Title

Pre-service Teachers' Acquisition of Scientific Knowledge and Scientific Skills Through Inquiry-Based Laboratory Activity

Abstract

Purpose

Scientific inquiry is a leading methodology that promotes science process skills to acquire scientific knowledge. There is evidence that primary school teachers have difficulties introducing inquiry-based activities in their classrooms. Hence, adequate teacher instruction in inquiry methodology is important to apply inquiry-based activities in school science lessons. This work aims to analyse if pre-service teachers succeeded in developing scientific knowledge and scientific skills through the application of an inquiry laboratory activity.

Design

This article is presented as a case study developed in a group of 82 pre-service teachers. This research methodology involved qualitative and quantitative data.

Findings

The results demonstrate that pre-service teachers could improve their scientific skills and knowledge through inquiry-based laboratory activity.

Originality

The present study assesses not only the scientific knowledge but also if students can acquire scientific skills by doing the inquiry laboratory activity and if these skills are related to low-order cognitive skills or high-order cognitive skills.

Keywords: inquiry-based learning, laboratory activity, pre-service teachers, scientific skills, scientific knowledge

Introduction

Educators, researchers, and policymakers are concerned about the decreasing interest of young people in pursuing scientific careers. The lack of interest of youngsters in science often becomes visible during secondary school. However, most of the students have already excluded the choice of scientific or technological subjects during their years in primary school (Osborne and Dillon, 2008; Tai *et al*., 2006). Today, contemporary frameworks for science education highlight the fact that one of the main goals for students is to become scientifically literate citizens (Organization for Economic Cooperation and Development [OECD], 2016). Scientific literacy can be defined as the capacity to use scientific knowledge to identify questions, explain scientific phenomena and draw evidence-based conclusions to understand the natural world and the changes made to it through human activity (OECD, 2016). This means that students need to understand scientific concepts to account for everyday natural phenomena as well as to understand the nature of science by experiencing how knowledge can be built, enhanced and validated though scientific investigation (Chin and Osborne, 2008).

The Rocard Report highlighted inquiry-based science education as providing a possible solution to a lack of interest in science (European Commission, 2007). Learning science by inquiry encourages students to not only learn concepts but also develop scientific skills by performing authentic scientific tasks (Harlen and Qualter, 2009; García-Carmona *et al*., 2017). Within this approach, inquiry-based activities are especially interesting. Students participate actively in observing, investigating, developing and understanding the physical world through direct interaction with phenomena (Harlen, 2013; National Research Council, 2012).

In this way, scientific skills play a key role in the performance of scientific inquiries, and many studies emphasize the importance of learning science skills at an early stage in order to enhance the student's understanding of scientific content and general science literacy (Coil *et al*., 2010; Durmaz and Mutlu, 2016). Thus, adequate teacher training and instruction in this methodology is the key to promoting and introducing inquiry-based activities in school science lessons (García-Carmona and Cruz-Guzmán, 2016).

However, although the literature highlights the educational benefits of inquiry-based learning activities, the incidence of their inclusion in science classrooms is still far from what would be desirable (Flores *et al*., 2009). Numerous studies highlight the difficulties that pre-service teacher students usually have when facing the different tasks involved in an inquiry-based activity process. One of the main reasons is the insufficient pedagogical training students receive at the university, and they also do not have any opportunities to test this strategy during their practicum periods in school (Cortés *et al*., 2012; García-Carmona and Cruz-Guzmán, 2016). For this reason, it is important to introduce scientific practices to university courses to improve pre-service teachers' self-confidence and help them to construct new expectations and opinions (Delamarter, 2015). In this way, the difficulties sometime come to their personal prior learning experiences. So, there are many factors which could contribute to student's scientific knowledge and skills, including high school, university and informal science experiences, socio-economic status and the influence of their peers, family and media (Kazempour and Sadler, 2015; Milford and Tippett, 2013). Numerous studies reveal the difficulties that students usually have when putting into practice the different science process skills involved in an inquiry-based activity, such as posing researchable questions (Hofstein *et al*., 2005), formulating hypotheses (Guisasola *et al*., 2006), taking reliable measurements and obtaining data (Barolli *et al*., 2010), identifying and controlling variables (Schwichow *et al*., 2016) and interpreting data (Kanari and Millar, 2004), among others.

