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Supporting pre-service elementary teachers in their understanding of inquiry teaching through the construction of a third discursive space

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ABSTRACT

Several international reports promote the use of the inquiry teaching methodology for improvements in science education at elementary school. Nevertheless, research indicates that pre-service elementary teachers have insufficient experience with this methodology and when they try to implement it, the theory they learnt in their university education clashes with the classroom practice they observe, a problem that has also been noted with other innovative methodologies. So, it appears essential for pre-service teachers to conduct supportive reflective practice during their education to integrate theory and practice, which various studies suggest is not usually done. Our study shows how opening up a third discursive space can assist this supportive reflective practice. The third discursive space appears when pre-service teachers are involved in specific activities that allow them to contrast the discourses of theoretical knowledge taught at university with practical knowledge arising from their ideas on science and science teaching and their observations during classroom practice. The case study of three pre-service teachers shows that this strategy was fundamental in helping them to integrate theory and practice, resulting in a better understanding of the inquiry methodology and its application in the classroom.

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Pre-service elementary teachers; education; inquiry methodology; supportive reflective practice

Introduction

Various studies have shown that the experience of children under 14 with school science is the main contributory factor in whether they pursue scientific careers (Lindahl, 2007; Royal Society, 2006). These findings are reflected in international reports that insist on the need to change science teaching in elementary education, a change that has to be rooted in teacher education (NRC, 2012; Osborne & Dillon, 2008). However, the observance of current recommendations for science teaching is challenging for pre-service teachers. These challenges are related to decisions over what and how to teach science, in such a way that it assists children to explore a central scientific idea, as they participate in activities designed to help them to establish connections with core scientific topics. This process will, in turn, encourage them to develop models and to learn about the nature of science

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(NRC, 2012). To do so, pre-service teachers need to broaden their knowledge and skills on science and science teaching, in addition to their capability to manage classroom behavior. Lastly, they need to start developing pedagogical content knowledge (Shulman, 1993) that would allow them to incorporate this type of science teaching into their general teaching.

The Nuffield report (Osborne & Dillon, 2008), which contains critical reflections on science education across Europe, proposes an educational model for preparing teachers that strikes a balance between theoretical components (knowledge of science and its teaching) and classroom practice (a broad range of tacit knowledge, only acquired from practice in the classroom). However, in many countries, including Spain, teacher training courses overemphasize the teaching of theoretical components. Thus, after their practicum, pre-service teachers often leave with the idea that teaching methods are irrelevant for real classroom practice (Cortés et al., 2012; Korthagen, Loughran, & Russel, 2006), where they usually follow the traditional expository methodology for science teaching (Cañal de León, Criado García-Legaz, García Carmona, & Muñoz, 2013). If pre-service teachers have no opportunity to observe innovative methodologies, such as inquiry teaching, and to put them into practice, then they will be unlikely to implement those methodologies as teachers; all the more so, if they have learnt science by following the traditional model, as the tendency is to teach as they were taught (Britzman, 1986). Authors such as Bryan and Abell (1999) and Schwarz (2009) pointed to the importance of teacher education that instills a reflective process in pre-service teachers, so that they can adequately integrate both theoretical and practical components. The difficulties that pre-service teachers experience with the integration of those components weakens their confidence in the capabilities of students to develop inquiries; they can be reluctant to use group work, fundamental for inquiry teaching; they neither organize student-focused classroom activities, as any constructivist methodology demands; nor do they develop assessments of low cognitive demand which is inconsistent with the teaching aims of constructivist approaches (see, e.g. Furtak & Ruiz-Primo, 2008; Metz, 2011; Osborne & Dillon, 2008; Seung, Park, & Jung, 2014).

However, there is little research on the challenges facing pre-service elementary school teachers who wish to integrate this knowledge on introducing inquiry teaching in the science classroom (Bryan & Abell, 1999; Crawford, 2007). The aim of this study is to examine this goal in the context of a specific educational approach – a third discursive space (Gutiérrez, Baquedano-López, & Turner, 1997), which, from the confrontation that arises between theory and practice, allows the emergence of new learning opportunities in the course of several activities for pre-service elementary teachers. These activities combined school practices and the final degree projects of pre-service teachers seeking to teach science through the inquiry methodology. This study forms part of a larger qualitative and longitudinal study that aims to reveal the experiential aspect in the evolution of the beliefs of pre-service teachers on science teaching throughout their education. In what follows, we examine the conceptual and methodological underpinnings to this third discursive space as an effective model for integrating theory and practice in science education.

Conceptual underpinnings

When having to teach any subject, including science, pre-service teachers need to connect and integrate several theoretical sources and practical experiences and bring together

aspects seen in different areas of their training. This is a task of the most difficult sort for pre-service teachers and one that is often not very well addressed in training programs (Darling-Hammond & Hammerness, 2005).

The practical knowledge they have comes largely from the set of ideas, conceptions and attitudes on science and science teaching and learning schematized over the many years they themselves spent at school (Briscoe, 1991; Mellado, 1998; Young & Kellogg, 1993). These schemata are consolidated over time and, according to some studies, undergo no significant changes at university (Aguirre & Haggerty, 1995). When pre-service teachers come to teach their subjects, these implicit conceptions are, in the end, of more importance than any knowledge of innovative methods for science teaching: they have neither experienced them, nor do they have sufficient confidence in the new approaches (Crawford, 1999; Helms, 1998; Luehmann, 2007).

Luehmann (2007, p. 831) believes that pre-service teachers need to be seduced into trying out innovative practices in their practicum and motivated to invest immense effort in them. She also emphasizes that they must achieve a certain degree of significant success to follow practices that are aligned with the recommended type of science teaching. However, pre-service teachers are not usually accompanied in their attempts to make sense of classroom practice, in relation to the proposals for change that are put forward and explored at university. Furthermore, school practices impose a series of limitations on the extent to which pre-service teachers can implement innovative teaching strategies (Crawford, 1999; Sykes & Bird, 1992), because school tutors very often reinforce the routine activities of 'transmission-style' science teaching. Another problem is that the new practices must be negotiated with school management and parents, which can be an even more daunting task for pre-service teachers (Windschitl, 2002).

