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What is a Scientific Experiment? The Impact of a Professional Development Course on Teachers' Ability to Design an Inquiry-Based Science Curriculum

María del Carmen B. Pérez
Universidad de Piura, Investigador en formación UNED, PERÚ
Melina Furman
Universidad de San Andrés, Escuela de Educación, ARGENTINA

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Designing inquiry-based science lessons can be a challenge for secondary school teachers. In this study we evaluated the development of in-service teachers' lesson plans as they took part in a 10-month professional development course in Peru which engaged teachers in the design of inquiry-based lessons. At the beginning, most teachers designed either confirmatory or structured inquiry activities. As the course progressed, however, they started designing guided and open inquiry lesson plans. We found four factors that accounted for this change: re-evaluating the need for lab materials, revising their views on the nature of science, engaging in guided and open inquiry activities themselves, and trying out inquiry-based lessons with their own students. Our results point to the importance of engaging teachers in prolonged and varied opportunities for inquiry as part of teacher education programs in order to achieve the challenge of changing teachers' views and practices in science education.

Keywords: experimental activities, levels of inquiry, scientific process skills, teacher training.

INTRODUCTION

Planning and implementation of experimental activities is considered one of the most important methods for students to immerse in the integration and construction processes of scientific knowledge (Rocard, Csermely, Walwerg-Henriksson, & Hemmo, 2007). However, in Peru, context of this study, as well as in other countries, experimental activities at the secondary level are usually carried out in a "cookbook" manner (Lord & Orkwiszewski, 2006). Research has shown that

Correspondence: María del Carmen Barreto Pérez,
Universidad de Piura, Investigador en formación UNED, Av. Ramón Mugica 131, PIURA PERÚ
E-mail: marycarmen.barreto@udep.pe
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Peruvian teachers usually support their students by providing guidelines so that students follow the protocols in a totally structured manner, without formulating any questions, engaging in methodological discussions, or planning the experimental design, all of which are key aspects for the learning of scientific practices. (Fernández, 2014; Figueiroa, 2003).

In response to the need to improve teaching, in 2010 the Peruvian Ministry of Education's *Technical Educational Guidance for the Area of Science, Technology, and Environment* included an educational model for the teaching of the sciences based on an inquiry approach (Ministerio de Educación del Perú, 2010). This model proposes offering students opportunities for collective construction of knowledge and places emphasis on the learning of scientific thinking skills and ideas about the nature of science (Harlen, 2000).

However, although studies have shown the positive impact of this approach on students' learning (Minner, Levy, & Century, 2010), educational research has acknowledged the difficulty of incorporating these types of practices in the classroom (Cañal, 2007; Luera & Otto, 2005; Zion, Cohen, & Amir, 2007). Different authors concur that this difficulty is associated with the need for the professional development of active educators, who in general have not been sufficiently trained in these types of educational approaches and who view science as a body of knowledge and the scientific method as a linear process with limited creativity (Krajcik, Mamlok, & Hug, 2001);

Along these lines, several studies point to the importance of taking into account teachers' conceptions about inquiry as an important feature of professional development programs, since they are a key factor that shape teachers' practice (Ireland, Watters, Brownlee, & Lupton, 2011). For instance, Ozel and Luft (2013) show that because beginning secondary teachers tend to conceptualize and enact teacher-centered forms of inquiry, induction programs focused on inquiry instruction need to be emphasized. Similarly, Lotter, Harwood, and Bonner (2007) show that teachers' conceptions of science and effective teaching practices, among other factors, influence the type and amount of inquiry instruction performed in high school classrooms.

Changing teacher practice to more inquiry-based practices, however, has been shown to be a complex and time-consuming process. Bell and Gilbert (1996) stress the importance of long-term professional development to help teachers change and reconstruct their role as science educators. That is, teachers need time to identify issues in their own practice while practicing, reflecting on, and revising innovative techniques in a supportive, collaborative, and real classroom environment (Lotter, Harwood, & Bonner, 2006).

Although the importance of engaging teachers in long-term professional development efforts has been documented, there is still debate on the kinds of experiences that are most effective in developing teachers' capacities to develop and implement inquiry activities in the secondary school classroom.

