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An analysis of the questions proposed by elementary pre-service teachers when designing experimental activities as inquiry

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ABSTRACT
A qualitative study of an interpretative nature is presented of the topics that elementary pre-service teachers (EPTs) choose and the types of questions they propose when designing an experimental activity (ExA) as inquiry, after receiving explicit instruction about it. The participants in the study were 154 EPTs organised into small groups to design an ExA. The data were processed using a rubric designed and applied through processes of inter- and intra-rater analysis. The results showed the instruction they had received to be, in general, effective for their formulation of quality questions that can generate ExA-based inquiry. Questions dealing with relations between variables were the commonest. In their free selection of the topic, the EPTs were most likely to ask high-order questions (i.e. ones that foster inquiry) on a wide variety of physics content. There were very few questions concerning biology, and none on chemistry, the environment, health sciences, and so on. After a discussion of the results, specific actions are proposed to improve future EPT training in the formulation of questions with which to initiate school science inquiry.

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Introduction

In the field of science education, there is broad consensus that learning through inquiry is an effective teaching strategy for scientific literacy (Abd-El-Khalick et al., 2004; Minner, Levy, & Century, 2010; Rocard et al., 2007). Although its meaning is not entirely unambiguously accepted within the community of science teaching researchers and educators (Bevins & Price, 2016; Cañal, 2007), inquiry-based science learning consists essentially of (InterAcademy Partnership, 2010):

> … students progressively developing key scientific ideas through learning how to investigate and build their knowledge and understanding of the world around. They use skills employed by scientists such as raising questions, collecting data, reasoning and reviewing evidence in the light of what is already known, drawing conclusions and discussing results. (p. 19)

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Particularly interesting in this educational approach are experimental activities (ExAs). In doing these, pupils are carrying out an inquiry in direct interactions with the natural phenomena they are studying (Criado & García-Carmona, 2011). This benefits the understanding of those phenomena and the development of skills related to scientific practice (Next Generation Science Standards [NGSS], 2013), among other aspects.

To promote ExAs that engage the pupils in authentic scientific inquiry, these should always be based on questions they find stimulating and understandable (Harlen, 2013; Lederman et al., 2014), and, above all, that are within their own capacity to research (Ferrés, Marbá, & Sanmartí, 2015; García-González & Furman, 2014). One aim should be that the pupils gain awareness of these characteristics so that they acquire the ability to formulate their own questions to undertake further scientific inquiry (Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005). In this sense, Banchi and Bell (2008) consider that the development of skills to learn through inquiry is greatest when it is the pupils themselves who formulate their own questions and design appropriate procedures to seek answers to them.

For over two decades, the formulation of questions has in general been considered to be one of the essential skills for the development of scientific competency (National Research Council, 2000; Osborne, 2014; Shepardson & Pizzini, 1991). For example, Cañal (2007) put forward a list of skills needed for inquiry, and the first of them was the identification of questions or problems. Sanmartí and Márquez (2012) argued that the process of learning science requires the goals to be adequately represented, and that these can be deduced from the pupils' questions. Therefore, children's ability to ask questions is recognised as being a skill that must be promoted in science education from the basic school levels onwards (Roca, Márquez, & Sanmartí, 2013).

The current reality is, however, that inquiry-based ExAs have hardly any presence in science classes at the basic education level (Cañal, Criado, García-Carmona, & Muñoz, 2013). Among other factors, this is due to insufficient training given to the teachers (Cañal, Travé, & Pozuelos, 2011; Gillies & Nichols, 2015; Newman et al., 2004). It is therefore urgent to undertake projects that start elementary pre-service teachers (EPTs) on an approach to learning science through inquiry, especially with respect to their design of ExAs (Criado & García-Carmona, 2011; García-Carmona, Criado, & Cruz-Guzmán, 2016a, 2016b).

In view of this context, the present authors have for some time been developing a project for the formation of EPTs in inquiry-based ExA design, with especial attention given to the formulation of questions with which to introduce these activities in their classes. The purpose of this article is to present the results and conclusions of the first progress achieved in this regard.