Introducing inquiry-based activities in all educative levels a challenging issue. Some studies indicate that science skills can only be acquired through learning by doing (Dean and Kuhn, 2007). The students usually lack experience, strategies and knowledge of the different science skills for performing effective scientific investigations. Moreover, novice learners in inquiry methodology present limited cognitive information-processing capacities that hinder the performance of a complex task such as an inquiry process (D'Costa and Schlueter, 2013; Solé-Llussà *et al*., 2017). Scientific skills involved in inquiry activities have been classified into low-order cognitive skills (LOCS) and high-order cognitive skills (HOCS) **(**Ergül *et al*., 2011; Lati and Promarak, 2012). On the one hand, LOCS are skills related to knowledge questions that require recall information or simple application of knowledge, as well as problems solvable by means of algorithmic processes such as mechanistic application. On the other hand, HOCS are operationally more complex and are related to problems unfamiliar to the students that require application, analysis and synthesizing capabilities, as well as making connections and evaluations **(**Ergül *et al*., 2011; Krathwohl, 2002; Lati and Promarak, 2012**)**.

Among the different learning approaches that could be implemented to develop these cognitive skills, laboratory activities allow to put into practice certain scientific process skills during their research at science laboratory (Kanlı, 2007). The study of Güngor (2014) demonstrates that pre-service teachers who are doing laboratory activities encourage students to ask more questions, to inquire and research, and they take the responsibility of their own learning. In this way, pre-service training should be essential to design suitable laboratory activities and thus, to emphasize the importance of meaningful, authentic activities that help learners to develop scientific inquiries in order to acquire scientific knowledge and science process skills (García-Carmona, 2019; Güngör, 2014). Sunal *et al*. (2008) pointed out that the principal focus of laboratory work should not be limited to learning specific scientific methods or particular laboratory techniques. Instead, students in the laboratory should use methods and procedures of science to investigate phenomena, solve problems, and pursue interests. Students can work cooperatively in small groups to investigate scientific phenomena and thus promote a positive learning environment for the students and the teacher (Hofstein and Lunetta, 2004). Practical work in learning science not only needs an active learner but also a teacher who develops learning environments that include laboratory experiences to help promote principal goals as well as specific objectives (Meinhardt *et al*., 2014).

Purpose

In accordance with all of the above, this paper aims to assess the application of an inquiry-based laboratory activity (Novo *et al.*, 2015). This inquiry-based laboratory activity is addressed to elementary education pre-service teachers in the framework of a university course aimed at science teaching. We analyse whether these students succeeded in developing students' scientific knowledge and scientific skills and what assessments the pre-service teachers make about the pedagogical approach. Specifically, the aims of this paper are:

- To analyse the scientific knowledge acquired by means of an inquiry-based laboratory activity and to determine if sociodemographic data are related to the scientific knowledge acquired.
- To demonstrate that by applying the inquiry-based activity in the classroom, students acquire scientific skills.
- To analyse students' expectations and opinions of inquiry-based learning as a pedagogical approach.

Methodology Design

Participants

The sample was composed of 82 students seeking the pre-service primary teacher's degree at the Rovira i Virgili University (URV) in Tarragona, Spain. Subjects with missing data and those who did not complete the two laboratory sessions were eliminated from the data set.

Demographic information shows that students were, on average, 22.5 years old (± 4.51). The vast majority of the participants are female (82%), one-third of them have a scientific background (which means that they obtained a high school diploma in science) and only 19% have parents with a university degree, and most of them (54%) have a high school degree (Table 1).

Students were distributed into five laboratory groups with 23 to 25 students in each group. In these laboratory groups, the students worked in small subgroups of two to three.

[TABLE 1 NEAR HERE]

Method

The present work used a case study as a research methodology which involved qualitative and quantitative data. A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context using different sources of evidence. A case study can establish cause and effect; indeed, one of its strengths is that it permits observation of the effects in real contexts and recognizes that context is a powerful determinant of both causes and effects (Cohen *et al*., 2013).

Intervention

The laboratory activity consisted of a qualitative and quantitative assay to measure the effect of temperature on the amylase activity in different kinds of commercial detergents. The laboratory activity was divided into two sessions of two hours each. During the first session, an experimental procedure was developed and within the second session, its analysis and the results' discussion were carried out. The details of the activity, procedure, required materials and equipment are described in our previous paper (Novo *et al.,* 2015).

