work, in developing project work, in communicating results and debating ideas, and in working collaboratively (DEB, 2001). However, inquiry requires a more active role of the student and new teaching strategies (Bramwell-Rejskind, Halliday, & McBride, 2008), which causes stress to teachers and place high demands on them making

the process of curricular change difficult. Consistent with these observations, in Portugal numerous studies show a gap between the formal science curriculum and the extended use of inquiry by the science teachers. Besides its focus on inquiry, this program presents a number of characteristics sourced on literature concerning beliefs and practices' change and concerning the role of collaborative and reflective processes on change. Therefore, first of all, the program develops around a problem related to the teachers' practice. Literature demonstrates that changes cannot be forced and hardly come true if teachers are satisfied with their practices (Fullan, 2001). Therefore, it is essential that change arise from a situation that is causing dissatisfaction and discomfort to the teacher and to involve actively teachers in its resolution, namely by developing new practices. Secondly, and considering that beliefs may hinder the construction of new meanings and the development of new practices (Crawford, 2007), teachers are pushed to collect data about their new practices and to reflect on that data. We based on the ideas of Guskey (2002) according to which, in order for teachers to change beliefs, they have to acknowledge the impact of their own innovative practices on students' learning. So firstly, teachers have to be pushed to develop new practices and to validate it; only afterwards, they will be able to re-appraise their original beliefs and possibly to change it. However, considering that individuals tend to analyze their experience in the light of their original beliefs and that teachers will hardly move beyond comfortable collaboration (Day, 1999), it is essential to challenge teachers to evaluate their experience in the light of new beliefs. Therefore, the third characteristic of the program is the role of the facilitator within the collaborative process. The facilitator stimulates the development of new practices and teachers' exploration of their own beliefs, challenges teachers' interpretations by introducing new perspectives, and pushes teachers' reflection further.

Considering this theoretical basis, the program of professional development (PACIR) involves an iterative cyclic process, organized around five stages: (1) to **P**lan (At this stage, teachers and the facilitator design a set of inquiry activities); (2) to **A**ct (At this stage, teachers implement the activities and the facilitator observe some classes and support the teachers); (3) to **C**ollect (At this stage, teachers collect information regarding students' learning, involvement, difficulties and ways of overcoming it; facilitator supports teachers in developing instruments for collecting data); (4) to **I**nterpret (At this stage, teachers and the facilitator interpret the results collected); (5) to **R**eflect (At this stage, teachers and the facilitator reflect on their experiences' and their classroom and curricular contexts, they explore relationships between new classroom practices and students' experiences, they revise, if needed, the lessons plan and the inquiry activities, and they mobilize theoretical knowledge for constructing new understandings regarding teaching and learning) (Figure 1).
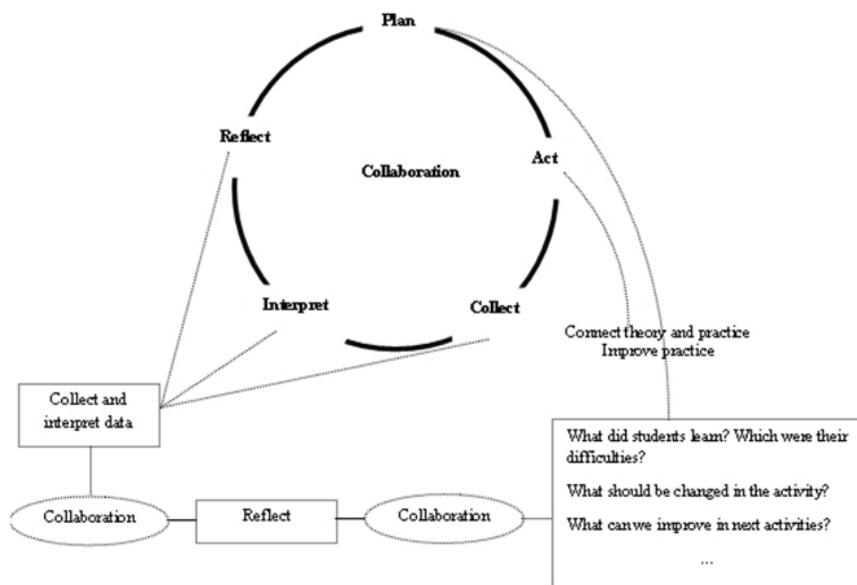
Figure 1. Description of the program PACIR.