This study was a 10-month (two academic semesters) analysis of the impact of a professional development course on the teaching of natural sciences. This course was designed to help teachers plan inquiry activities in the classroom and was part of a two-year graduate program offered by a university in Peru to secondary school teachers. The course was aimed at helping secondary school science teachers foster their students' ability to formulate research questions and develop experimental designs to answer those questions and at helping teachers with instructional design of experimental activities to do with students.

In order to analyze the development of the 35 participating secondary school science teachers, we characterized the type of inquiry activities they planned at the beginning and during the development of the course. In the analysis we considered the level of openness proposed, from confirmatory or structured inquiries in which the protocol to be performed is totally proposed by the teacher to more open inquiries in which students make decisions on how to approach the research process (Eick, Meadows, & Balkcom, 2005).

The purpose of the paper is to offer evidence on the performance of secondary school teachers in developing experimental activities throughout a professional development course, considering how their performance evolved during the professional development process, and analyzing the factors that influenced the changes that were observed. This not only allows assessment of the impact of the program but also makes a contribution as a tool for the educational development of other development programs addressing similar objectives.

THEORY FOUNDATION

Teaching by inquiry is a methodology for formulating and treating problems that has been adopted by different countries (Porlán, 1999), including Peru (Ministerio de Educación del Perú, 2010). In general, this approach promotes the integrated teaching of conceptual knowledge and scientific skills and carrying out research on daily life problems and social construction in the classroom learning community using explanatory models and theories (Furman & De Podesta, 2009).

In this approach, the design of activities facilitating planning, implementation, analysis, and assessment of experiments autonomously by students has acquired great importance as a teaching objective (Roesch, Nerb, & Riess, 2015). In this trend, Banchi and Bell (2008) have identified in teachers' practices different types of experimental activities based on their "level of inquiry" or "level of openness." This distinction is based on a model in which the participation of teachers and students in performing the experimental activity is not always the same in terms of the definition of the problem to research, the development of the experimental design, data analysis, and the development of conclusions. Banchi and Bell (2008) define a series of levels for experimental activities that is organized based on the progressive and growing autonomy of students in the proposed activity. The four proposed levels are: (1) confirmatory inquiry, (2) structured inquiry, (3) guided inquiry, and (4) open inquiry.

In the confirmatory level are experimental activities that present a concept that students must prove experimentally. Students are given details of the procedure to follow and are presented with the expected results beforehand.

In the activities categorized as structured inquiry, however, the teacher proposes to students the question or the problem to be solved, the answers to which students do not know beforehand. As in the confirmatory inquiry, teachers provide them with the procedure to follow, in the style of a "cooking recipe" (Colburn, 2000, p. 42).

Moving towards a greater autonomy of the student, the third level is called guided inquiry. In guided inquiry teachers propose the research question and help students in designing and performing research in the classroom, but students are the ones who define the steps of the activity (Martin-Hansen, 2002).

We find the highest level of autonomy of students in the type of activities referred as open inquiry. In this level, students plan and carry out all the phases of the research, while teachers provide support to them throughout the process.

Different specialists concur on the importance of posing activities with growing inquiry levels that promote more complex learning and a greater level of autonomy to students throughout their school experience (Cuevas, Lee, Hart, & Deaktor, 2005). We propose also that the movement from one level to the next be gradual, as working with experimental activities with greater levels of openness means a learning process, both for teachers and for students (Sanmarti, 2002).

RESEARCH QUESTIONS

The importance of educating teachers in the design of inquiry-oriented experimental activities that are based on both educational research and curricular guidelines involves teachers' learning and ownership. Based on this premise, this study addressed the following research questions:

- Research question 1 (RQ1): What are the levels of inquiry of the experimental activities that secondary school teachers propose in their classroom before starting the professional development course?
- Research question 2 (RQ2): How do the levels of inquiry of the experimental activities proposed by teachers vary throughout the course?
- Research question 3 (RQ3): What factors contribute to the variations in level of inquiry of the experimental activities proposed by teachers?

METHODOLOGY OF RESEARCH

We carried out a mixed methods study, with quantitative and qualitative components. The study was performed in two phases, diagnostic and process, evaluating the type of experimental activities proposed by teachers at the beginning and during their participation in the professional development program. We then analyzed the factors that influenced the changes that were observed.