Theoretical framework and background

Recently, Osborne (2014) argued that formulating questions for pupils that are designed to get to know their ideas about science can help them focus their efforts on building the desired learning. This is not the case with the normal use of the contents of the textbook which are full of explanations and answers. When questions are put, they tend to be of a low cognitive level, that is, of an encyclopaedia type (Martins, Torres, Moutinho, Santos, & Vasconcelos, 2014). Consequently, a basic teaching skill that teachers should have is to know how to formulate questions that make their pupils curious to learn about the phenomenon through scientific inquiry appropriate to their educational level (Harlen, 2012).

Authors such as Graesser, Ozuru, and Sullins (2010) consider that the basic premise for the formulation of a 'good question' aimed at acquiring new information is for there to be an awareness of having encountered an obstacle to understanding an issue. In this sense, it is crucial to set out well-defined learning goals for the pupils, together with ways they can reach those goals, so that they can formulate their own scientific questions, or make 'their own' those suggested by the teacher. That is to say that there is a metacognitive basis in the nature of a question that is related to human learning acquisition mechanisms (Ciardiello, 1998).

Despite the importance given in the literature to the formulation of questions in science learning, there have only been a very few studies that have explicitly analysed the learners' abilities in this respect. One example is a study by Hofstein et al. (2005) of secondary school chemistry pupils. It found that those pupils who participated in inquiry-based ExAs and read a scientific article advanced in their ability to make more and better inquiry questions than those who only participated in traditional ExAs. Roca et al. (2013) analysed the abilities of pupils aged 12–14 to formulate scientific questions in the context of the water cycle. The questions formulated by the pupils were oriented predominantly towards making causal explanations and descriptions. In no case did they formulate questions that required checking, assessing, or giving an opinion.

Consequently, the analysis of pupils' abilities to formulate questions that trigger scientific inquiry is currently a problem that science teaching research needs to address in greater depth. Furthermore, this is especially necessary into the EPT training about which preceding studies are not known.

Questions to initiate scientific inquiry: the context of elementary pre-service teacher education

The approach to inquiry-based science education is complex because it requires different skills on the teacher's part (Garritz, 2012). The scientific competency with which EPTs begin their training in teaching science is often manifestly improvable (Cortés & Gándara, 2006; García-Carmona, Cruz-Guzmán, & Criado, 2014; Newman et al., 2004) and they typically have little confidence in being able to teach science (García-Carmona & Cruz-Guzmán, 2016). Therefore, getting them to assimilate the learning-through-inquiry approach and accept it as the ideal way to teach science is undoubtedly a difficult challenge for teacher educators (Kim & Tan, 2011). The EPTs will consequently be more likely to promote inquiry-based learning in their science classes if they have acquired the corresponding skills beforehand, in their initial teacher training (García-Carmona et al., 2016b; Yakar & Baykara, 2014).

To give EPTs training in formulating good questions, Martí (2012) suggests promoting the idea that these are questions which are focused on the person and need to be formulated at the appropriate moment of the learning process. To this end, they must be contextualised, interesting, or meaningful for the pupils, well formulated in the sense of really expressing what is to be researched, and accessible in the sense that the pupils will be capable of answering them (Hodson, 2014).

In the same vein, Perales (2000) adds that to achieve this objective, the questions should move away from the usual academic statements of problems, which already include sufficient data and clues for the solution to be found, to a more genuine type of scientific problem in which the data are, at first, partially or even completely unknown. In this sense, Shodell (1995) distinguishes two types of questions: descriptive questions, which are the most usual and seek to clarify information, and critical questions, which are basic in an approach to scientific thought as they tend to interpret and apply what has been studied. Stressing the latter usually improves students' creativity and high-order thinking skills (Cuccio-Schirripa & Steiner, 2000).