Before the students became engaged in the laboratory activity, a pre-test (containing sociodemographic data, knowledge items about enzymes and questions focused on students' expectations) was performed. The inquiry laboratory activity consisted of two sessions.

Throughout the first session, the students prepared detergent samples in order to incubate them at two different temperatures (4º and 40ºC). After 48 hours of incubation, the second session was focused on the observation, analysis and discussion of the results, both in the small group and in the class group. Within two weeks of finishing the laboratory activity, students were asked to write reports bringing up their results. In this report, students had to answer a provided set of questions that were used to evaluate their achievements regarding several learning outcomes (Table 2). Additionally, 15 days after the second session was conducted, students took a post-test consisting of the same scientific knowledge questions than the pre-test and some new questions focused on their expectations and enjoyment of the laboratory activity. This delay between in-person class testing and post-testing was purposely planned to test the persistent effects of the laboratory activity beyond the immediacy of the intervention.

Assessment Instruments

The assessment of the laboratory activity 'How do detergents work?*'* follows the workflow represented in Figure 1.

To obtain evidence regarding the acquisition of scientific knowledge and the students' expectations, a pre- and post-test were performed. The pre-test included: i) some socio-demographic data; ii) 10 knowledge questions about enzymes and their properties; and iii) three opinion items focused on participants' expectations about the activity. All questions about knowledge were presented with three possible answers: true, false or 'I do not know'. The validation of the knowledge questions was as follows: once we had completed the initial draft, we asked a committee of five experts in biotechnology, molecular biology and pedagogy to validate the questions. To quantify participants' expectations of the inquiry laboratory activity, each one completed a questionnaire at the beginning of the activity. This questionnaire had a 4-point Likert scale (strongly disagree (1), disagree (2), agree (3) and strongly agree (4)) and consisted of three statements selectively chosen and worded to give an overall subjective assessment of the expectations of the activity.

[FIGURE 1 NEAR HERE]

The post-test included the same knowledge questions as the pre-test. Additionally, students were asked their opinions about the inquiry-based laboratory activity. This part includes six questions, which the students answered on a 4-point Likert scale (strongly agree, agree, disagree, and strongly disagree). Finally, students were asked to fill out a qualitative questionnaire consisting of a table on which they should express their opinions about three aspects that they would maintain and three aspects that they would change regarding the inquiry-based laboratory activity. A coding system blinded the researchers from identifying the students and helped them to match the students' pre- and post-tests.

Apart from the pre- and post-tests, we used a laboratory report to assess whether students had acquired scientific skills. The laboratory report is made up of eight questions about the inquiry-based laboratory activity. By means of the report, we could collect information about the inquiry-based approach (identify the variable, analyse and represent the results graphically, get/generate hypotheses and conclusions, and become aware of the important role of the controls). The laboratory report was developed in groups of two to three students and the maximum score was 10.

Learning outcomes

The learning outcomes that students should reach by means of this inquiry-based laboratory activity are listed in Table 2. We divided learning outcomes into two groups: the first one includes learning outcomes related to scientific knowledge about the characterization of enzymes (identified by A); and the second one comprises learning outcomes with regard to the inquiry-based learning application, in other words, the acquisition of the scientific skills (identified by B). In this table, we detail the activities related to different learning outcomes and specify in which question has been assessed.

To assess how the application of this methodology influences the acquisition of scientific knowledge and skills, it is important to properly record outcome learnings, and one approach is Bloom's taxonomy of cognitive domain. We classified our outcome learnings according to Bloom's Taxonomy (Krathwohl, 2002). This classification is composed of six categories that are ordered from simple to complex and from concrete to abstract. Bloom's is a well-defined and broadly accepted tool for categorizing types of thinking into six different levels: remember, understand, apply, analyse, create and evaluate (Crowe *et al*., 2008). The three first levels belong to what is known as lower-order cognitive skills (LOCS) that are related to processes of memorization and recall. The last three levels – analysis, creation and evaluation – are involved in the use of high-order cognitive skills (HOCS) that are related to the application of knowledge and critical thinking (Crowe *et al*., 2008).