Context of the study

The research was carried out from 2012 to 2013 with a group of 35 secondary school science teachers who participated in a teaching course in natural sciences that was part of the university Specialization in Science, Technology, and Environment program promoted by the Peruvian Ministry of Education within the framework of the National Program of Continuous Education and Training. The course was taught for 10 months, in the first and second academic semesters of the graduate program, and involved an average of 37 class sessions of 3 hours each that were taught weekly. All the participating teachers were working at the time of the study, teaching science classes in secondary schools in the Piura Province. Of these teachers, 57% worked in rural schools. The mean years of experience for these teachers was 13 years teaching science in secondary schools.

The overall objective of the Specialization in Science Technology and Environment program was educating science teachers in theoretical contents and in methodological strategies to improve their teaching performance. In particular, the course emphasized the teaching design of experimental inquiry activities, both guided and open, as well as building research skills among the participating teachers that they could use during participation in similar experimental activities designed for their students.

Throughout the classroom sessions, teachers participated in a series of inquiry activities on different curricular topics, with inquiry levels both guided and open, and they worked in planning experimental activities to be conducted with secondary level students. The activities performed in the sessions involved exploring diverse phenomena and objects such as chemical reactions, the biology of yeasts, reaction time, polymers, soaps and detergents, Volta's batteries, and combustion.

Phases of the process and sources of data gathering

The research process was organized into two phases: diagnostics and process. In each of these processes, we analyzed a set of information sources to account for the learning process of the teachers throughout the course.

Diagnostics phase

In the diagnostics phase we evaluated the inquiry level of the experimental activities proposed by teachers before the beginning of the course as a way of knowing their starting point. For this purpose, we analyzed the teachers' narrative records from two experimental activities that they had conducted in the classroom. Based on the following guidelines, participating teachers selected and described in detail two class sessions conducted previously in which they proposed that their students conduct experimental activities:

Recall and write two experimental activities that you proposed in your classroom, specifying the questions that your students formulated during the development of the activities. Also, explain what you requested your students to do during the activity; for example, posing hypotheses, carrying out measurements, and drawing graphs.

From this information, we performed an interpretative analysis of the content to characterize the activities proposed by the teachers based on Banchi and Bell's (2008) dimensions regarding the roles of professors and students in developing the question and the design of the research to determine the level of inquiry of those activities.

Process phase

In the process phase we analyzed the inquiry level of the experimental activities proposed by the teachers during the teaching of the course.

For this purpose, we analyzed the 280 written reports presented by the participating teachers throughout the classroom sessions of the course. At the end of each of these sessions, taking as a baseline the model of the classroom session and the topic taught, we requested that the teachers design experimental activities to take to their classrooms. The information provided by the teachers needed to be sufficient for the other participating teachers in the course to replicate the activity in their classrooms. The content of the report needed to provide details of the steps to follow, the research question posed, the way of interacting with students, the required materials, and the type of skills promoted by the development of the experimental activity. This information facilitated analysis of the activities proposed and determined their level of openness.

Complementarily, we administered three instruments of data gathering to elucidate the perceptions of the teachers with regard to the proposed activities and their learning process in the course. These instruments were (a) a semi-structured questionnaire at the end of each of the classroom sessions and (b) two semi-structured questionnaires that were administered at the end of each of the academic semesters. The purpose of the first questionnaire was to promote in teachers a meta-cognitive reflection on each of the classroom sessions, based on the following questions:

- What did I learn today?
- Did it change in some way what I already know? In what ways?
- How would my teaching practice change from what we have seen in the classroom?

The second questionnaire was aimed at knowing the perceptions of the teachers about the contents taught, the methodology used, and the changes produced in their own teaching practice. The following questions were posed:

- What did I learn in the course?
- Did it change what I thought at the beginning with regard to how to teach science in the classroom? Why?

- What in the course attracted my attention the most?
- How have I been applying this in my teaching practice?
- You may not have implemented some topics developed in the course because they are considered to be difficult to implement in the classroom. If so, what difficulties would you have in applying what you learned in your classroom?