Thus, teaching education programs should be intentionally designed to make the practicum a teaching experience that successfully integrates new theory with implicit conceptions. These programs should be spaces in which pre-service teachers can analyze and reflect upon what they see, believe, and actually do, in the light of the theoretical knowledge acquired. At the same time, support should be available from university supervisors and their peers during their practicum. Not only should pre-service teachers take part in relevant experiences (Bryan & Abell, 1999; Munby & Russell, 1992), their participation must be interpreted and recognized, as well as valued and accepted. These opportunities may allow them to build a bridge between theory and practice, as they offer the chance to make sense of their teaching practice in the context of innovative science teaching ideas. This reflective process on teaching practice has emerged as an effective tool for pre-service teachers. With it, they can identify their progress in relation to the expected results and learn from the evidence drawn from practice (Seung et al., 2014). As explained below, we use the idea of a third discursive space to support this process.

Before an explanation is given on how the third discursive space was generated, it is important to highlight some difficulties that pre-service teachers have with inquiry teaching, the teaching methodology used in this study. This methodology assumes that learning science and learning about science requires activities that include the analysis of scientific questions through the use and the development of many process-related skills (how to identify variables, proposing and planning experiments, controlling them, interpreting, summarizing and evaluating data, etc.); the development of explanations and models using evidence; the extraction of conclusions from the results; public presentations and

discussion of the results; and group work (NRC, 2007). All these activities are foreign to the science teaching that the pre-service teachers experienced during their schooling (Zembal-Saul, Blumenfeld, & Krajcik, 2000). Hence, they generally have very little understanding or experience of inquiry, a limited understanding of the nature of science, and little or no relevant scientific knowledge (Abd-El-Khalick & Lederman, 2000; Campbell & Bohn, 2008; Harris, Jensz, & Baldwin, 2005; Windschitl, 2003). They also display a certain level of rejection towards science and less confidence when teaching it (Epstein & Miller, 2011; Lewis, Dema, & Harshbarger, 2014; Russell et al., 1992). All these points hinder the possibilities that pre-service teachers have of using this science teaching methodology in their classes.

Generation and management of the third discursive space to improve pre-service teacher education

In linguistic studies, some authors such as Gee (1996), proposed that a discourse not only integrates ways of talking, listening, writing, and reading, but also ways of acting, interacting, believing, valuing, and feeling into patterns associated with a recognizable social network. So, alternative and competing discourses meet in multicultural contexts, generating conflict and tensions, such as the ones described by Gutiérrez, Baquedano-López, and Tejeda (1999) in ethnographic studies of urban schools. The results of their research suggest that, instead of ignoring them, these tensions should be transformed, through determinate learning activities, into new learning opportunities, that act as zones of proximal development (Vygotsky, 1978). These learning activities shape 'a third discursive space', a hybrid discursive space where conflict and differences from diverse discourses may be transformed into areas of collaboration and learning (Gutiérrez et al., 1997). This third discursive space merges the discursive space arising from the participant's day-to-day environments, which, to a large extent, determine their personal conceptions, with the discursive space from a more formal sphere, such as school. Identifying the first or second space is arbitrary; the idea is that one of them is dominant or privileged in a particular social interaction and the other is marginalized. The necessary tensions that arise in activities where both spaces meet can give rise to the possibility of reconstructing them to form a third discursive space of meaningful knowledge that is richer for the participants. In the case of pre-service teachers who have to teach science in elementary school, one of these conflicting discursive spaces is determined by the theoretical knowledge on new methodologies for science teaching provided at university. The other discursive space is composed of the set of many implicit ideas they already hold about science and its teaching. These mental schemata arise mainly from their experiences as students and from what they have observed during their practicum at school. Depending on the situations, pre-service teachers privilege one discursive space over the other: during their teaching, they tend to privilege their personal ideas, but in university activities they privilege their theoretical knowledge. And there is not enough room in their training to integrate both in a useful way. So, if this third discursive space can be constructed, it may help pre-service teachers to reconsider and to develop a deeper understanding of the problems arising from the practice of science teaching. It may also help them with the proposal and the exploration of alternative solutions that they might need to address such problems. We believe that pre-service teachers can be helped, if this third discursive space can be

generated, to develop effective strategies for science teaching, as well as a professional identity more in line with current requirements.

In Spain, pre-service elementary teachers enroll on a four-year educational program. At the University of Burgos, they have to participate in two supervised teaching practices over a period of three months at elementary school in the last two years of the degree. These practicums are supervised by school tutors – teachers, not necessarily linked to the university program, who agree to the practicum taking place in their class– and by university supervisors. The first practicum is dedicated to pre-service teachers' observations and a little classroom collaboration. In the second practicum, organized in the last year of the educational program, pre-service teachers have to both prepare at least one full didactic unit on any subject and implement it. In addition, during this last year, they have to develop a final degree project, in the form of a research assignment on a topic of interest, related to school teaching and supervised by a university teacher. We developed several activities, at the intersection of the practicum and the final degree project, described in the following section, for the generation of the third discursive space. The proposed activities were designed to encourage pre-service teachers to question their preconceived ideas, debate theoretical reasons for their decisions, develop solutions, provide evidence for their statements, and connect teaching decisions to outcomes; hence, the importance, in this context, of studying the effectiveness of this third discursive space at helping pre-service teachers to integrate theory and practice.

Context

The area of Didactics of Experimental Sciences of University of Burgos offers in the degree program for elementary teachers three compulsory subject modules designed to expose pre-service teachers to constructivist science teaching strategies, among which is the inquiry methodology. In these subjects, pre-service teachers experience these methodologies while they revise (or learn) core science ideas and current views on the nature of science. As discussion of the inquiry methodology and its characteristics alone is not sufficient for its implementation by pre-service teachers (Haefner & Zembal-Saul, 2004; Seung et al., 2014), they perform small open inquiries to solve integrated science problems (NRC, 2012) in the last of these compulsory subjects, scheduled prior to the second practicum. They then independently develop an inquiry teaching science unit for school children. The units must be designed as guided or coupled inquiries, using the classification proposed by Martin-Hansen (2002).

After attending to these compulsory subject modules, most of the students finally consider the viability and the necessity of using teaching inquiry for science at elementary level as a means of improving on traditional and ineffective methods of teaching (Greca, Meneses Villagrá, & Díez Ojeda, 2016). Three of these pre-service teachers, who undertook their final degree projects and practicum under the supervision of the same university lecturer, participated in our study.