In Table 2, the different activities were classified by considering which Bloom level students were involved in when engaging in each activity. The inquiry-based learning is an active pedagogy: its application promotes HOCS that require deep conceptual understanding (Madhuri *et al*., 2012). The authors consider that the learning outcomes were acquired if the percentage of correct answers is at least 60%.

[TABLE 2 NEAR HERE]

Statistics analysis

A correlation analysis was carried out to measure the extent of the relationship between socio-demographic, knowledge and opinion variables. The overall approach involved examining the differences between the pre-test and the delayed post-test results in knowledge using a repeated-measures t-test. The data from an opinion questionnaire was analysed as a unique variable and was split into factors. Pearson's correlation coefficient (r) was used for measuring the correlation between quantitative variables (age and knowledge). Additionally, a point-biserial coefficient (rpb) was calculated between nominal (biology background) and quantitative variables; a biserial coefficient (rb) was calculated between ordinal (parent's background) and quantitative variables, and the rank-biserial coefficient (rrb) was calculated between nominal (biology background) and ordinal (parent's background) variables. To measure the consistency of the questionnaire, a reliability analysis was used to calculate the Cronbach's alpha. The reliability of the pre-test expectations questionnaire in the survey is 0.722 and, in the satisfaction, and usability questionnaire in survey, it is 0.809. Data were analysed statistically with the IBM SPSS Statistics 24.0 software (IBM SPSS Inc., 2016). The results were evaluated at a significance level of $p < 0.05$.

Results

Scientific knowledge assessment

The scientific knowledge acquisition was evaluated using two different tools: i) an individual survey containing knowledge questions (aforementioned pre- and post-tests) about enzymes and their properties; and ii) a final report that was group work. The knowledge test is composed of 10 questions related to learning outcomes A (Table 2). The final report is composed of eight questions but only questions 1, 2 and 3 are related to learning outcomes A. Both instruments were punctuated between 0 and 10. In the knowledge test, each correctly answered question earns one point whereas in the final report, questions 3 and 8 earn a maximum of two points and the rest of them earn one point.

Analysing the knowledge gain results globally through pre- and post-tests, an interesting evolution is observed (Figure 2). In the pre-test, correct answers represented 25% and in post-test, they go up to 65%, indicating a clear knowledge gain. The percentage of wrong answers did not noticeably change between the pre-test (14%) and the post-test (24%). Interestingly, in the pre-test, 62% of students answered DK ('I don't know') while in the post-test, this answer drops down to 11%, indicating that most of students, after the laboratory activity, were able to truly answer the questions and not simply use the DK answer for almost everything (Figure 2).

[FIGURE 2 NEAR HERE]

The knowledge test scores (with a maximum score of 10) significantly increased from 2.44 (SD = 1.82) before performing the laboratory activity to 6.54 (SD = 1.39) after completing it. This result indicates that students' knowledge significantly increased after doing the inquiry-based laboratory activity.

[FIGURE 3 NEAR HERE]

Analysing the results of each question, it can be seen that in all the questions of the test, there was an improvement in the results, but the level of achievement is different for each question. When we analyse the results individually for each question of the pre-test and post-test (Figure 3), we can see that in all questions, the percentage of correct answers is higher in the post-test than in the pre-test. The differences between the pre- and post-tests were statistically significant in all of them by means of a t-student test.

However, for questions 4 and 6, the percentage of correct answers was 41.5% and 23.2% respectively (Table 3). In question 4, students thought that all enzymes develop the same function as amylases, which is to break some concrete molecules. However, question 6 was if 'Amylase acts on the protein' and it obtained a lower percentage of correct answers than question 4.

[TABLE 3 NEAR HERE]

To determine the acquisition of the A learning outcomes, it is also considered questions 1, 2 and 3 from the final report. All of them obtained marks above 60% of the score, and this fact reinforces the good results obtained in the knowledge test.

After the inquiry-based laboratory activity, students significantly increased their knowledge on different issues related to enzymes (Table 3). Students were then aware that detergents could be present in soap composition; they gained a better understanding of how enzymes work during the washing process and some of their properties (such as whether they are biodegradables, the concept of specificity, etc.).

In the following paragraph, the learning outcomes are associated with students' cognitive levels and whether they were achieved through the inquiry-based laboratory activity is also specified:

A1. To identify the presence of the amylase enzyme in some detergent compositions (LOCS). Considered acquired.