Collaboration between teachers and the facilitator is a central dimension of this program. Indeed, the facilitator develops a collaborative relationship with the teachers, stimulating teachers to plan and to implement inquiry activities, supporting or confronting teachers' interpretation of difficulties and students learning, introducing new perspectives, promoting teachers mobilization of theoretical knowledge and even sharing with them theoretical artefacts for planning the lessons, for interpreting the data and challenging their reflections.

Teachers started the program by selecting a topic of the science curriculum that they would teach according to an inquiry perspective. The selection of this topic depended on the school year of each of the teacher as well as on their personal interests. After topic selection, the first planning session began in collaboration with the facilitator. In this session, each teacher defined the sequence of classes and the number of inquiry activities that they would develop. Teachers and facilitator met for planning every activity; the number of activities depended on the initial sequence and on the topic selected. Each planning session lasted two hours and teachers were involved in at least two weekly sessions. During these sessions, teachers planed with the facilitator, a sequence of lessons on a topic of the science curriculum and they discussed and built the sequence of classes, consisting of various inquiry activities. After the construction, each inquiry activity was implemented in the classroom and teachers collected data from their students, by means of interviews, classroom audiotapes and written documents in order to learn about the effects of their new practices on students' experiences. Meanwhile the facilitator observed the implementation process, difficulties met, strategies for overcoming it, and students'

reactions. After implementing each new activity, teachers in close collaboration with the facilitator interpreted data and reflected on the effect of the new practices in students' experience. At this moment, they were confronted with their initial expectations and fears and they were challenged to construct new meaning by mobilizing educational knowledge.

Participants

Five Physics and Chemistry teachers participated in the study. They were teaching in different middle schools within the region of Lisbon. They had different years of teaching experience (Table 1). Nevertheless, they were all struggling with their teaching methods and they all wanted to develop new practices. Furthermore, they were all acquainted with inquiry and were motivated to develop inquiry activities for facilitating science learning. Therefore, they all volunteer to be part of PACIR, as they saw it as an opportunity to learn and to develop new practices.

Table 1
Teachers' Characterization.

Teacher	Age	Teaching Experience	Formal Education	Science Subjects (grades) Taught During the Program
Anna	47	23	Master degree in Teaching Physics	Physics and Chemistry (7th grade)
Maria	42	17	Master degree in Science Education	Physics and Chemistry (8th grade)
Alice	25	3	Graduation in Chemistry; Enrolled in a Master degree in Science Education	Physics and Chemistry (9th grade)
Laura	28	5	Graduation in Chemistry	Physics and Chemistry (9th grade)
Cameron	33	11	Graduation in Physics	Physics and Chemistry (8th grade)

Data collection

Multiple data collection methods were used: (i) Individual interviews at the beginning of the program, with the goal to explore teachers' formal education and experience, teachers' motivation and expectations about the program and teachers' beliefs concerning teaching and learning and science education; (ii) Individual interviews to the teachers at the end of each stage of the cycle PACIR with the goal to make teachers evaluate the process of change and to identify aspects deemed essential in this process. As the cycle was repeated several times throughout the school year, each teacher was interviewed about 30 times; (iii) Individual interviews at the end of the school year with the goal to explore teachers appreciation of the role of the collaborative process in their own professional development and their evaluation of inquiry activities; (iv) Audiotaped interactions among

facilitator and teachers during the stages to plan, to interpret and to reflect, in order to describe the collaborative process; and (vii) Teachers' written reflections.

Data analysis

For analyzing the interviews, the written documents and the interactions between teachers and facilitator, an inductive strategy of content analyses was used, recurrently examining the data to uncover salient patterns and themes associated with the research aims (Miles & Huberman, 1994). All documents were read and the targeted text was segmented. Each segment was assigned a code according to its features. After rereading the segments and codes, a final group of categories and sub-categories was arrived. For this study, the categories and subcategories listed below were used (Table 2).