The activities that were proposed to generate a third discursive space merit further discussion. The first ones related to the observed classes. The pre-service teachers had to choose four science teaching events that had occurred during their practicums for discussion in their meetings with the university supervisor, in which they may or may not have had some type of intervention. They had to reconstruct the events; to contrast them with

their theoretical training, while questioning the implicit theories and beliefs they might have observed in each case; and to reflect on any possible gaps and/or conflicts detected between their beliefs and training (Barnett, 1992). Each event report had the following structure: selection of the case, indicating data, theme, and value; reconstruction; contrast with the theoretical formation, and final conclusions. The report had to be uploaded to an on-line folder, so that fellow students could comment on it. Finally, these cases were discussed with the university supervisor and with fellow students. The pre-service teacher that proposed the case had to draft a final reflection accompanying proposals for improvement.

Other activities in use were the inquiry-teaching sequences that these pre-service teachers designed followed the general model they had learnt in the university discipline in which they had developed small-scale inquiries (that follow the NRC guidelines 2012). This construction entailed close interaction and discussion with the university supervisor. It is worth highlighting the mediation of the university supervisor, to gain the consent of their school tutors to an inquiry-based sequence, so that pre-service teachers could implement the unit that they had designed. These school tutors would not have used inquiries in their regular science teaching and some were skeptical about its use. Their feelings towards inquiry teaching, expressed in the interview with the university supervisor and in their comments to pre-service teachers, were similar to those described by Windschitl (2003): teachers believe that teaching science by inquiry is tedious, too laborious, and only good for above-average students, meaning that it cannot be integrated into normal classes.

During the implementation of these units, the pre-service teachers were observed by the university supervisor. Possible improvements were then discussed in relation to these observations. The school tutors were asked to discuss these classes, especially the school students' behavior, bearing in mind the teacher's knowledge of the class. The final activity was related with the final degree project. Each pre-service teacher discussed the aspects that they wanted to research regarding the implementation of the units. They established the areas, the methodology, and the data sources they would use. The final project, along with the design of the unit and the investigation, included an evidence-based global reflection on their impressions of their teaching, in the light of the professional knowledge they had acquired. During the process to develop the final project, the pre-service teachers searched for and worked with research papers on inquiry teaching.

So, several activities – reflection on science teaching events; design and implementation of inquiry-based units; critical evidence-based analysis of the pre-service teachers' teaching performance; an overall reflection on the practicum – were organized, to encourage the creation of the third discursive space, through the contrast between the theoretical knowledge, and the practical and implicit knowledge of science and its teaching held by pre-service teachers. Many of the face-to-face meetings with the university supervisor, in particular those related with the cases and the design and development of the inquiry units, were group meetings, promoting a rich exchange of points of view and experiences of the pre-service teachers.

It was explained to the pre-service teachers that these activities were designed to help them in their professional development given the challenge that pre-service teachers face when theory is put into practice and they were encouraged to play an active part in them, questioning both the theoretical assumptions and their own beliefs. That is, they were offered the opportunity to join in the mutual creation of the third discursive space.

Although their engagement was recorded throughout the whole process, the participants were explicitly asked to relate it in a final written activity one month after their assessment in both the final degree project and the practicum.

In this context, the utility of the third discursive space, constructed as an aid to help elementary pre-service teachers was studied, not only to master the inquiry methodology better and to be more confident in its use, but also to integrate this methodology along with general aspects of class management (behavior, assessment, etc.) – problems that may be added to the challenges of science teaching. The following research questions guided our study:

What conflicts emerged in the third discursive space between the beliefs of science teaching held by pre-service teachers and their knowledge acquired during the degree, particularly in relation to inquiry teaching? What solutions arose from reflection in this discursive space? Was this new knowledge useful for them?

Methodology

This research used a descriptive case-study methodology (Yin, 2009) to analyze the effects of the proposed educational approach in the real-life context in which it occurred. This assessment was done as the participants developed their understanding of science teaching, in particular using inquiry teaching, within the real context of classroom activity, aided by reflection on their practice and their own research on its implementation. Although the case study methodology cannot be generalized, it was used because it can provide insights and understanding into the experience of the pre-service elementary teachers during the proposed educational approach. We selected three of the nine pre-service teachers who developed their final degree project in science teaching in 2014. Having followed the participants in detail since their admission to the degree program, these three pre-service teachers were selected, because their cases had a wealth of information and because they differed in several aspects: age, science background and interests, and teaching experience. Pablo had studied technology for his high school certificate and a number of subject modules on an engineering degree. He showed, from the first subject on science in the teaching degree, an evident interest in school science. Ana and Isabel had studied humanities at high school, were uncomfortable with school science and had, in their own words, 'poor subject knowledge' (Isabel, OQ; Ana, FQ). While Isabel, although finding science boring had obtained good grades in science subjects at high school, Ana had always performed poorly in science and maths subjects. The limited science background of both Isabel and Ana – in terms of content and motivation – is quite common in pre-service elementary teachers in Spain. All three also differed in age and teaching experience; Isabel was the youngest and the only one who had worked with children in summer camps. Ana had gained a degree in tourism before entering the teaching degree, and Pablo, as he himself said, had 'tried' a year of engineering. Nevertheless, all three were highly committed to teaching, having chosen to follow a vocational teaching degree.

Data sources and collection

Various data sources were used. As this study forms part of broader longitudinal research, responses from questionnaires and science teaching units designed over two previous

years were available (see Table 1). The reports written by the pre-service teachers (as indicated in the previous section, the pre-service teachers had to prepare written reports on class observations, the practicum and the final degree project) and the field notes for the meetings with the university supervisor (at the end of each meeting, all content and student questions and answers were recorded) were compiled throughout the period in which the activities that fostered the generation of the third discursive space took place. We employed two specific instruments to analyze the utility of the proposed activities to the pre-service teachers for better integration of theory and practice in the specific case of inquiry teaching. The level of inquiry of the teaching units was assessed using the Inquiry Scoring Rubric (ISR, Forbes, 2009) – on a scale of 0–3 in five items, higher scores corresponding to their application of the crucial elements of inquiry teaching. Besides, the level of inquiry teaching that they had demonstrated in each lesson under observation, was assessed in accordance with the Reformed Teaching Observation Protocol (RTOP, Piburn et al., 2000), which measures the extent to which science teaching classes are actually inquiry based. One month after graduation, the pre-service teachers were asked to respond to a questionnaire on their teaching experience on science teaching, so as to compare their views before and after the teaching practice. This information was not part of their required assessments, in an attempt to obtain answers that were not biased by evaluation. Nevertheless, it is worth noting that there was no overlap between this research and the ways pre-service teachers were assessed. In their degree program, the final grades obtained in the Practicum and in the Final degree are a composition of

Table 1. Data collected.