A2. To determine the enzymatic activity (LOCS). Considered acquired.

A3. To identify the specificity of amylase to starch (HOCS/LOCS). Considered acquired.

A4. To characterize the effect of the temperature on the amylase activity (LOCS). Considered acquired.

A5. To identify some characteristics about enzymes and its uses (HOCS/LOCS). Considered acquired.

These five learning outcomes were evaluated considering all the questions in the pre- and post-test as well as questions 1, 2 and 3 of the final report.

The first goal was clearly achieved; since we can assume that all the A learning outcomes were acquired. Although, all A learning outcomes have been achieved those corresponding to LOCS are achieved with higher percentages than those corresponding to HOCS, as the learning outcomes associated with LOCS require less cognitive effort on the part of students.

Scientific skills assessment

The second goal of this inquiry-based laboratory activity was to demonstrate that students acquire scientific skills. To assess this goal, authors used the final report that students delivered two weeks after finishing the laboratory activity. We assume that all activities except these two were consolidated by most of the groups. In terms of the report marks, the average mark was 6.3, but the range of marks was from 3.7 to 10. Nine out of 40 reports (22%) did not pass, in other words, they obtained less than 5 points.

The vast majority of tasks in the final report were related to the acquisition of scientific skills. In Table 4, we show the average punctuation of each question in the final report. We can see that in all activities (last row in the table), except for activities related to learning outcomes B1 and B8, the punctuation represents more than 60% of the maximum punctuation of each question. On the one hand, learning outcome B1 is related to the ability to generate a hypothesis when given a research question, and in this task, most groups were not able to give an adequate answer. On the other hand, learning outcome B8, which is related to the ability to understand and write the objective of the laboratory activity in their own words, was a task that most groups were not able to perform.

[TABLE 4 NEAR HERE]

To assess the scientific skills acquired, each activity of the final report was related to a B learning outcome. Then, the learning outcomes related to scientific skills were associated with students' cognitive levels, and we assessed their achievements.

B1. To generate a hypothesis (HOCS). Considered not acquired.

B2. To identify dependent and independent variables (LOCS). Considered acquired.

B3. To interpret the role of positive and negative controls (HOCS). Considered acquired.

B4. To formulate scientific explanations (HOCS). Considered acquired.

B5. To perform some statistics tests (mean, deviation, t-student test) (LOCS). Considered acquired.

B6. To draw and to expose their graphic representation (HOCS/LOCS). Considered acquired.

B7. To interpret the value of replicates in an experimental design (HOCS). Considered acquired.

B8. To describe the aim of the experiment in their own words (HOCS). Considered not acquired.

Correlations between socio-demographic data and scientific knowledge

The Pearson correlation coefficient was calculated to determine the relationships between socio-demographic data and the knowledge measured in pre- and post-tests (Table 5).

A biology background has a positive correlation with the pre-test mark; therefore, the students who had a biology background obtained better marks in the pre-test. On the contrary, the students who had a biology background obtained the same post-test marks as students who did not have a biology background. Throughout all of this laboratory activity, all students with or without previous knowledge about science reached the same scores in the knowledge test. The other socio-demographic data did not show correlations on the pre- and post-test marks.

[TABLE 5 NEAR HERE]

[FIGURE 4 NEAR HERE]

Students' expectations and opinions

Pre-test expectations

Analysis of the Likert Expectations Scale for each of the outcome measures are shown in Table 6. The results indicate that most students had high expectations of the activity, as 95% of them agreed or strongly agreed. Regarding whether the activity will help improve their knowledge, 93% believed that it would. The last question was related to whether they believed that the activity would be dynamic and motivating, and 92% of the students agreed or strongly agreed. Most of the class had great expectations of the new pedagogical approach before doing the inquiry-based laboratory activity.

[TABLE 6 NEAR HERE]

Post-test satisfaction and usability after laboratory activity

An evaluation questionnaire was used to assess the students' satisfaction with the inquiry-based laboratory activity which is divided into two parts, a quantitative questionnaire and a qualitative questionnaire.