Data analysis

Following from the information gathered from the sources, we proceeded to classify the activities prepared by the teachers according to the inquiry levels proposed by Banchi and Bell (2008), as described previously. The analysis was performed in two parts: first we analyzed the activities that were conducted in the first academic semester and then those in the second semester. In both cases we calculated the frequency of the different levels of inquiry in the experimental activities that were proposed. We compared statistically the results from each inquiry level (confirmatory, structured, guided, and open) with a means test among the following groups: (a) the initial situation diagnosed in the first academic semester and (b) the first and second academic semester. We used the statistical software STATA considering a level of 99% of significance.

For the analysis to the answers of the questionnaires, we used grounded theory (Glaser & Strauss, 1967) to look for emerging patterns in the testimonials from the teachers that would realize the factors from their perceptions that would have an influence on the changes observed. The answers were processed using AQUAD-7 software, which permitted an analysis of the frequency with which teachers referred to any keyword, providing an indication of what was most significant for each formulated question.

RESULTS

When analyzing the level of inquiry of the experimental activities proposed by teachers before and during the course we found that overall there was a gradual increase in the level of openness.

All teachers initially proposed experimental activities corresponding to the Levels 1 and 2 (confirmatory and structured). After the first academic semester, the activities in Level 1 (confirmatory) disappeared and the majority of teachers proposed structured inquiry activities (Level 2). Finally, after the second semester, the vast majority were able to propose Level 3 activities (guided inquiry). It is worth noting that no examples of open inquiry (Level 4) were presented and even after the training there were confirmatory activities, which shows the difficulties that teachers face in promoting activities involving open inquiry.

In the following sections we will provide greater details of the results obtained. In the first section, we will describe the initial situation of the teachers, providing some examples from the activities proposed and interpreting their implications for student learning. We will then do the same with regard to the phases of the process, both at the end of the first and second semesters, providing an account of the changes in the types of experiments proposed by the teachers.

Finally, we will describe some factors that show the changes observed, taking into account the perceptions of the teachers.

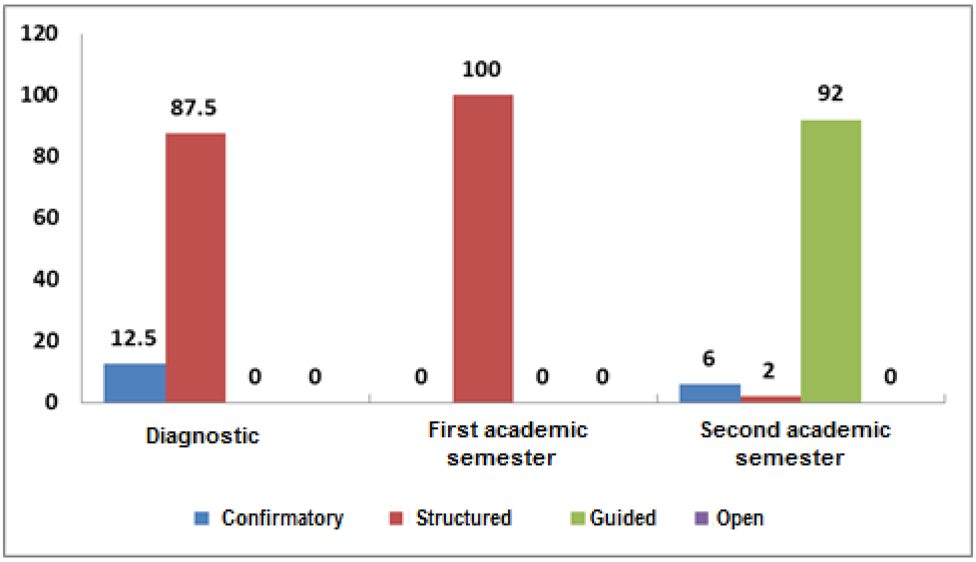

Figure 1. Percentage of inquiry levels of experimental activities posed by teachers throughout the course. Note: With 99% reliability, there are significant differences in the means of Levels 1 and 2 between the diagnostic levels and the first semester. There is also a significant difference of means in Levels 1, 2, and 3 between the first and second semester.