Timing	Data	Code	Objective
Before the compulsory subject on inquiry in science teaching	Pre-test on the nature of science and science teaching and learning	PT	Determine the knowledge and the beliefs of the pre-service teachers that shaped the first discursive space and the framework for the interpretation of their practicums
After the compulsory subject on inquiry in science teaching	Open questionnaire on their experience with approaches to teaching science for inquiry and its possible use in elementary school	OQ	The same objective as the previous activity
After the compulsory subject on inquiry in science teaching	Inquiry teaching units designed by pre-service teachers in this subject	TU	Know their background for designing units by inquiry
During practicum	Supervisor's field notes from the face-to face meetings	FN	Detect the conflicts and the knowledge emergent in the third discursive space
During practicum	Written reflections about actual cases in their practicum	WR	The same objective as the previous activity
During practicum	ISR for the teaching unit designed	ISR	The same objective as the previous activity
During practicum	RTOP from the observed classes	RTOP	The same objective as the previous activity
After Practicum	Practicum written report	SPWR	Evaluate the knowledge generated in the third discursive space and its usefulness from the pre-service teachers' points of view
After Practicum	Final degree project written report	FDWR	The same objective as the previous activity
One month after graduation	Open questionnaire answered by the pre-service teachers on their science teaching experience	FQ	The same objective as the previous activity

several grades, given by different people. In the case of the Practicum, the final grade is composed of the grades given by the university supervisor, the school tutor, and a self-evaluation. In the case of the final degree project, each pre-service teacher has to defend it before a tribunal.

Table 1 chronologically displays the different data that were collected and their objectives for the research questions.

Data analysis

The empirical material was analyzed using thematic analysis, one of various approaches in discourse analysis (Paillé & Mucchielli, 2003). It was chosen because of its flexibility and the possibility of determining patterns in the discourse of the pre-service teachers without a preset rigid idea (Braun & Clarke, 2006). The material was read repeatedly, and separated from all the material, the data set that was going to be used. In this process, we were looking for excerpts in which aspects related to theory and practice in science teaching appeared, whether in the form of conflicts between what the pre-service teachers thought and what the theory actually stated, as well as fresh understandings. This data set was then fragmented into significant units and codified, following which the different codes were sorted into potential themes. Although our search for themes was not strictly theoretically driven, when identifying them, we had in mind the literature that related to the difficulties that pre-service and in-service teachers experience when teaching science education in non-traditional ways. These themes were identified at a semantic level (Braun & Clarke, 2006); that is within the explicit meanings of the data, without looking for anything beyond what the pre-service teachers had said or written.

The themes were detected separately, for each subject, in the field notes from the face-to face meetings and class observations, and in the written reports, in order to triangulate the data via analysis and the different available sources (Patton, 1990). In other words, each data set was independently analyzed on a thematic basis. Then, the themes from the whole data set for each subject module were compared and themes that could be found in most of them were separated. Recurrent themes among the three pre-service teachers were chosen and grouped into categories related to our research questions.

The author of this study, also the university supervisor and data analyst, has conducted extensive participatory observations with the research participants (with whom she has worked on the three compulsory subject modules) that contributed to the internal consistency and validity of this study. Nevertheless, this role could contribute to bias. An independent researcher and member of the department team therefore re-analyzed the data and, in addition, triangulated its sources, in order to address this possible bias. All of the few significant differences between both analyses were resolved by consensus.

Results and discussion

The results are presented in the four following subsections: the first one describes pre-service background and the other three follow the same sequence as the research questions. So, the pre-service teachers' knowledge and beliefs, which determine both the first discursive space and the framework for the interpretation of their school practices (Crawford, 1999; Luehmann, 2007), will first be examined. Then, some of the tensions

detected during the activities developed to foster the formation of the third discursive space will be presented along with the solutions (new knowledge) that appeared to have been achieved. After that, we will see whether these solutions were effectively put into practice – through the analysis of the design and implementation of the didactic units. We will then see whether the pre-service teachers recognized the new knowledge as useful for them.

The knowledge and beliefs of the pre-service teachers prior to the learning activities of the third discursive space

As indicated in the description of the participants, their science education prior to university differed, as did their impressions of science and science teaching. Pablo, the only one with quite a solid knowledge of science, was in favor of teaching science in a 'practical way'. His idea was that children have to understand science by seeing or doing experiments related with their environment. Ana and Isabel, on the contrary, at the beginning of their degrees, saw the textbook as the main source for teaching.

> I always went for humanities and was never interested in anything scientific. In fact, I hated mathematics, physics and chemistry. At that time [beginning the degree], I thought the science book was useful for teaching, owing to my lack of knowledge. (Ana, FQ)

However, they both changed their attitudes towards science after studying science teaching during the degree and how they thought it should be taught. 'Now, I still know nothing about science, but I have an insatiable thirst to learn more about it and to practice it … Not relying so much on the textbook and devoting more time to contextualized, practical and applied activities' (Ana, PT). Thus, as in the case cited by Bryan and Abell (1999), these pre-service teachers believed, before their practicum, that teaching lessons by following the textbooks was ineffective and that learning required doing and manipulating. According to the test (PT), our subjects tended to classify science as a product (Gess-Newsome, 2002), without considering it as a way in which we construct representations of the world, showing an inductivist view of the scientific methodologies. However, they had a clear vision of science as a set of tentative theories of knowledge and of the diverse factors that affected their development. Moreover, none of them had developed inquiries in science subjects before the last discipline at the university described above, although Pablo had done traditional closed experiments in physics at high school. In developing the inquiries, the pre-service teachers under study did fairly well, understanding and effectively stating hypotheses, designing experiments, determining variables and responding to the questions based on empirical evidence. However, the outcome varied when the participants had to apply this methodology to the design of the teaching units. While Isabel managed to design an appropriate and coherent unit, the sequence of activities proposed by Pablo, who began with a potentially interesting problem, covered practical good-fun activities, rather than activities that encouraged the students to construct scientific knowledge. Ana encountered problems in posing a clear sequence, so it was unlikely that the students would resolve the problem and learn the proposed scientific concepts. However, at the end of the practice, Pablo, Ana and Isabel said they were convinced that inquiry teaching was the optimal way to teach science: 'I'll certainly try to use this methodology in my classes' (Isabel, OQ).