1. Quantitative questionnaire

The questionnaire was composed of six items related to satisfaction and usability. The students' opinions after concluding the activity was satisfactory because regarding all the items, most of the students answered that they agreed or strongly agreed (Table 7). The vast majority of students agreed or strongly agreed that the activity was motivating and dynamic; they would like to do this type of activity more frequently, and nearly 90% would recommend this activity.

[TABLE 7 NEAR HERE]

2. Qualitative questionnaire (Students' opinions)

The last part of the post-test consisted of a table in which students wrote down three aspects that they would like to maintain and three aspects that they would like to change in the laboratory activity (Table 8). This questionnaire was in open answer format, and students could write what they considered convenient; therefore, a huge variety of ideas was collected. In order to analyse all of them, we opted to group similar answers and classify them into topics, which have been summed up in Table 8. We would highlight that the aspect that students most want to maintain is inquiry as a pedagogical strategy.

[TABLE 8 NEAR HERE]

Discussion

The present work evaluated three different aspects. Firstly, it analysed whether the students gained scientific knowledge through the inquiry-based laboratory activity. Secondly, it evaluated whether the students were able to develop scientific skills. Finally, it analysed students' opinion regarding this inquiry approach.

Each main learning outcome was divided into more concrete learning outcomes that were related to the levels of Bloom's taxonomy. Thus, the learning outcomes involved in the knowledge test represented, in general, activities related to LOCS. Otherwise, the tasks developed in the final report were firstly related to HOCS (Crowe et al., 2008; Krathwohl, 2002).

Analysing the results from the scientific knowledge test, we focused our attention on two aspects. The first one was that the percentage of 'I don't know' answers decreased considerably, so this means that after developing the inquiry-based laboratory activity, the students were more confident of their answers. At the same time, as students answered more questions, the percentage of correct answers increased. In this sense, when the punctuation of the pre- and post-tests was calculated, the marks improved with statistical significance. Our results are corroborated by other researchers who implemented the inquiry-based laboratory approach and found acquisitions of knowledge (Ketpichainarong *et al*., 2010; Rissing and Cogan, 2009; Simsek and Kabapinar, 2010).

The increase in the gained knowledge from a well-defined inquiry-based laboratory activity with some well-planned learning outcomes could be effective, and students could learn without using the master class. Furthermore, according to other authors, the laboratory activity contextualizes the contents that students must learn, and these contents make sense for the students in facilitating their learning (Ozdem *et al*., 2013).

After this general perception of knowledge increase, the knowledge test was analysed in more detail, question by question. It appears that the percentage of students who answered correctly increased significantly for all questions. Most of the answers showed that more than 60% of the students answered them correctly. Even the question about the specificity of enzymes according to the temperature obtained 100% correct answers. We cannot overlook the fact that questions number 4 and 6, which are related to the specificity of enzymes, had few correct answers since less than 40% of the class answered them correctly. Question number 4 assumes that ‘all enzymes act broken molecules’. In the inquiry-based laboratory activity, students worked concretely with amylases that are a type of enzymes that specifically break amylases; in the class, they were taught about other kinds of enzymes that break other substrates such as proteases or lipases. But there was no explicit explanation about other kinds of enzymes with other functions. This is a point of the activity that we need to reconsider in further applications. Question number 6 affirms that ‘amylases act on the proteins’. We attributed the low percentage of correct answers to this question to the fact that students were confused about the concept of amylases. They thought that amylases could act on proteins by breaking them down instead of realizing that amylases are a kind of protein with enzymatic activity. We believe that students confused some vocabulary terms since enzymes are proteins, but in this case, these proteins called amylases act on other kinds of molecules (carbohydrates) called starches. The learning outcome ‘A3. To identify the specificity of the enzymes’ must be revised in the development of the inquiry-based laboratory activity. The students wrongly believed that enzymes are a big family of molecules that can do different activities. However, enzymes have only one function. Amylases act by breaking down polysaccharide starches, but other enzymes act upon other molecules (lipids, proteins, etc.) and do not always break them down (enzymes could speed up the rate of chemical reactions, join molecules together, etc.). We think that concepts related to questions 4 and 6 were not well understood by the students, and in the future, these concepts should be emphasized during the laboratory sessions and in the explanation contained in the laboratory guide. This finding is parallel to the previous research findings (Kyza, 2009; Şimşek and Kabapınar, 2010). There was an increase in scientific knowledge, but not all the concepts were acquired by everyone in the classroom. Regarding the learning outcomes related to the pre- and post-tests, it could be concluded that all of them were achieved.