Regarding the questions that initiate inquiry activity, more than three decades ago, Dillon (1984) analysed different taxonomies that had been proposed up to that date in the literature, and proposed a categorisation that can be summarised in three levels: first-order questions focused on the properties of some phenomenon and entailing knowledge of individual attributes; second-order, focused on comparative relations of concomitance (conjunction and disjunction); and third-order, focused on contingent relations between variables, such as correlation, conditionality, or biconditionality (causality). Dillon considers those of causal character to be of the highest order because the search for answers to them is what science ultimately aspires to.

Over the past decade, other authors have given details as to what questions should be like to be used to initiate proposals for learning science through inquiry. For example, Hofstein et al. (2005) proposed exploratory ('What is … ?'), descriptive ('What happened to the temperature?'), and low-order causal questions ('Why … ?'). They consider to be of high order those questions in which at least one independent variable appears and which ask how changes in this or these affect the dependent variable(s). Included in this type are predictive ('What if … ?') or relationship ('How does … influence … in … ?') questions. Typically, these questions can only be answered with further inquiry and knowledge based on scientific models of a certain degree of abstraction.

Lund and Lund (2010) establish a simple classification of quantitative questions: (a) descriptive ('What is … ?' or 'How often are … ?', etc.), which seek to quantify the answers in values of one or more variables, (b) comparative (descriptive for each group), which seek to compare two or more groups on the results of some variable ('differentiate' and 'compare'), and (c) relative, which seek relationships of causality, associations, trends, and/or interactions between two or more variables in one or more groups.

Harlen (2013) also posits an interesting taxonomy of questions for science learning through inquiry. With regard to the format, she distinguishes between open (e.g. 'What did you observe with … ?') and closed (e.g. 'Which of them took less time in … ?') questions, and between questions focused on the object of study (e.g. 'Why did this one take longer than … ?') and those focused on the person (e.g. 'Why do you think that this took longer than … ?'). With regard to the content, she discusses the formulation of questions that can encourage the pupils to (i) explain their ideas about the phenomenon being studied (e.g. 'What do you think will happen if … ?'), (ii) develop procedural skills for inquiry (e.g. 'How can you measure … ?'), and (iii) collaborate, share their ideas, reflect, and evaluate their learning (e.g. 'What have you learnt after the experience that you did not know previously?').

Roca et al. (2013) propose a classification with which to catalogue the researchable questions composed by secondary school students when they are given inquiry tasks. It consists of seven categories for the analysis of a question's objective: description, causal explanation, check, generalisation or definition, prediction, management, and assessment or opinion.

Sanmartí and Márquez (2012) argue that, to promote an inquiry ExA, the question should relate various relevant variables and be as specific as possible. In addition, they emphasise that formulating a good question requires applying knowledge about variables (distinguishing the parameters that vary from those that are controlled in an experiment) and about how to design processes to collect data. It also requires possessing theoretical knowledge (every question is based on a part that is known in order to look for new information).

Merino and Herrero (2007), however, call for more examples of open scientific inquiry proposals in teacher training since teachers decide not to innovate in the laboratory because of the shortage of realistic proposals that are solid alternatives to the traditional planned 'kitchen recipe' laboratory practicals (McLaughlin & MacFadden, 2014). In this line, García-Carmona et al. (2016b) suggest that there is a need to give EPTs instruction in planning ExAs, starting by providing them with an initial question to serve as an introduction from which they can progress to designing ExAs based on the formulation of their own questions. The following typology of ExAs is taken as a basis (Cañal, García-Carmona, & Cruz-Guzmán, 2016): (i) observation of a phenomenon ('What happens when … ?', 'How does … occur … ?', etc.), (ii) determining cause–effect relationships ('What do you think is the cause of … ?','How do you think … influences … ?', etc.), and (iii) designing a method or instrument to carry out checks or observations ('How would you check … ?', 'How would you measure … ?', etc.).

Research questions

Based on the above, we set out to conduct a qualitative study of a descriptive and interpretative type, with the purpose of finding answers to the following research questions:

(1) What kind of questions do EPTs formulate when they are designing an ExA as inquiry?
(2) What school science content or topics do EPTs choose in formulating their questions for inquiry in their design of an ExA?