Diagnostic phase

As can be seen in Figure 1, before beginning the specialization (diagnostic phase), teachers proposed experimental activities corresponding to the first two levels of inquiry. A total of 12.5% of the activities described by teachers corresponded to the confirmatory level of inquiry, while the remaining 87.5% corresponded to the level of structured inquiry. No teacher proposed experimental activities involving guided or open research.

The results show that the experimental activities that were brought to the classroom before the specialization were proposed as illustrative demonstrations from of a theory or guidelines for the students, confirming Valverde, Jiménez, and Viza's (2006) suggestion that mostly confirmatory and structured inquiry types of experimental activities were used by teachers. As we have proposed, the experimental activities in these two levels of inquiry result in students not getting intellectually involved in the process; the experimental design does not stimulate them to pose questions nor look for answers to their questions (Marques-Vieira & Tenreiro-Vieira, 2006).

We illustrate the confirmatory level of inquiry using the case of a teacher who proposed solving the following question to explain to students the topic of heat conduction by metals: Which of the two rods, copper or aluminum, will better conduct heat? To solve it, students were shown two rods, one copper and the other aluminum, to which clips were placed to hold candle wax. A candle was then lit to heat up the rods. The teacher then explained that the clips that fell first would be the ones on the copper rod because this metal conducts heat better. The students were asked to observe and write down the results to confirm what he taught them.

This is an example of an activity in which students have a very low degree of autonomy and the teacher has a predominant role in defining the problem and the experimental design. Students limit themselves to verifying what the teacher has already told them will be the results. Chinn and Malhotra (2002) also suggest that although students might propose other questions on the phenomena they have observed, they cannot verify them; the research is limited to what the teacher has presented.

Process phase

First academic semester

After the first academic semester we see significant differences in the level of experimental activities posed compared to the beginning of the course, when 100% of the activities proposed by teachers were focused at the structured level of inquiry. This represents progress, in that teachers moved away from confirmatory level activities, providing evidence of partial assimilation of what was learned in the course. If we compare the confirmatory level activities proposed at the beginning with the ones from the end of the first academic semester, we find there is a significant drop of 12.5% ($p < 0.01$). Similarly, we can see that there is a significant increase at the end of the first academic semester of 12.5% in the activities proposed with a structured level ($p < 0.01$).

These findings give us evidence that, after participating in a series of guided-inquiry activities (Level 3) in the class sessions of the course, teachers were able to learn the importance that experimentation serves when an answer is not known beforehand as opposed to when an answer has already been given by the teacher or the textbook. This progress is significant in emphasizing the role of experimentation in students' knowledge construction process. From this point of view, conducting experiments becomes an opportunity to find answers to natural phenomena that can contribute to our understanding rather than merely illustrating procedures of previously given knowledge.

However, in this first phase, teachers still did not completely understand that performing experiments in the classroom does not just mean following a series of instructions; part of the didactic value of experiments is their presentation of opportunities for learning scientific thinking skills. As we discussed previously, when students are presented only with structured guides where they are told what is going to change and stay constant and what measurements that will be made and where to fill that data in the tables, the learning is limited. In these instances students acquire a series of skills in the scientific processes of data analysis but do not learn other skills such as formulation of questions, development of hypotheses and experimental design (Merritt, Schneider, & Darlington, 1993). This way of carrying out experimental activities in the classroom does not achieve the objective of helping students to think and act in the way that scientists produce knowledge rather than only reproducing what others have performed (Peters, 2005).

As an example of an activity at a structured inquiry level, we show the following: a teacher proposed that his students explore the factors that affect the speed of chemical reactions. For this purpose, he proposed the following researchable question to the students: "What factors affect the speed of a chemical reaction?" The teacher continued his session writing on the board the factors he would take into account: temperature, particle size, and concentration. He then provided detailed drawings for the students to follow showing how to complete the procedure. Finally, the students were asked to perform the experiment, record their results, and prepare their conclusions.

By proposing this type of activity in the classroom, teachers promote the acquisition of a series of procedural skills such as managing instruments, making measurements, recording data, and constructing graphs. This type of activity also encourages students to interpret their results and prepare their own conclusions without having been given the answer to the question beforehand. As we have mentioned previously, these activities limit the autonomy of students to definition of the problem, procedure, and data recording. Students play the role of mere "implementers," without the intervention or development of more complex thinking skills.