Whereas the pre- and post-tests were focused on determining the level of understanding of scientific knowledge (mainly related to LOCS), the final report permitted analysis of the acquisition of scientific skills related to HOCS. In the majority of the tasks, students needed to apply, analyse, or synthesize the contents of the laboratory activity. To successfully complete the final report, it was necessary to understand well all the concepts used during the laboratory session. Therefore, to evaluate the level of success regarding the acquisition of the learning outcomes related to the final report, we had based on the marks of each activity. The activities included in the final report are related to scientific skills. Students could demonstrate which scientific skills had been developed through the inquiry-based laboratory activity. The final report is composed of eight questions and six of them received high marks (more than 60% of the maximum punctuation). We assumed that most of the groups would achieve the outcome learnings related to these activities. On the contrary, there were two questions which did not obtain more than 60% of the maximum mark. The tasks with less punctuation were the outcome learnings related to generating a hypothesis (B1) and to describing the aim of the experiment in their own words (B8). If we focus on the type of skills involved in these groups of questions (with high marks and with low marks), we can see that in the group of questions with higher marks (questions 1, 2, 5 and 7), three out of four are associated with LOCS, whereas the questions with low marks (questions 3, 4, 6 and

8) are related to HOCS. This means that in order to answer correctly questions associated with HOCS, students needed to understand the content well to be able to apply it to answering the questions.

On question 3, related to collecting and analysing data, question 4 which asks students to explain the aim of experiment, question 6 regarding explaining the conclusions and question 8 about posing a new hypothesis, all students presented low punctuation, and this fact reveals that students had difficulties answering them. These questions required calculating, summing up, formulating a hypothesis, and identifying and controlling variables. We detected these difficulties other authors also found (García-Carmona *et al*., 2017; Yoon *et al*., 2012).

We agree with García-Carmona *et al*. (2017) that the major obstacle for the pre-service teachers is that they have insufficient scientific knowledge and training in science education. This result is similar to those of some authors who assumed that elementary school teachers have limited science knowledge (Arnold *et al*., 2014; García-Carmona *et al*., 2014). The reason is probably related to the fact that pre-service teachers have not dealt with inquiry laboratory activity, and they are not used to work that applies HOCS. Furthermore, most of them did not have biology or a scientific background. They are used to learning in a passive manner, memorizing contents since the way the teacher teaches is the way that students learn. In this sense, according to Güngör (2014) to improve scientific skills enable students think critically, find answers and satisfy curiosities and for these reasons to develop the scientific skills is essential. We consider that it is important for pre-service teachers to learn through active methodologies that enhance the skills needed to apply the content and solve practical problems by developing high-order cognitive skills. The development and acquisition of HOCS by students should be a major instructional goal in science teaching (Ergül *et al*., 2011; Lati, 2012).

Studying the socio-demographic data, we found that a biology background was the only factor that presented a correlation with pre-test marks. Students with a biology background (meaning they chose that scientific area in secondary school) had higher marks in the pre-test than students without this background, and this difference is statistically significant. It is important to highlight that in the post-test, both groups of students (with and without a background in biology) obtained practically the same marks. In other words, the knowledge gained through the inquiry-based laboratory activity had no relationship with the prior scientific knowledge of the students. These results reinforce the idea that active methodologies, which place the students in the centre of learning process, can generate learning even in students without the same scientific knowledge. According to García - Carmona *et al*. (2017), pre-service primary teachers generally display low scientific knowledge and abilities in science education. This fact represents a major obstacle to them acquiring the teaching skills they will need to be able to teach science through inquiry scientific knowledge involved. However, García-Carmona *et al.* (2017) underlined that students need to be familiar with inquiry, and when students are comfortable with it, and then inquiry-based activities can become useful for learning science. When some of these inquire-based activities were applied as Güngör (2014) study concluded that pre-service teachers in the treatment group performed better in terms of both achievement and scientific process skills than those of the control group, who received traditional laboratory education.