Methods

Participants and context

The study was carried out during the 2015–16 academic year with 154 EPTs (age range: 21–28 years; average: 23.8 years) of which only two were men. They were enrolled in a subject of science teaching (5 credits) in the Undergraduate Degree in Elementary Education of the University of Seville. The participants formed two class-groups that were selected because of their accessibility at the time of the study (they received instruction from the first author of this article). Therefore, it was a sample of participants chosen for convenience.

The intention with the training in science teaching that these PETs received was for them to achieve an initial development of basic teaching competencies regarding: the purposes of basic scientific education; knowledge of children's conceptions and their difficulties in learning science; the school science curriculum; the selection and organisation of the content; strategies for teaching and learning science; and evaluation. The design and experimentation with ExAs as inquiry form part of the penultimate of these blocks.

Regarding the participants' profile, the majority of them had a low preference for science, as is common among PETs of this university degree in Spain (Bonil & Márquez, 2011; García-Carmona & Cruz-Guzmán, 2016; García-Carmona, Cruz-Guzmán, et al., 2014). More than half of the participants had accessed the undergraduate degree through an academic route unrelated to science, mainly from the social sciences or humanities baccalaureate (65%), or from higher vocational training related to education (17%). And many of them had last studied science when they were 14–16 years old. Consequently, an important part of the EPTs began their training as teachers with an insufficient scientific background.

In the first year of the university degree, the EPTs studied several subjects on basic fundamentals of science (15 credits in total). However, although their programmes include carrying out ExA, these activities are usually implemented with a traditional approach as described above. Therefore, the participants did not have any experience with the inquiry-based science learning approach before studying the subject of science teaching.

The process of the teaching intervention

In planning the explicit instruction on the formulation of questions with which to initiate an ExA as inquiry that will be described below, we took into account the experience we had gained in the subject of science teaching from the academic course previous to that of the present study. In this academic course, the EPTs were organised into the small work groups (31 groups in total), and each one was required to design one ExA freely. To make this task, they had not received any instruction regarding the formulation of questions to initiate an ExA as inquiry. Twenty-nine groups of the total designed ExAs that started with a question. Hence, we focused on these 29 questions to detect training needs of EPTs in relation to the formulation of inquiry question. This preliminary analysis, which was made from an exploratory approach, provided the following information:

- Approximately one-third of the questions posed by the EPTs were unclear, or not well formulated in the sense that they are not directly related to the ExA proposed later.
- Among the clear and coherent questions, there stood out those that proposed problems which were not specific and/or are difficult to approach by means of any scientific inquiry. Examples of these were questions demanding a causal explanation with formulations such as 'Why does the Earth revolve around the sun?' or 'Why does it rain?'.
- Most questions did not relate variables with each other. They usually sought a conceptual definition or a general description. For example, 'How does pollution affect birds?'; 'What are the agents that pollute the atmosphere?'
- No questions were formulated that required the quantification of a variable or the comparison of results.
- About one-third of the questions analysed were of high order, that is, they require further inquiry to be answered. However they are all of a predictive character – 'What will happen when we add oil to water?'; 'Will it (what is going to be made) be

the same soap that our parents buy?'. None of them required checks or the establishment of causal relationships, associations, trends, or interactions between two or more variables.

Bearing in mind both the above preliminary information and the theoretical framework outlined previously, we planned a specific teaching intervention to provide our students with training in formulating researchable questions. The intervention was designed around the question: 'To initiate a school-level inquiry, what question shall we propose?'.[1] It was developed as follows:

First session (2 hours):

(1) The general characteristics that questions aimed at promoting classroom inquiry were presented (it lasted roughly one hour). These were in line with what was described above in the theoretical framework, with special emphasis on the fact that they must be concrete, understandable, and operative for analysis by experimentation. In addition, it was emphasised that the questions had to be focused on specific learning objectives, and in their formulation, these should be to relate variables.