From this result, a first important reflection arises. Although teachers had already participated in one semester of guided-inquiry activities (Level 3) and despite the realization that these activities would enable teachers to discover for themselves how to plan experimental designs with their colleagues in order to answer a researchable question so that they could replicate these designs in the classroom, our data reveal that this did not end up serving as a model to promote these experimental activities to a level of greater openness (in this case, Level 3). All teachers still proposed more structured activities when they could have planned open inquiry activities themselves.

Therefore, these results lead us to think that in order for a working teacher to learn to propose an experimental activity with a level of inquiry different from a structured one, training during one semester may not be sufficient. To a large extent, learning to plan experimental activities with a greater level of openness requires extensive change in the way of conducting experimental activities in the classroom, as teachers are rooted in the practice of their school experiences. In fact, for many years textbooks have continued to provide a source of consultation for teachers (Calvo & Martín, 2005) where the experimental activities are posed as a script that is prescribed for teachers to follow (Mordeglia, Cordero, & Dumrauf, 2006). In this, respect it is interesting to note that even in the *Technical Educational Guidance for the Area of Science, Technology, and Environment* from 2010, in which an inquiry teaching approach is promoted, the examples of classroom experimental activities show a structured script that students should follow, even though teachers are expected to lead students to develop experiences, "proving what occurs in the practice" (p.49).

Second academic semester

After the second academic semester of the training program, as shown in Figure 1, we perceived a clear progress toward greater levels of openness in the activities. A total of 92% of the activities proposed by the teachers were guided inquiry, which was not previously evident in their repertory. A small percentage (2%) was still in the structured level of inquiry, while 6% was at the confirmatory level of inquiry. There were no examples of open inquiry (Level 4) in the second semester of the course while teachers participated in that type of inquiry activity during the course. These results indicate that, after participating in a series of activities of open and guided inquiry in which they acquired practice in formulating researchable questions and developing experimental designs, teachers were progressing towards planning more open activities for their own classroom activities.

The increase in guided-inquiry activities (Level 3) shows the positive impact of the course on teachers. The following is an activity of this type of inquiry proposed by a teacher who, after dealing with the topic of pH and its relationship with dental care, gave his students the following problem: "Mercedes wants to buy toothpaste to help avoid tooth decay and protect her teeth. When going to the pharmacy to buy her toothpaste, she finds five different toothpaste brands. Can you help her choose the right toothpaste?" In this context, she presented to her students the researchable question: "How would you determine which toothpaste has the appropriate pH for the care and protection of Mercedes' teeth?" To find a solution, students needed to plan an experimental design and conduct the experiment to determine the pH of toothpastes and help Mercedes to choose the most appropriate one for the care of her teeth. During the process, they had to look for information about the effect of pH on tooth care as well as use the knowledge about measuring pH that they had learned in class.

Our results show that the process by which teachers learn to prepare experimental activities involving higher levels of inquiry is gradual, while, as mentioned, it requires teachers deviating from practices that they have used for years. We observed that participation in guided and open inquiry activities throughout the 10 months of the course facilitates teachers' progress in their ability to plan activities of this type for their own students.

Finally, activities of open inquiry (Level 4) were not found, even though during the course teachers participated in some activities of this type. In their testimonials, teachers admitted to the limited feasibility of performing this type of activity in their classes because they considered it difficult to guide several different activities; better planning and programming of the activities would be required from the beginning of the school year. They also believed that it would take more time to carry out open inquiries, which is similar to the findings by Trautmann, MaKinster, and Avery (2004).

Factors that affected the changes observed

Our results reveal that throughout the course, teachers progressed in their ability to propose experimental activities involving more open inquiry. In this respect, it is interesting to know what factors were more relevant in achieving that type of learning. Based on the teachers' questionnaire responses, we have identified four factors that influence how experimental activities are planned. These include the materials required to perform the activities, models of guidelines for performing the guided and open activities, the nature of science, and the implementation of the activities in their classroom.

Materials necessary to conduct the experiments

A factor that influenced teachers' achievement of greater levels of inquiry in their planning is the change in their view of the need to have complex materials to do research in the classroom.