During their first practicum, the participants followed a traditional methodology for science teaching, making almost exclusive use of the textbook, and they had no opportunity to teach any topics in this area. Furthermore, like most of their fellow students, when they returned from these practices, they were critical of the training received on the degree course, classifying it as very theoretical:

> … this practicum is very revealing for any student who wants to get anything out of this degree, … so as not to waste the time that we have wasted without taking into account or, rather, without knowing anything about how children actually are, how they behave and what really motivates them. (Pablo, SPWR)

With this knowledge and these motivations and beliefs they began their second practicum with the aim, as stated above, of implementing and assessing an inquiry teaching unit.

Tensions and Solutions

Some of the different themes are discussed below that we found in the three participants. These themes fall into the category that responds to the research question on the conflicts that emerged from the activities that were developed for the third discursive space and the tentative solutions that were achieved.

Confidence in student capabilities: A fundamental element for the introduction of innovative teaching methodologies such as inquiry is the confidence of the teacher in the students' capabilities. It means giving students a certain degree of autonomy and placing them at the center of the activity. Moreover, as reported in the literature, elementary school students can satisfactorily construct evidence-based explanations (Duschl, Schweingruber, Shouse, 2007; Hardy, Jonen, Moller, & Stern, 2006; Metz, 2011) using, among others, the inquiry methodology. As indicated in the previous section, our pre-service teachers have been taught to deal with open, guided and coupled inquiries. They also received enough theoretical knowledge during the degree course to expect high levels of confidence in the capabilities of all the school children both for learning and for achieving a satisfactory level of performance. Nevertheless, the participants hardly felt sufficiently confident with that knowledge, reflecting the results obtained in other studies (Wallace & Kang, 2004). In fact, the three, including Isabel, whose children were older and considered the best group in the school, assumed that students would not be able to understand the elements required of an inquiry or would neither analyze the data nor construct evidence-based explanations. This problem emerged in the very first learning activities developed for the generation of the third discursive space, in particular the actual science-teaching events and repeatedly resurfaced throughout the process of designing the inquiry teaching unit. During the case studies, the pre-service teachers were expected to reflect on their behavior as science teachers and the behavior of their students in a critical way. The reflections on these science teaching events were useful for connecting the theory learnt on students' capabilities and their observations of classroom practice. Also, this activity helped the participants to 'rethink' their school personal experience of learning science, a fact that appeared to be, in the cases of Ana and Isabel, the main obstacle to their gaining confidence in the capabilities of their students. In general, a sort of minimum consensus was reached regarding the possibilities of the students, which included a kind of

'*l*et's begin and see what happens. If it doesn't work, if kids feel lost, we will have to change' (Isabel, FN).

The question of children with special educational needs deserves particular attention. During his degree, Pablo followed subject modules on inclusive education, but his experience in the first practicum made him aware of the difficulties involved in working with them: 'I feel it is impossible that only one teacher can properly attend to a student with severe problems or significantly delayed maturity. It's simply impossible' (Pablo, SPWR). Pablo also clearly stated that 'teaching science by inquiry is only appropriate for above-average students. I fear the kids with special needs that I have in class would not do so well' (Pablo, FN), as most teachers believe (Windschitl, 2002). The solution agreed upon in this case was to compile evidence, so as to examine whether students learning with the traditional method achieved different results in terms of learning, than students learning with the inquiry method, and to establish whether this methodology helped children with learning difficulties to learn science.

Group work and class behavior: Learning how to manage class behavior is a key concern for all pre-service teachers and is something that hinders incorporating inquiry strategies into their teaching repertoires (Abd-El-Khalick & Lederman, 2000). Group work is fundamental for inquiry teaching (Furtak & Ruiz-Primo, 2008; Metz, 2011), which makes it a challenge for pre-service teachers who have little personal experience of working in this manner. An experience which often turns out to be negative*:* 'I've never worked well in groups; time is wasted and nothing gets done' (Isabel, FN). Furthermore, in the cases examined here, the school tutors managed to maintain a reasonable working atmosphere, even with disruptive students, but without working in groups. As stated in the literature, pre-service teachers consider that successful management of class behavior is done by in-service teachers who know the correct techniques, the only ones with which they can feasibly work (Korthagen et al., 2006). During their degree, Anna, Isabel, and Pablo learnt about the 'theoretical' advantages of group work (as they said, they had never seen school students working this way) and several general techniques and they used it to design teaching units in several subjects during the degree. Nevertheless, they were reluctant to work in groups in their classes, claiming that the children were not used to group work and that it could be complicated. The design of experimental activities, included in their teaching inquiry units, compelled them to address group work. During consultation with the university supervisor, the pre-service teachers discussed how to adapt some theory-based rules, for each of their specific contexts, on how to integrate group work into the classroom. The first solution was to work with groups that they arranged in accordance with their knowledge of the expected behavior of their students.