(2) Clarifications were made of the concept of variable, types of variables, relationships between variables, and control of variables. To reinforce this, some examples of questions considered as adequate to initiate an ExA as inquiry were presented. These examples of questions were referred to the following phenomena: influence of the slope of the terrain on soil loss, relationship between muscle mass and physical exercise, and influence of the eluent on the chromatic separations.

Second session (2 hours):

(3) The foregoing was reinforced with the aid of the example used by Sanmartí and Márquez (2012) regarding the formulation and reformulation of questions to investigate the influence of the acidity of water on seed germination. This context requires that the question formulated generates scientific inquiry in the classroom. Therefore, an explanatory causal question like 'Why does the sun exist?', although of a high scientific complexity, is not considered appropriate for this purpose.

(4) The EPTs were organised into group of 3–4 members (35 groups in total), and they were asked to formulate one inquiry question about a freely selected topic in the school science curriculum. When it was observed that some groups had difficulties for posing quality questions, they were encouraged to think about how they would conduct the experiment to answer their questions posed, in order to return to the identification of suitable questions.

Third session (2 hours)

(5) The questions formulated by groups followed a process of peer assessment in class. Every group assessed the quality of the inquiry question posed by another group and made it improvement suggestions, according to the criteria that had been dealt with so far. A key in this process is that the other groups put themselves in the place of the pupils who would be carrying out the inquiry.

(6) When the questions then returned to their authors, these might then reformulate them or not according to the advice they had received. It would be the second and final proposal, which is analysed in this study. Consequently, it was formulated 35 questions in

total (one for each group), although 3 of them were dismissed because they were not understandable, as it can be seen below.

(7) Group reflection, dialogue, and exchange of opinions with the teacher. They said that they had discovered how difficult it is to formulate a high-quality question to initiate an inquiry activity with their future pupils.

Instrument of analysis

The data resource was the groups' reports in which they registered their proposals of ExA including the question with which to initiate the inquiry. To analyse the questions formulated by groups, an evaluation rubric was constructed. In its design, we started from the inquiry ExA typology proposed by Cañal et al. (2016) as described in the theoretical framework. Following the results of the preliminary analysis described above, the rubric was enriched with contributions taken from Roca et al. (2013), adding whether the question seeks to make generalisations or predictions, and the consideration of Ferrés et al. (2015) as to whether the questions formulated for inquiry are clear and consistent. The suggestions of Sanmartí and Márquez (2012) regarding the presence or absence of relationships between variables in the questions were also added. The result was a complete first rubric with which to analyse the information that was to be collected in this study.

However, when beginning to analyse the information, it became clear that there was a need to further complete the rubric with the contributions of Hofstein et al. (2005) which differentiate between high- and low-order questions according to their potential to trigger scientific inquiry via experimentation. In a framework of science learning through ExA, this taxonomy is more interesting or useful than others such as, for example, that of Dillon (1984) which merely classifies the questions exclusively using criteria of scientific complexity.

Consequently, all the questions that do not trigger some scientific inquiry through ExA were considered to be of low order. Within these are included:

(1) Questions seeking a generalisation or conceptual definition (e.g. 'What is … ?') because they can be answered with a simple search for information.
(2) Questions that lead to a simple description of a phenomenon, and whose answers can be composed without any scientific basis. For example, to the question: 'What happens if I put a marble in a bowl of water?', an answer could be: 'It sinks'. Questions that seek to 'differentiate' and/or 'compare' variables in two or more different groups, contexts, or situations, but do not demand any experimental inquiry. For example: 'Which planet is farther from Earth, Mars or Jupiter?'. However, questions of observation or description would not be considered to be of low order if they involved making any type of representation or model. For example, 'What is the sun's apparent movement during the day?' is a question that involves tracking the shadow projected by a stake in the ground throughout the day. This would enable the pupils to make their own representations through drawings of the apparent movement of the sun.
(3) Causal explanation questions of the type 'Why … ?', since they do not promote scientific inquiry. For example: 'Why does the Earth spin?' or 'Why do we heat an egg?'.