At the beginning, 91% of teachers justified the use of confirmatory and structured activities because of the difficulty they had in finding sufficient materials to conduct experiments with students. Also, the limited time they had in class resulted in teachers conducting demonstrations in class. In the words of one of the teachers, "The materials that the school has are not enough to develop experimental activities in each group. Therefore, students do not manipulate the materials and in general the teacher performs the demonstrative experiment."

However, throughout the course, that justification was decreasing. In fact, towards the end 38% of teachers explained in their testimonials that they did not need sophisticated materials to perform experimental activities. For example, one of them said, "Activities that develop inquiry abilities can be performed using simple and easy-to-find materials," which means that the initial problem that was expressed about lack of materials was no longer relevant.

After the course, teachers started to recognize that in order to prepare an experimental design that posed activities with greater degree of openness it was not necessary to have a very sophisticated laboratory.

We consider that this view was the result of exclusively using household materials that were readily available throughout the course. In this respect, the course enabled teachers to consider other possible materials they could use in experimental activities. As the course progressed and teachers observed that they could design experiments to research questions posed from daily life situations without needing to have special or expensive materials, this progressively changed their position. This was stated precisely by a teacher: ". . . the design of experimental activities and the use of materials do not require a complex lab." This way, teachers were convinced that they had multiple ways of performing experiments with students, e.g., by converting easily available materials into measuring instruments (Aragón, 2004), identifying the best toothpaste based on its pH, and replicating Volta's battery with coins.

Models of guidelines for performing guided and open activities

As the literature has shown, science teachers generally refer to guidelines or protocols to develop experiments in the classroom, which means that experimental activities are conducted at a structured level. The teachers who participated in this professional development course were no exception to this. Before the course, many of the teachers had referred to guidelines for procedures, as expressed by one teacher: "I used to develop experiments using predetermined guidelines."

However, the teachers' testimonies show that because the course offered various models of guidelines and protocols for classes with higher levels of openness they were able to be more decisive in their ability to plan activities with greater levels of openness. As the training sessions progressed, teachers recognized the importance of planning more challenging tasks for students: not just tasks where they need to complete the data requested (and many times communicated beforehand) but ones that give them the opportunity to develop more complex skills as they carry out the guidelines of activities themselves during the course.

At the beginning of the course teachers thought that experimental activity should be carried out only at a structured level. One teacher noted: "At the beginning of the course I thought that in order to perform experimental activity I needed to provide students with guidelines whose instructions they should follow to the letter." Referring to the class sessions, the teacher then added: "Now I understand that students can prepare their own experimental design, propose hypotheses, and plan the procedure to follow, even the data gathering method." As a result of having models of sessions with greater degrees of openness involving Levels 3 and 4 activities during the course, teachers were able to change their views about the way in which they were carrying out experimental activities in the classroom.

When teachers participated as students in guided and open activities, they had the opportunity to participate in the preparation of an experimental design to resolve a proposed researchable question. This was a challenge for them, given that they were not used to performing such activities. As classes progressed and teachers gained more experience with these activities, they gained self-confidence that, according to their testimonials, translated into proposing similar activities to their students who were preparing experimental designs. In the words of one teacher: "When I planned an experiment to do with my students, I always had used what was proposed in the text books. I had not done my own experimental design. Now that I have confirmed that I can do it I can guide my students to do it also." As Ireland et al. (2011) pointed out, the experience of taking part in activities of different levels of inquiry as learners enabled teachers to focus on students' experience within the activities they planned for their classrooms.

The nature of science

Another factor that influenced the evolution of teachers towards the ability to plan activities with greater levels of openness was a review of their notions about the nature of science as a teaching object.

At the beginning of the course, the teachers generally resorted to experiments to prove a theory covered in the class. Most of the teachers sustained a conception of science that was strongly linked to science as a product: a set of facts and theories that teachers must transmit to their students. This is clearly conveyed in the comment of one of the teachers who reflected: "I thought science was taught only as a product and a verification of what was explained."