Regarding the students' opinions about the inquiry-based laboratory activity, we want to focus on those students who wanted to continue working with the inquiry-based learning as a pedagogical strategy. Although it was the first time that this group of students used this methodology, they felt comfortable with it. Students saw that it was a planned way of working, with a clear aim that they had to achieve. Students highlighted the importance of developing a practical activity. Indeed, inquiry-based learning is recognized as a suitable resource for integrating theory with scientific practices (Ozdem *et al*., 2013). Students also liked the fact that they could work in small groups that allow discussion and dialogue before taking a decision. However, students expressed that there were some aspects that they would change in this inquiry-based laboratory activity. The first one was that they preferred to know the content before developing the activity. This opinion is in accord with the work of Kim and Tan (2011). In their study, pre-service teachers mentioned that the lack of knowledge was a challenge, but they overcame it by means of developing the practical work. Another aspect that pre-service teachers suggested changing was checking different substances, not just commercial detergents. This opinion indicates that students were engaged with the activity and had curiosity about the topic. Finally, students mentioned that they enjoyed spending more time in this type of experimental activity. In this regard, experimental activities tend to generate extra motivation in students to learn science (Bulunuz, 2012).

Inquiry-based learning has been considered the most appropriate educational approach for learning science (García-Carmona *et al*., 2017; Harlen, 2012; OECD, 2017, 2019; Rocard *et al*., 2007) and the most reliable means of efficacy formation (Bhattacharyya *et al*., 2009). While applying inquiry-based learning, students could acquire scientific knowledge, develop scientific skills and, more concretely, HOCS (Simsek *et al*., 2010; Madhuri *et al*., 2012). All this evidence reveals that the inquiry approach presents more advantages than the traditional strategies for acquiring knowledge, process skills and attitudes towards science (Duran and Dökme, 2016; Minner *et al*., 2010). This approach will help empower the student to be an active learner, resulting in higher quality learning, as suggested by Groundwater-Smith (2019). According to Bhattacharyya *et al*., (2009) the inquiry approach permits students to learn through direct personal experience by connecting their prior knowledge with new information while they become more capable of understanding data. Furthermore, the inquiry-based activity can engage students, stimulate their interest and increase their enthusiasm (Taraban *et al*., 2007).

Yoon *et al*. (2012) suggest that in order to develop inquiry-based learning correctly, pre-service teachers need to understand the different domains of teachers' knowledge, such as 'subject matter knowledge', 'nature of inquiry' and 'pedagogical knowledge'. We agree with other authors who highlight that pre-service teachers have insufficient scientific backgrounds to carry out inquiry-based laboratory activities in the classroom (Bhattacharyya *et al*., 2009; García-Carmona *et al*., 2017). This evidence indicates that if we want teachers to use pedagogical inquiry approaches in their classrooms, they need better training while studying for their pre-service teacher degree.

Conclusions

To sum up, our work reinforces the findings by other authors about inquiry-based learning as a good pedagogical approach in terms of learning science. However, pre-service teachers have insufficient scientific backgrounds and lack of familiarity with inquiry-based leaning as an approach that presents high complexity. Inquiry-based activities encourage scientific knowledge learning by using scientific process skills. In this paper, through the inquiry process, students were encouraged to develop basic scientific abilities to learn science by doing science. Authors assume that inquiry permits students to acquire higher-order cognitive skills, to develop the skills related to experimental laboratory activity and to collect, organize and analyse data which allow them to build scientific explanations and conclusions. In this sense, we demonstrated that students could improve their scientific knowledge as well as their scientific skills by means of an inquiry-based laboratory activity.

According to some authors, pre-service teachers are not very familiar with inquiry-based learning, although this pedagogical approach appears in the science primary education curricula. Hence, it is necessary to introduce inquiry-based leaning activities during pre-service instruction. This investigation, which employed an inquiry-based laboratory activity, has permitted the determination of which scientific skills present more difficulties for pre-service teachers to master. Thus, it is necessary to detect the difficulties that this methodology presents to students in order to reinforce scientific instruction during their education towards a degree and to consider this methodology at all educational level.

It would be interesting to analyse in future research the effectiveness of more experiments related to other chemistry topics. The objective of these experiments would be to conclude whether inquiry-based laboratory activity increases preservice teachers' acquisition of scientific knowledge and scientific skills. This would allow us to obtain stronger results and to analyse to what extent learning is acquired through procedural experiments.

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