Student-centered focus: Any constructivist methodology assumes that teachers focus on students and their comprehension processes and organize the class according to such a focus (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Llewellyn, 2007). In inquiry teaching, they also have to recognize and manage the difficulties associated with the functional operation of the inquiry method in class (Baker, Lang, & Lawson, 2002). Although pre-service teachers acquire theoretical knowledge on these topics in different subjects in the degree, these are other difficult aspects for new teachers (Seung et al., 2014), who may worry more about their own activities than the students' own activities. Furthermore, these aspects are difficult to plan into the design of a sequence. In fact, in our study, they only appeared through class observation and analysis. Ana and Pablo, who were less

experienced, had particular difficulty in relation to this point, and were more focused on what they wanted rather than on what the students were doing or requesting. Ana tried to explain everything to students, talking for too long, which bored her (seven-year old) students and dried up their interest in what they had to do. Pablo left them on their own 'too much', and the students, also aged seven, could not keep themselves focused on the task. None of them were aware of the consequences of their behavior. Following classroom observation, these aspects were problematized, in order to help the participants to establish a different approach to their attitudes in class, something in between their observed behavior and the need to develop student-centered classes. Nevertheless, they recognized that it would be a quite difficult point for them to modify. For example, Ana (FN) said that, although seeing that the children could do fine, it would be difficult for her to leave them 'too much on their own' in the classroom.

Inquiry design: Despite the interest and previous preparation of these pre-service teachers for inquiry teaching, all of them had difficulties in planning their teaching units to incorporate practices that effectively involved their students in inquiry processes; a problem frequently reiterated in the literature (Eick & Dias, 2005; Hashweh, 2005; Seung et al., 2014). In general, their first attempts demonstrated a more traditional view of inquiry, focused on compiling data rather than focused on criticizing and negotiating ideas, and drawing conclusions (Asay & Orgill, 2010; Seung et al., 2014). The main point addressed through the activities developed in the third discursive space was the importance of planning support and guidance activities in the sequences, so that the students could make connections between the evidence and the explanation (Hapgood, Magnusson, & Palincsar, 2004; Metz, 2011). To do so, the participants' own experiences with open inquiries in the degree subject dedicated to inquiry teaching was taken and adapted to their specific contexts (teaching topic, children age, material and time availability). Also, the research articles on inquiry teaching were discussed, which they were using in their final degree project. Finally, Isabel and Ana appeared to have found good solutions to design their teaching unit, appropriately capturing important aspects of the inquiry methodology (as will be shown in the next section). Pablo had deeper problems, despite a reasonable level of scientific knowledge with which to tackle his teaching topic. His initial conceptualization of inquiry teaching could be classified as experience-centered (Ireland, Watters, Brownlee, & Lupton, 2012), which in practice meant showing the students a series of motivating experiences related to the teaching topic following by explanations. This practice, common with elementary school teachers, which uses experiences to motivate without providing sufficient attention to authentic learning by the students, or confirmation of accurate insights, was coherent with his personal view: 'When it came to school science, I always thought we were explained less than I wanted to know' (Pablo, FQ). Thus, despite having the tools for designing sequences by inquiry, his personal history and school practice seemed to stop him from designing something more in line with this methodology. Work with Pablo included a reflection on his personal experience and on his own ideas with regard to the basis for the inquiry methodology, leading him to design a sequence that tried to capture its crucial elements. Nevertheless, there was no space in his sequence to allow the students to assess the explanations and they only shared the results, without justifying them, because he considered that these two aspects could not be achieved with seven-year-old children. So, his sequence was the result of a trade-off between theoretical aspects of the methodology, the inherent limitations of school practice and his own beliefs.

Another aspect related to inquiry design was the participants' beliefs regarding the Nature of Science, a problem that clearly manifested itself when designing the teaching units. Nevertheless, it is not discussed in this paper due to its complexity, but it will be addressed in appropriate detail in further publications.

Assessment – what to assess and what is learnt? Another problem facing both in-service and pre-service teachers is assessment. What should be assessed? How should it be done? What tools should be used? Although they learn a range of ways of carrying out continuous assessment, teachers usually fall back onto their own experiences. They define assessment formats that are inconsistent with the teaching aims, reflecting only the assessment of low cognitive demands based on exercises and tasks favoring memorization (Osborne & Dillon, 2008). Pablo's first proposal was of this type. However, the need to compile data to respond to his research questions and the gradual understanding of the inquiry method led him to propose a true continuous assessment scheme. This scheme was coherent with the methodological approach and his aims, with the assessment centering on the students' work throughout the teaching sequence. The final exam placed the students in a new situation in which to apply the acquired knowledge, converting it into a further learning opportunity. Pablo, after designing the exam, expressed concern that the children might not fare very well with this type of test as they were not used to it. He felt reassured after deciding to set the test as an exercise that would not be marked.

The perceptions of pre-service teachers with regard to overcoming the students' preconceptions were also related with assessment. Although pre-service teachers generally find it difficult to assess the previous knowledge of students and to adjust their lessons accordingly (Buck, Trauth-Nare, & Kaftan, 2010; Zangori & Forbes, 2013), the three participants in this study appeared not to have this problem. Notably, however, Isabel expressed her 'disappointment' when carrying out the assessment and not finding that all the students had overcome their preconceived ideas: 'I thought that all, or at least the best students, were not going to repeat any of their mistaken ideas' (Isabel, FN). Based on this reflection, Isabel was encouraged to re-examine the basic ideas about preconceptions and their (slow) processes of change, so that she could gain greater awareness and would be able to moderate the clash between her expectations and the outcomes. This approach appeared important to assuage her feelings of frustration and so that she was not put off from trying to use innovative strategies.

Place in the school community: Pre-service teachers must maneuver within school contexts, negotiating their practices with the school tutors, the school management and the parents (Anderson, 1996; Luehmann, 2007). As stated in the theoretical underpinnings, we sought to ensure positive experiences in the school setting for the pre-service teachers who were trying to apply an innovative approach. So, the university supervisor acting as a mediator, negotiated with school tutors to avoid tensions. Nevertheless, our three participants felt some tensions between their proposals and the traditional teaching style that predominated in the schools; a matter of much critical commentary from them all, both in the face-to face meetings and in their written reports:

> Regarding the difficulties, the most notable were of an institutional nature or came from the teachers. The state and the institutions do not take the student into account and, therefore, do not provide student-centered education. The same thing occurs with some teachers, without generalizing. The truth is that they usually impose many obstacles [to innovative science

> teaching approaches], but this appears to come from their own ignorance of the sciences. They, therefore, hide behind the textbook. (Ana, FDWR)

On this point, no 'better' solution was found in the third discursive space; the reflection could be seen as an attempt to rationalize their feelings of the school context as a major barrier to the introduction of future innovations. They appear to be aware that their opinions regarding the possibility of teaching school science in a non-traditional way may change in accordance with the restrictions and realities of the schools (Bright & Yore, 2002) which appeared to resist change.