This statement refers to teachers taking into account the dimension of science as a process of building knowledge when experimental activities are carried out in the classroom. Eighty-one percent of the teachers recognized that through the course they had learned to work with both dimensions of science. In particular, teachers recognized the need to promote the acquisition of scientific process skills in their students. In reference to this, a teacher stated: "I have realized that it is important that students prepare hypotheses and make predictions."

Implementation of activities in their own classrooms

Finally, the fourth factor that influenced the progress of teachers was the possibility of implementing some of the activities that were planned in the course with their own students.

At the beginning, teachers were a little cautious about the possibility of working with their own students' inquiries at more open levels. However, when putting into practice with their own students some of the activities that were planned during the course, teachers started observing that students could perform them satisfactorily and that these types of activities promote more active participation in the classroom and meaningful learning. As one teacher said:

Before, I thought that it would be difficult for my students to propose experimental designs, but I found to my surprise that they provided suggestions and showed much creativity when they were allowed to do so; students were more participative. They were involved and understood the experiment.

The testimonials from teachers throughout the course supported the feasibility of students performing more open activities in the classroom and the ability of students to propose their own experimental designs in response to questions that were proposed. On one hand, one of the teachers commented:

With this type of activity students prepare their experimental guidelines, differentiating the different parts of the activity. In the beginning, they did it with the help of a teacher, but now they carry it out by themselves (always with some orientation). Many students already prepare hypotheses and differentiate between the formulations of these from the researchable question.

On the other hand, another teacher highlighted at the end of the course that the course promoted getting involved in this type of activity with students:

I propose more open activities because previously students followed a scheme or "recipe" from the teacher and were not able to do researchable schemes or propose researchable questions. They would always go to the teacher to find out what to do next.

These comments show that teachers perceived that using more open experimental activities in the classroom enabled their students to acquire scientific process skills. Teachers were able to experience for themselves the feasibility of implementing more open and challenging activities with their own students. We consider that this factor was fundamental in the changes observed in teachers' planning, while it gave teachers a "proof of possibility" (Cochran-Smith, 2004) that also offered them evidence of the possible positive effects in the learning and participation of students in science classes.

CONCLUSIONS

We analyzed in this paper the impact of a course in professional development on the ability of secondary school science teachers to design inquiry activities. Throughout the course, and more evidently after the second academic semester, we saw that teachers who participated in the course showed a deeper and better understanding of inquiry and its implications in the teaching of sciences than they had shown at the beginning. Teachers started taking into the classroom experimental activities with a greater degree of openness, planning the skills of the scientific process they were going to promote among their students, bringing them closer to phenomena related to daily life, taking into account the dimensions of science both as a product and a process of knowledge generation, preparing their own experimental activities, and contextualizing them and planning the theoretical aspects.

Our study reveals that the possibility of having various models of class sessions with more open inquiry levels where promoting the skills of the scientific process and conceptual content are the major element and participating personally in the realization of this type of experience substantially contributes to this change. Our results show that generating an appropriate environment where discussions can be conducted and having low-cost materials available for teachers to test their experimental designs using topics with appropriate conceptual content and related to daily life have the potential to allow teachers to better understand and internalize the meaning of teaching of science by inquiry.

In this framework, it is interesting to analyze the discourse from teachers with regard to the implementation of guided or open inquiry experimental activities and the feasibility of doing so in the classroom. Beyond that, the perceptions of the teachers are the key to understanding what is happening in the classroom. In this sense, the fact that our results show changes in the ideas of teachers that are accompanied by a process of systematic reflection is an encouraging result to consider for continuous teacher education.

Our study also shows that the process of changing teachers' views on experimental activities as resources for learning and the evolution of the ability to design more open opportunities of inquiry takes time. In this case, teachers showed significant progress after the second semester of the course. This result has implications for teacher education, including the importance of allocating enough time so that teachers can participate in multiple and varied opportunities for inquiry. .

The training of teachers in the inquiry approach continues to be a challenge in many countries of the world, including Peru. Our results provide a measure of optimism and show the possibility that this challenge is compatible with the objectives of most graduate programs. At the same time, the study opens new questions about the most effective strategies to continue strengthening the inquiry approach among teachers, progressing towards the possibility of implementing inquiry activities with greater levels of openness in different topics of the curricula and designing coherent evaluations with this teaching model.

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