Table 2
Categories and Subcategories of Analyses

Source of data	Categories	Definition	Subcategories
Interviews and written documents	Beliefs regarding learning	Teachers ideas concerning what is learning	Learning as memorizing and reproduction
			Learning as knowledge construction
	Beliefs regarding teachers' role	Teachers ideas concerning what is the expected from a science teacher	Teachers as knowledge transmitters
			Teachers as facilitator of knowledge construction and of learning
	Beliefs regarding students' role	Teachers ideas concerning how students should behave in class and how they learn	Students listen to the teacher and reproduce scientific knowledge
			Students are responsible for their own learning and knowledge construction
	Beliefs regarding inquiry	Teachers ideas concerning issues that interfere of the development of inquiry activities	Curriculum characteristics
			Students characteristics
			Time constraints
		Teachers ideas concerning the benefits of inquiry	It facilitates concepts' learning
			It facilitates development of competences
			It improves students' engagement
	Evaluation of collaborative process	The importance of the collaborative relationship for supporting change	Affective dimension
		The importance of the collaborative relationship for promoting learning	Pedagogical dimension

Source of data	Categories	Definition	Subcategories
Interactions between teachers and facilitator	Facilitator's strategies for stimulating new practices	Accept previous ideas and propose a new ones	
		Reassure teachers' confidence	

RESULTS

Teachers' beliefs about learning, teaching and inquiry

Initially, teachers' beliefs regarding learning were centred on the acquisition of knowledge. In their views, learning mainly consists of acquiring new knowledge by means of solving exercises and through the memorization of scientific concepts. For instance, two of the teachers explain their views:

> When students are able to solve exercises, I recognize that they have understood content (…). And I think that this is great, as it means that students were able to retain something in their heads (Interview at the beginning of PACIR, Anna).

> For me it is important that students learn scientific knowledge. It's really important that (…) they can demonstrate what they know by applying their knowledge on a summative test (Interview at the beginning of PACIR, Laura).

All participating teachers revealed this type of beliefs. Their understanding of the role of the teacher is consistent with it: It consists of explaining the scientific concepts and of assuring that students have acquired these concepts by questioning the students, as illustrated on the following excerpts.

> My lessons are very expositive. I explain the topic. (…) They know that my classes are mainly expositive and I think that they learn. (Interview at the beginning of PACIR, Alice).
> A teacher is expected to expose the topic. She may question the students; nevertheless, she has always to write down on the blackboard all the ideas and to dictate a resume of the ideas in order for students to have it written. These written ideas are important, as they will help students studying for the tests (Interview at the beginning of PACIR, Cameron).

Accordingly, students are expected to play a passive role. They have to listen to the teacher and to reproduce the scientific knowledge when asked to, mainly in a context of summative tests. Therefore, students are seen as passive receivers of knowledge and

teacher is considered as the main element in the process of teaching-learning. On the contrary, by the end of the program, teachers showed a strong appreciation of the active role played by the students in the construction of their knowledge and in their own learning. For instance, one of the teacher states: "Students have to play the main role in the class. (…) Students are able to learn by themselves" (Interview at the end of PACIR, Maria). Also in the same direction, Alice states "student has to assume a proactive role, either listening or searching. There has to be a balance in everything" (Interview at the end of PACIR, Alice). These expressed beliefs regarding the role of the student in learning and in the classroom are associated with a more constructivist learning focus, which emphasis learning as meaning construction and strategies such as, questioning, reflecting, arguing, interpreting, and writing, among others.

These changes in teachers' beliefs came along with changes in how teachers positioned themselves in relation to inquiry. Indeed, initially and despite having volunteer to participate in this program, teachers showed resistant in developing open inquiry activities, justifying their position with arguments such as: students' poor performance; students' lack of habits with inquiry activities; and lack of time for fulfilling the program, as shown on the following teachers' quotes.

> Students need that teachers tell them everything. Inquiry activities are too open, and so students have lots of difficulties (…). It is much better to plan closed activities where we can clearly direct the students" (Interview plan stage, cycle 1, Anna)

The only thing I see as a limitation [of inquiry] is time. I expect that students will take long in developing these activities. (…) We have the program to fulfil and I think that students will take a long time in developing these activities (Interview plan stage, cycle 1, Cameron)

These arguments seem to be anchored in their initial beliefs about learning and about the role of the students and the teachers. And, indeed, at the end of their involvement with the program, teachers showed a more favourable position regarding inquiry, emphasizing its positive aspects. Teachers recognized that inquiry facilitates concepts' learning and the development of competences such as group work, autonomous work and inquiry competences (e.g. to plan experiences, to interpret tables and graphs, to explain their results). In addition, teachers recognized that inquiry activities were important for engaging students' with science classes. For instance, two of the teachers explain their views:

> [They learnt to do] research, to work in groups. They learnt to tolerate and to respect each other opinions, and to share their opinions with colleagues. They acquired the know-how. They feel now more comfortable to plan experiences, to interpret tables and graphs, to interpret texts. But the truth is that the way they learnt was totally different. They searched for information and retained it in their mind. Having to explain their results to the others helped them a lot. (Interview at the end of PACIR, Anna)

They were able to perform successfully by their own. It is interesting to observe them when they are doing their work (…). Plus I have this strange feeling that students almost do not need me (...). Students are able to perform the activities by their own, and they even assume a different role during the classes. And one more thing, I am confident that they liked it. (Interview at the end of PACIR, Cameron)

Strategies used for stimulating the development of new practices

The program of professional development started with the design of inquiry activities. However, this type of activities challenged teachers to think of and use other teaching strategies. Indeed, inquiry activities are much more open activities that the ones that these teachers were used to implement in their classrooms; there is no specific solution or one specific way to get to the solution; rather students have a high involvement in deciding their own goals and strategies. So not only this type of activities require distinct classroom behaviour from the students as well as a different role of the teacher. In addition, inquiry is based on a different way of conceiving learning and assessment; it requires a different classroom organization and management and different way of understanding the science curriculum. Given this, and despite having voluntarily decided to get involved with PACIR, initially teachers used their routine ways of understanding science teaching and learning for planning the activities, and they reacted and opposed the ideas of the facilitator. They argued using their own knowledge and their beliefs concerning teaching and learning. In order to stimulate breaking with their routine practices, the facilitator and the teachers were involved in a process of negotiation. In this process, the facilitator accepted that teachers would keep some of their old practices but simultaneously she stimulated them to test new ones; for that she resorted to two type of strategies: 1) do not call teachers' prior knowledge and beliefs into question and at the same time introduce new ideas, and 2) constantly assure confidence to the teachers and encourage them to go beyond their comfort zone.

Students' assessment was a delicate theme and it involved careful negotiation. Indeed, assessing students' learning when they are involved in inquiry activities was one of the issues that made teachers more uncomfortable with. This issue emerged several times during the planning stages. In next dialogue, both teacher and facilitator negotiate different strategies for assessing students' learning. According to the facilitator, two important dimensions of assessing inquiry activities are: a) to involve students with self-assessment practices (in order for them to understand what their difficulties are and to know where and how they can still improve and learn); and b) to develop specific instruments for assessing competences of inquiry. The teacher reacts to these ideas, exposing her fears and doubts, as well as her specific difficulties.

Laura – I am going to add written feedback concerning what students have to improve for the next activity.
F –That sounds good.

Laura – But now, assessing competences… That sounds more complicated. I'm not going to do that.

F – But if you want students to learn how to formulate questions, to plan, to execute the activity, and to draw conclusions, you will have to assess these actions. Don't you think so?

Laura – Yes, I agree with you … (laughs). But, I was wondering whether I can assess these actions using a different strategy. You see, I can give a self-assessment document to the students, as you suggest. But then, how do I use it?! So, I was thinking of assessing these actions as I do with a test: I attribute to each step of the activity a score and I assess the overall activity by calculating a general score.

F – If you think it's easier to calculate a general score, you can do it. However, I still think that it's important to give feedback concerning each step of the activity and...

Laura –Yes, I will give feedback to the students. I agree with you do (…). Now, I just do not know which competences I will assess and how I will assess it.

F – This is my suggestion: First define which competences you expect to develop with each activity. Then it will be easier to build an assessment grid using a scale from 1 to 5.

Laura - I can even make a list of competences together with you, but I still prefer scores.

F – All right. We can define the competences. And you can use a single score for assessing the competences instead of using a scale. In what concerns self-assessment, it is useful for your students to acknowledge the work they have done; and it is also useful for you. (…) It is important to make them think about their work and to let them know how are they going to be assessed in order for them to improve and to learn.

Laura – Yes, I understand it. I'm just afraid that they don't get serious about self-assessment.

F – If self-assessment is important for you, it will also be important for the students. You have to make it relevant for the students.