We also took into account the contribution of Lund and Lund (2010) who, in addition to a descriptive category, classified questions into comparative and those that establish causal relationships, associations, trends, and/or interactions between two or more variables. This improved the classification of questions such as: 'Would water and oil mix if one of them were at a higher temperature?', which was considered to be a high-order question because it seeks to establish trends between two variables (temperature and miscibility). Another example is the question 'What happens to ice when the weather is hot?', which, although it might have a predictive profile, was classified as low order because it does not promote any inquiry in which variables are handled. In addition, it can lead to simple and unscientific responses such as 'ice melts'. Thus, it was classified as being a descriptive question.

After all these additions to the rubric, all the questions were re-classified. The rubric was considered to be complete when all of the questions had a clear categorisation for the researchers. The final rubric is that presented in Table 1, in which contributions from the literature reviewed to build our own taxonomy for analysing the questions are cited.

Process of using the rubric to classify the EPTs' questions

In order to classify the questions presented by the participating EPT into the categories of the above rubric, we used a method of analysis that combined intra- and inter-rater processes (Padilla, 2002). Thus, one of the researchers made a preliminary classification of the responses, which was returned to and modified several times until reaching a first complete classification. This process took several months. Then, this classification was subjected to scrutiny by the other two researchers to determine coincidences and discrepancies. At first, the three researchers reached agreement on the over 90% of cases. The few cases of discrepancies (the remaining 10%) mainly referred to questions of descriptive profile bearing in mind what is explained above about this type of questions. The researchers discussed about these cases of discrepancies until reaching an agreement by a majority (i.e. 2 vs. 1, or total agreement) on the classification that would be most appropriate. Consequently, at the end of this process, the three researchers reached a total agreement on the classification of all questions.

Furthermore, in order to contribute to the objectivity of the analysis, we had recourse to the use of low-inference descriptors (Latorre, 2003). In particular, we included textual examples of the EPTs' questions in the results section so as to provide evidence of the categorisations made.

Results and discussion

Quality and types of the questions formulated

Table 2 lists the types and the quality of the questions formulated by the 35 EPT groups after they had received the teaching instruction described above. With regard to the quality of the questions, it can be seen that the vast majority (32 of 35 questions) were clear and coherent, posing concrete problems which were approachable in the classroom, and which related variables. The few questions considered unclear from being incomplete, too open, or fuzzy were of the following type:

> How do different types of fruit grow?

Table 1. Rubric used in the analysis of the questions formulated by the EPTs in their designs of inquiry ExAs.

	Characteristics of the questions	Freq. %
Quality of question	The question is formulated clearly and coherently (Ferrés et al., 2015).	
	The question identifies concrete and approachable problems for inquiry (Hofstein et al., 2005).	
	The question relates variables (Sanmartí & Márquez, 2012).	
Types of question	*Low order:*	
	(1) The question seeks a generalisation or conceptual definition (Roca et al., 2013) (e.g. 'What is a planet?'; 'How are volcanoes?').	
	(2) The question promotes a description (Roca et al., 2013) or exploration (Cañal et al., 2016), but no scientific inquiry is necessary to answer it (e.g. 'What will happen if I throw a ball upward?'; 'How is the inside of an electric toy?').	
	(3) The question is limited to 'differentiating' and/or 'comparing' variables in two or more different groups, contexts, or situations, with a more descriptive than investigative goal (Lund & Lund, 2010) (e.g. 'Which is faster, a lion or a tiger?'; 'Which is bigger, Earth or Saturn?'; 'What are the differences and similarities between tree and plant?').	
	(4) The question has a causal explanation, but is difficult to investigate scientifically; that is, 'Why … ?' (Hofstein et al., 2005) (e.g. 'Why is the sky blue?'; 'Why is seawater salty?').	
	High order for a scientific inquiry:	
	(5) The question requires a check to be made (Cañal et al., 2016) (e.g. 'How would you check whether or not wood is a good conductor of electricity?'; 'How would you test the importance of light for plants?').	
	(6) The question is of a predictive type (Roca et al., 2013) (e.g. 'What would happen to an inflated balloon if we introduce it in a deep freezer during several hours?'; 'What would occur in each case if we add (a) sugar, (b) salt and (c) flour, to a container with ice?').	
	(7) The question is of a relationship type: causal, association, trend, and/or interaction between two or more variables (Cañal et al., 2016; Hofstein et al., 2005; Lund & Lund, 2010) (e.g. 'How does changes in water temperature influence on solubility of cocoa into it?'; 'How will the size of an object's shadow change if we modify the position of light source?').	