The application of the solutions that were generated

The design and implementation of the teaching unit developed by the pre-service teachers were studied to evaluate whether they had effectively incorporated some of the solutions they had develop in the activities of the third discursive space. Table 2 shows the subjects covered, the assessment of the design of each unit with the ISR and the assessment of the observed lessons following the RTOP.

The ISR values showed that Ana and Isabel had managed to design a teaching sequence that captured several of the crucial elements of inquiry. Pablo, however, had difficulties with the items related to the assessment by the children of the explanations and their communication and justification of those explanations. Again, in the classes that were observed, Isabel and Ana achieved higher than average scores for almost all the RTOP items that were assessed, achieving high scores for propositional knowledge, covering fundamental concepts, promoting a coherent conceptual comprehension, and establishing relationships with other areas. Both managed to establish a good climate of group work. In the case of Isabel, she alternated group work with 'seminar' sessions and individual work. Ana, who managed to develop relevant communicative interaction with students, in a classroom culture in which contributions from students were encouraged, developed a daily routine of group work with them that consolidated itself among the children as their favorite style of work organization. Pablo, although trying to use some of the solutions that were generated, had greater difficulties when he was observed. Despite mastering the subject matter, he demonstrated lower propositional knowledge than Ana and Isabel, getting the lowest values for classroom management and the inquiry method. In fact, he was unable to manage the class properly, particularly group work. He explained that it was due to his own inexperience with combining freedom and guidance (for seven years old). 'However, time was wasted, as the class control that should have been imposed, given that it was the first time this methodology was being used, was not imposed' (Pablo, FDWR). This appears to indicate that those who appear to start out with the best conditions for science teaching in line with current recommendations (interest in science, good scientific knowledge) are not necessarily better prepared to develop a pedagogical content knowledge that is coherent with such recommendations.

Usefulness of the solutions found

Although it seems that pre-service teachers employed most of the solutions generated in the third discursive space, it is necessary to establish whether they found them useful. This

Table 2. Subjects from the teaching units covered by the pre-service teachers and their assessments of both teaching unit design and lesson observation.

	Subject/estimated length	Year/ age of pupils	Aim	Assessment teaching unit design – ISR	Assessment of observed lessons – RTOP
Pablo	Forces (six sessions)	2/7 yrs	Comprehension of the concept of force; distinction between action-at-a-distance and contact forces	**Overall**: 7/15 Scientifically oriented questions: 2/3 Gathering, organizing, and analyzing data:2/3 Formulating explanations from evidence to address scientifically oriented questions:1/3 Evaluating explanations in light of alternative explanations: 1/3 Communicating and justifying explanations:1/3	**Overall**: 42/100 Lesson design and implementation: 11/20 Propositional knowledge: 11/20 Procedural knowledge: 7/20 Communicative interactions: 6/20 Student/teacher relationships: 7/20
Ana	Scientific method (6 sessions)	2/7 yrs	Comprehension of the scientific method using the factors that influence germination	**Overall**: 13/15 Scientifically oriented questions: 3/3 Gathering, organizing, and analyzing data:3/3 Formulating explanations from evidence to address scientifically oriented questions:2/3 Evaluating explanations in light of alternative explanations: 2/3 Communicating and justifying explanations: 3/3	**Overall**: 59/100 Lesson design and implementation: 13/20 Propositional knowledge: 15/20 Procedural knowledge: 12/20 Communicative interactions: 8/20 Student/teacher relationships: 11/20
Isabel	Human nutrition (12 sessions)	4/9 yrs	Comprehension of nutrition as a complex process the function of which is to provide cells with the matter and the energy that vital functions require	**Overall**: 13/15 Scientifically oriented questions: 2/3 Gathering, organizing, and analyzing data: 3/3 Formulating explanations from evidence to address scientifically oriented questions:3/3 Evaluating explanations in light of alternative explanations: 2/3 Communicating and justifying explanations: 3/3	**Overall**: 65/100 Lesson design and implementation: 12/20 Propositional knowledge: 17/20 Procedural knowledge: 13/20 Communicative interactions: 12/20 Student/teacher relationships: 11/20

aspect is an important facet, if it is intended to consolidate the learning that may have come about. Their perceived usefulness should appear in the final degree project and the practicum report, where the activities of the third discursive space related with the analysis of the didactic implementation and the reflections on the whole process were developed. These results relate to the six themes discussed above in the 'Tensions and solutions' subsection.

In relation with the class management and group work, the pre-service teachers found that the children worked well.

> The students worked adequately in groups, a work format that encouraged everyone's learning (including some students with special needs in the group), motivation, relationships

> between classmates and interest in the activities. Furthermore, all the children shared the same feelings, emphasizing their satisfaction at working in groups, sharing opinions with their classmates and being able to help at all times. (Isabel, FDWR)

After analyzing the audios of her classes Ana, who found difficulty in not explaining everything to her students, reported that

> [regarding the analysis] less time needs to be devoted to questions and explanations from the teacher and more to doing and experimenting. It's very important to let the students express themselves and reason. In short, the teacher must step aside and let the students speak, so they may gain confidence and self-esteem and learn to express themselves in public. (Ana, FDWR)

As regards student capabilities, Isabel admitted that 'Initially I wasn't sure that the teaching approach [learning by inquiry] was going to work with fourth-year school students …' (Isabel, SPWR), and she was surprised with the results obtained. Let us remember that in this case, it was necessary to reflect with her on how to overcome preconceptions and on the need to evaluate the whole process. Ana expressed the thought that

> In conclusion, according to the data under analysis, it is possible that 7-year-old students not only understand and remember the phases for carrying out an inquiry, but can also implement it, although, at this level, with a lot of guidance. Additionally, they show a high level of motivation and interest in each phase, demonstrating not only that it is possible to carry out inquiries in the student-centered classroom, but also that the students feel that this gives them control over their own learning. (Ana, FDWR)

It is worth stressing Pablo's conclusion on the use of the inquiry methodology with special needs children. Despite his initial misgivings, he came to the conclusion that not only the gifted students reaped benefits from inquiry teaching, but also that it was possible with and beneficial for students with lower cognitive capabilities.