Laura – I will do as we will plan and I will see what happens. If self-assessment does not work, …

F – … we will revise the entire process. (Audiotaped interactions plan stage, cycle 2, Laura)

Although Laura seems to accept some of the facilitator suggestions concerning assessment, she also anticipates some difficulties and she expresses some doubts concerning the viability of the suggestions. In face of these anticipated difficulties and of her doubts, she plans the activity using her usual framework. The facilitator does not question the teacher's ideas and she accepts some of those ideas (for instance, using the general score for assessing students learning). However, the facilitator keeps on insisting on the importance of formative assessment of inquiry competences' and of students' self-assessment. In addition, the facilitator keeps on assuring the teacher that everything will work out fine. The teacher accepts to take the risk, despite some of her doubts remain.

During the process of negotiation, the facilitator took particular caution in never calling teachers into question. She valued teachers' knowledge and experience, while

simultaneously encouraged the teachers to leave their comfort zone and to try out new practices, as can be seen in the following dialogue:

> Anna – To begin an activity by asking the students what they know about the planets… Just like that…
> F – Yes. They have already heard several things related to the characteristics of the planets.
> Anna – But they may mention different things!
> F – Yes, they may … And there's no problem. It will enlarge the dialogue.
> Anna – Oh, my God! And will I be able to guide the dialogue?
> F – Yes, you will be able to do it! You will walk from group to group, you will raise questions, you will answer to students' doubts, you will listen to their opinions, and you will celebrate opposing ideas emerging within the groups...
> Anna – But what if they do not have any ideas?
> F – They always have ideas! (…)
> Anna – (...) Will students get where I want them to, if I give them such a degree of freedom?
> F – Well, it depends on what we want to (...). What do we expect from the students? I think that we want much more than just memorizing scientific concepts. How can we facilitate that?
> Anna – I realize that I will have to play a guiding role here.
> F – It will be a different role. You will be able to perfectly manage the situation.
> Anna – My students have a lot of difficulties... You will see.
> F – I will observe your students and I bet that I will form a different opinion. (…)
> Anna – OK. I understand your point. (Audiotaped interactions plan stage, cycle 2, Anna)

The dialogue develops around the degree of openness of the inquiry activities. Teachers are used to work with very closed and controlled learning situations where there is only one sole way and one solution, and where they control all the phases of the process. Contrarily, inquiry expects that activities will have many solutions and many ways to arrive at those solutions, and that students will have a main role in looking for the solutions. Anna exposes to the facilitator her main fears related to this more active role of students (e.g. fear that students will diverge from planned point, that they will not have any ideas, or that they will not arrive to the expected point). She also reveals some doubts concerning the effectiveness of inquiry learning. For sustaining her position, she argues with her students negative academic characteristics (*My students have a lot of difficulties...*).

Facilitator's strategy of constantly assuring teachers' confidence in their capacity to deal with anticipated difficulties was essential for guaranteeing that they would persist with the new practices. Indeed, after developing and implementing the activities, the teachers started to recognize some potential in creating more open activities and in using different assessment strategies. However, this was a long process and teachers showed

frequently trapped in their routine ways of doing and thinking, as is illustrated on the next dialogue.

> Laura – I am so much used to stand next to the blackboard, explaining the lesson topic… I am going to have a hard time changing this. Am I supposed to change it?
> F – Yes, of course! How will you be able to implement a new strategy based on students' discussions and on their involvement with the tasks, if you stand next to the blackboard explaining?
> Laura – Yes, I realize that. I was just making sure.
> F – Do you think that standing next to the blackboard makes sense? You have to change your role. Students will become the centre of your classes.
> Laura – Yes… I know that it makes no sense. But I will miss standing next to the blackboard.
> F – Why?
> Laura – I guess that I do need to talk.
> F – You will be able to talk (laughs)…
> Laura – I am not saying that type of talk. I mean, I will miss explaining the lesson topic to the students.
> F – I understand you. But don't you worry as you will still have an important role to play in your class as a teacher. However, you will be so busy walking from group to group, that you won't miss spending hours explaining things. (…) Explaining during one hour and a half…
> Laura – No one listens to me, that' true... So I walk from group to group. Students work by their selves and my role is to walk around, to question them, to monitor their work and to guide them... It's strange, all of a sudden. And the students on their own! They will get lost. OK. But they will have to work on their own. I've got it. And that is what is going to happen!
> F – They will not get lost because you will guide them. (…).
> Laura – I understand it. I just needed to hear you once again. (Audiotaped interactions plan stage, cycle 2, Laura)

In this situation, the teacher acknowledged that she should assign a more active role in order to facilitate students' learning. However, when she was confronted with the implications concerning her own role as a teacher, she hesitated. The dialogue between the two conveyed confidence to Laura in what concerns the new roles in the classroom, and supported her decision to reorganize the teaching-learning process.