How does the wind influence the classroom windows fogging up?

Consequently, it appears that the instruction that we had designed had been effective for the EPTs to be able to formulate questions of a predominantly scientific nature, regardless of the order (high or low) of their classification. This is also a notable result when compared with the study of Ferrés et al. (2015) in which it was observed that a considerable part of secondary school science pupils enrolled in an inquiry-based learning project had difficulty in identifying the research problem, and formulated ambiguous and generic inquiry questions.

It should also be noted that most of the questions (more than 88%) posed problems that were approachable and that related variables. Examples:

How does water's salinity affect the buoyancy of a body?

How does the lack of light affect the growth of a plant?

Table 2. Results of the analysis of the questions the EPTs formulated.

	Characteristics of the questions	Freq. % ($N = 35$)
Quality of question	Clear and coherent[a]	91.4
	Concrete and approachable problems	93.8
	Relating variables	88.6
Types of question	*Low order:*	
	(1) Conceptual	6.3
	(2) Exploratory/descriptive	9.4
	(3) Comparative	3.1
	(4) Causal explanation	0
	High order:	
	(5) Checking	15.6
	(6) Predictive	18.8
	(7) Relationships	46.9

Note: [a]The questions classified are just those formulated coherently because of the impossibility of classifying the unclear questions. The resulting maximum limit, 100%, would therefore be 32.

> Which grows faster, a plant in the sun or a plant in the shade?

There were fewer questions referring to the relationship between variables. Examples:

> How is the rainbow formed?
>
> What happens when we mix different liquids?
>
> How does the rain form?

According to the literature (Aydoğdu, 2015; Schwichow, Zimmerman, Croker, & Härtig, 2016), perhaps the questions that require a control of variables are those that include the aspects of scientific practice with which science pupils and EPTs usually have the greatest difficulties.

With respect to the types of questions, and particularly among those of low order, there stand out the low number of conceptual questions (formulated by only 6.3% of the groups) and the absence of causal explanation questions. This can be regarded as a success of the planned instruction. Examples:

> Do carnivorous plants get nutrition through the roots?
>
> How does the rain form?

Perhaps the insistence of the process of instruction on getting the EPTs to formulate questions that relate variables diverted their attention away from formulating the types of questions mentioned above. This result contrasts with those obtained by Roca et al. (2013) with pupils aged 14–16, who mostly proposed causal relationship questions and, to a somewhat lesser extent, descriptive questions.

They also formulated, although sparsely, comparative (3.1%) and descriptive questions (9.4%). Although these are of low order, they can be interesting to foster scientific inquiry at basic educational levels (García-Carmona, Criado, & Cañal, 2014; Martí, 2012). Therefore, one appreciates that there is an attempt, although weak, to propose inquiries of greater quality that are approachable at school.

> What happens to the drop of ink as it passes through the oil? What happens to the drop of ink as it passes through the water?

> Does water have the same colour when in a transparent container as in a coloured one?

The most frequent high-order questions were those that establish different types of relationships, trends, or interactions between variables. Thus, 46.9% of the groups formulated questions which sought to determine the effect of one or more independent variables on a dependent variable.

> How does the lack of light affect the growth of a plant?

> How do temperature changes affect the natural state of water?

> What determines the shape of our shadow?