> In conclusion, it could be said that this type of methodology especially appears to help children with problems for abstract thinking, as science refers to everything that surrounds us and can be represented for these levels, fostering, in this way, a basic understanding of concepts. Brilliant students also benefit from this type of methodology as it improves their social interaction through group work and their experience of the contents that they otherwise would have only studied abstractly and disconnected from the world in which they live. (Pablo, FDWR)

In brief, the evidence appears to support the affirmation that the third discursive space was useful for empowering the science teaching activities of Ana, Isabel and Pablo; helping them to reconceptualise the teaching of science through inquiry and to generate practical solutions with varying degrees of effectiveness. The two main reasons given for their failure to completely integrate theory with practice, even with the assistance of the third discursive space, were: (1) that they were unable to manage to integrate the relevant range of knowledge and its sources – owing to their personal history, beliefs and preconceived ideas – and, (2) because of routine practice at school that resisted innovative teaching process. A process of discussion and reflection was needed to try to overcome these problems that allowed them in some cases to find viable solutions and in others cases to reach 'compromises' that only gelled after analysis of the evidence.

The third discursive space was essential for the three pre-service teachers to complete their practicum with the perception, resulting from their analyses, reflections, as well as the comments from the school tutors and children, of a certain degree of significant success regarding their inquiry science teaching.

> Apart from the fact that I now feel capable of getting up in front of a group of students and awakening their interest and curiosity for science classes, I believe I can do it so that they feel excited about learning and really come to understand the content and to absorb it via experimentation and observation, taking memorization and repetition off the map of science teaching. (Isabel, FQ)

Conclusion

The participants in this study apparently held sufficient theoretical knowledge – related to psychology, pedagogy and science teaching – and were also motivated to teach science by inquiry. However, by themselves, they were unable to transfer this knowledge-for-practice into knowledge-in-practice (Zangori & Forbes, 2013). In this respect, our results on their difficulties in designing and implementing the teaching unit, support the work of other researchers that point precisely to this gap between theory and practice in science teaching education (Seung et al., 2014; Smith & Southerland, 2008). On the other hand, these results counter the fallacy that pre-service teachers can develop appropriate professional knowledge before practice, which is usually the basis for teacher educational programs in many countries (Bryan & Abell, 1999; Russell & Munby, 1991). Thus, although many studies find that the most significant factor determining the implementation of an inquiry teaching is that the teachers themselves possess knowledge of it (Rop, 2002; Van Driel, Beijaard, & Verloop, 2001), our study would suggest that this knowledge is in itself insufficient.

Furthermore, although pre-service teachers' participation in school practices was fundamental for them to start to develop their pedagogical content knowledge, it was not enough. They needed help in interpreting their experience and producing useful solutions for developing inquiry teaching (which involved gaining confidence in student capabilities; being centered in students; introducing new forms of class management, as group work; designing appropriate inquiry lessons and coherent assessments with their teaching aims), which took place in the specific educational approach related in this paper. In the proposed activities, they were encouraged to question their preconceived ideas, debate theoretical reasons for their decisions, provide evidence for their statements, and connect the teaching decisions to the outcomes.

Although all the proposed activities involved a supportive reflective practice, the third discursive space emerging from them was much more: pre-service teachers were explicitly challenged in the deliberate and conscious creation of a space where they could discuss and overcome the challenges of working in two 'different' worlds: the theoretical knowledge on new methodologies for science teaching provided at university with the practical demands of their practicum teaching. And, with this support, the three pre-service teachers participating in this study developed useful solutions grounded in theory that allowed them to implement innovative science teaching in real classroom contexts. Two of them went on to develop quite good guided inquiries, considered effective for science teaching (Blanchard et al., 2010). Pablo was also successful in developing a better science teaching, although not at the same level as Ana and Isabel. His case is interesting

because, despite the apparent absence of the most significant obstacles reported in the literature blocking the implementation of the inquiry methodology (lack of interest in science, poor scientific knowledge, very naive ideas about NOS), he had more difficulties than the other participants to change his ideas about inquiry teaching. He said that the main problem was associated with his inexperience with children (FQ), which is certainly a very important factor. But we also think that the influence of his personal history, as in the cases dealt with by Melville, Campbell, Fazio, Stefanile, and Tkaczyk (2014), was the main stumbling block. In all the cases, teaching skills and knowledge of the methodology was only really acquired through the experiences by which they were supported (Eick & Dias, 2005) in a third discursive space, in which the university supervisor acted as a mentor in a personal and professional relationship (Melville et al., 2014).

The problems that the pre-service teachers experienced were not only directly related to the inquiry methodology but also to classroom management, as noted in the study by Seung et al. (2014). Nevertheless, our study has shown that the concerns of the pre-service teachers regarding classroom operation and management are not minor matters, as they interfere in the use of the inquiry method and have therefore to be explicitly addressed.

Altogether, the time spent by the university supervisor on the activities that promoted the third discursive space never exceeded the time allotted on the degree course for the supervision of the practicum and final degree project: most of the activities were group activities, allowing the university supervisor to work with several pre-service teachers at the same time; others were done by the pre-service teachers and the remaining ones (class observation, reading and evaluation of written reports, etc.) were compulsory.

The role of the school tutors is a question of further research. Although their influence could be seen in pre-service teachers' reflections, it would be interesting to examine this question in greater depth. It is also necessary to study this proposal with a larger sample. In this sense, we are using this same approach with pre-service teachers over shorter periods of time, in out-of-class inquiry activities with children before the last practicum.

The development of an appropriate knowledge-in-practice for innovative science teaching, in particular inquiry teaching, is no easy task. More time is required (Lotter, Singer, & Godfrey, 2009; Van Driel et al., 2001) for the pre-service teachers to be able to develop appropriate knowledge in practice. It also appears necessary to include professional development/mentoring programs (El-Hani & Greca, 2013; Nam, Seung, & Go, 2013) and post-training to help them to develop appropriate science teaching practices that are aligned with current trends. Nevertheless, this paper provides evidence of an educational approach that appears to make positive contributions in that direction. In fact, the activities developed in the third discursive space appear to have helped our participants to acquire this knowledge in practice.

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