Teachers' evaluation of the collaborative process

In their evaluation of the collaborative process, teachers mention that the facilitator worked as a constant supply of new inputs; these inputs were essential for teachers to revise their previous ideas and knowledge. In addition, teachers most often highlight that the quality of the relationship between them and the facilitator was essential for conveying a sense of trust, and for assuring confidence that they would be able to deal with the new

challenges. This sense of being able was essential for the teachers to overcome their fears and anticipated difficulties, and for them to take the risk to implement new practices.

> Collaboration has these things; it doesn't let us give up. You had an important role assuring me that the process was moving in the right direction and that students were learning. This was important. In addition, I don't feel alone in this process and I know that you are by my side, encouraging me to keep on moving (Interview reflect stage, cycle 1, Maria).

The sense of *having someone by their side* was essential for stimulating new practices. In addition, the continued presence of the facilitator during the several stages of the program also guaranteed that the teachers gained confidence and that they persisted with the new practices, as explained by the following teacher.

> Your initial help was important. I knew exactly what I should do, and how I would behave in the classroom. I had a clear goal. (…) Now I am sure that if the smallest thing went wrong, I would have step back (…). But that didn't happen. And this was mainly because our deep discussion and planning before the classes. And also to your persistence, always assuring me that everything was going to work out well. That was important. (Interview reflect stage, cycle 8, Anna).

Teachers' improved confidence for dealing with new situations is also reflected in their greater autonomy concerning decision-making and in their sense of control, as highlighted by the teachers:

> With your help, I was able to overcome the difficulties that I firstly anticipated with the open questions; that is particularly true for the first two activities. My usual strategy for starting a new topic was to make precise and direct questions to the students. (...) Now I have my own ideas and from lesson-to-lesson, I can even think of new improvements for the activities. (Interview plan stage, cycle 7, Alice).
>
> Collaboration allowed me to move my thinking further. Now I have a different idea concerning students' learning. [Collaboration] also helped me to reflect about students' difficulties (...). It also helped me recognize my own difficulties, for instance my difficulties related to the construction of the activities. I didn't know how to do; although I thought that I knew… (Interview reflect stage, cycle 3, Cameron).

Reading and re-reading some theoretical material and sharing ideas made teachers critically reflect on their own difficulties and to understand the nature of those difficulties as well as to define ways to overcome it. Therefore, teachers state that they learned new knowledge concerning teaching strategies and that they revised some previous knowledge;

this process caused them to enrich the activities, and to become more autonomous, as written by one of the teachers.

I'm learning and in some situations also relearning. Yet, it's a more significant learning as I already have some teaching experience. If I was by myself, I would have not done any of this. First, developing inquiry activities demands me extra work and secondly I had some difficulties in understanding some of the points involved in inquiry. It is much easier with the facilitator, as I can analyse and discuss about what is at stake with inquiry. And also this shared process encourages me. (Written reflection, Laura)

Finally, it should be noted that the possibility to collect evidence for supporting critical analysis of students' learning and behaviour was essential for teachers to revise their knowledge and beliefs, such as Cameron's statement reveals.

The collaborative work was important because it helped me to develop different strategies, to understand inquiry activities according to a new perspective and even curriculum itself. We talked about and we reflected on how we could improve our teaching in order to help students learn better. I wonder whether if I was alone in this process, I would have been able to do differently from what I used to do and from what I used to value. (Interview reflect stage, cycle 6, Cameron).

DISCUSSION AND CONCLUSION

Teachers spontaneously decided to participate in the program as they were not satisfied with their practices and they wanted to try out new ones. However, teachers' initial beliefs about teaching and learning influenced their beliefs regarding inquiry. They didn't refuse to implement inquiry activities. However, initially they wanted to develop inquiry activities in the light of their previous beliefs; rather than activities with a high degree of openness, requiring a different role from the students and the teacher and a different perspective of assessment. For supporting their positions, teachers held on to several arguments, such as restricted time for implementing open activities and students' characteristics (such as lack of autonomy). These results are aligned with the study of Wallace and Kang (2004), according to whom early beliefs about learning, about the role of the teacher and the student affect how teachers position themselves in relation to inquiry, often showing resistance to the use inquiry in their classes.

Other studies also show that beliefs regarding teaching affect teachers' perceptions about teaching and their approaches to teaching (Lam & Kember, 2006) and that often teachers resist curricular innovations due to many obstacles that they perceive in it, namely students' resistance, time management, inadequacy of new strategies for teaching certain curricular contents (e.g., Barak & Shakham, 2008). Beliefs act as a framework that affect how teachers perceive and interpret reality. Teachers tend to pay attention to certain aspects of reality and to interpret experience according to their initial beliefs, which makes them confirm initial beliefs, making difficult the process of change (Llinares, 2002). Thus, it is crucial to stimulate teachers to develop new practices and to gather

data on the impact of new practices on students' learning. According to Guskey (2002), this is a key dimension for changing beliefs. The author states that it is "the experience of successful implementation that changes teachers' attitudes and beliefs. They believe it works because they have seen it work, and that experience shapes their attitudes and beliefs" (p. 383).

Nonetheless, this looks like a paradox: How can we stimulate teachers to develop practices about which they do not have any formed or sustained idea or opinion? The results of this study confirm previous studies (e.g., Mukminin, 2019) that in order to stimulate teachers to leave their comfort zone and to develop new practices it is essential to develop a caring and trusting context, where teachers feel comfortable and willing to take some risks. In this study, the collaborative relationship between teachers and the facilitator worked as that caring and trusting context.

The initial collaboration with the facilitator in planning the activities, and in anticipating difficulties and strategies for dealing with them, worked as an initial trigger to break with teachers' routine practices. Afterwards, while implementing new practices teachers were encouraged to collect data on the impact of the new practices on students' learning, and they were challenged to interpret the obtained results and to reflect on their practice according to a different perspective. The strategy of never calling teachers into question and valuing teachers' knowledge and experience, while simultaneously supplying them with a new perspective for analysing experience, was essential for initiating and maintaining a process of negotiation of meanings and of revising beliefs. This affective dimension of the context of collaboration is essential, as some studies show that beliefs mismatch may affect what teachers decide to share and their commitment to change (Tillema & Westhuizen, 2006). In addition, considering Levine and Marcus (2010) results, the characteristics of the different sessions – clearly directed to a goal, and structured in order to accomplish that goal (whether planning inquiry activities, or discussion about its implementation) may have open up discussion and facilitated sharing experiences.

Additionally, *seeing it work* and understanding *what's making it work* formed a pool of experiences and practical knowledge to which teachers could resort to in order to reappraise their beliefs and practices. The facilitator played a key role in assuring that *it would work*, i.e., in assuring that the risk of something going wrong was reduced (which would make teachers confirm their initial beliefs and retreat to their routine practices) and working out less positive situations in a new light. Simultaneously, while involved in new practices, in sharing experiences and negotiating new meaning with the facilitator, the teachers also developed new knowledge and competences. Literature demonstrates that lack of suited knowledge and competences can constitute important barriers to develop new practices (Fullan, 2001). According to Crawford (2007), the development of new practices requires the connection between theory and practice as it creates a context that facilitates teachers' reappraisal of their practices. In this case, the teachers gained a sense of confidence and of control, which were essential to backup teachers' change.

In conclusion, this program of professional development corresponds to the needs recognized in educational literature for teachers' training (Davis, 2003). It involved

a facilitator and teachers in deep collaboration, fostering the implementation of new practices, discussion and exploration of new ideas, reflection on teaching and learning experiences. It also promoted research of teachers' practices, decreasing the gap between educational theory and teachers' practice. Finally, this program enabled teachers to have positive experiences that met their needs. Altogether, this program promoted professional development and changes in teachers' practices and beliefs.

AUTHORS' CONTRIBUTIONS STATEMENTS

M.B. conceived of the presented idea, adapted the methodology to this context, collected and analysed the data. S.F. adapted the methodology to this context and analysed the data. A.M.F. adapted the methodology to this context and analysed the data. All authors discussed the results and contributed to the final version of the manuscript.

DATA AVAILABILITY STATEMENT

Data used and analyzed during the current study are available from the corresponding author, M.B., on reasonable request.

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