> Does an object's buoyancy in water depend on its density?

As also as in the study of Hofstein et al. (2005), it stands out that some explicit training on the formulation of questions for inquiry-based science teaching favours the EPTs' formulation of more and better researchable scientific questions. This is especially notable given that, as has been mentioned above, when they do not receive any training in this regard, questions that relate variables receive practically no consideration in their ExA designs.

In addition, there was a lower proportion of high-order questions of a predictive nature (18.8%). It seems that these are not very intuitive questions for the EPTs. Perhaps this was because predictive-type questions require the formulation of a hypothesis which has to be based on scientific knowledge, and students often find it difficult to relate this to what they observe in an experiment (Abrahams & Millar, 2008; Peker & Wallace, 2011). Predictive questions such as the following were formulated:

> Which will reach the ground first, a lead ball or a cork ball?

> What colour do we get if we mix the primary colours? (Red and yellow, yellow and blue, blue and red, or all of them).

Checking questions were also proposed, albeit in smaller proportions than the foregoing (15.6% of the groups). Examples:

> How many drops of yellow should be added to the blue to get green?

> Does heat affect an ice cream in the same way as a banana?

We therefore obtained similar results to those of Roca et al. (2013) who found that only a small portion of the questions posed by secondary school pupils were of a predictive or checking type. Regarding the former, their relative scarcity is perhaps due to the EPTs' not having assimilated the predictive power of science as one of its characteristic features

(Bell, 2009), essentially because it is something that is rarely discussed in science classes (Duschl, Schweingruber, & Shouse, 2007).

In relation to the scant attention paid to questions of a checking type in the EPTs' ExA designs, this could be explained by the difficulties that students generally have in giving scientific explanations based on evidence (García-Rodeja & Sesto, 2016), but, above all, by their feeling the need to find such evidence to enrich their answers (McNeill & Krajcik, 2008).

The content or topics of school science chosen to formulate the questions in the ExA design

In addition to the quality and type of questions posed by the EPTs, the content or topics of the school science curriculum chosen for those questions were analysed (Table 3). We observed a predominance of questions related to physics (81%). Perhaps this is because these are phenomena considered by the EPTs to facilitate experimentation and the control of variables. This result contrasts, however, with the animosity that primary teacher education students usually show to this area of science relative to others such as biology (Mellado et al., 2014). Second, and at a considerable distance (19%), the EPTs proposed questions related to biology.

It is worth noting that, in relation to biological phenomena, the EPTs managed to formulate high-order questions, especially questions demanding classroom inquiry into the functions of animals' food and their relationships, or the requirements for the process of photosynthesis. Perhaps this achievement is because EPTs often feel safer or that they have a better preparation in the content of biology than in that of physics. They generally have a more limited knowledge of the latter when they start their teacher training (Annetta & Dotger, 2006; García-Carmona et al., 2016b; Menon, 2015).

Table 3. Characteristics of the questions formulated according to which domain of school science was selected.

Curricular content	Topic	The content the question is asking about	LO				HO		
			Cp	Ds	Cmp	ExC	Cmb	Prd	DR
Physics	Fluid properties	Surface tension		1					
		Density		1				1	1
	Forces	Equilibrium of forces: P and E (Buoyancy)						1	4
		Gravitational acceleration						1	
		Others (wind)							1
	Changes in states of matter	Melting, solidification, condensation, and evaporation	1	1			2	2	3
	Optics	Colours			1		2	1	
		Propagation of light (shadows, rainbow)							1
	Solutions	Influence of temperature							1
Biology	Animals	Functions in animals (food and relationships)							2
	Botany	Requirements for photosynthesis					1		2
		Nutrition in carnivorous plants	1						

LO: Low order; HO: High order; Cp: Conceptual; Ds: Descriptive; Cmp: Comparative; ExC: Causal explanation; Cmb: Checking; Prd: Predictive; DR: Relationships.

Of the content related to physics, some of it was only used in conceptual or descriptive questions, therefore of low order. The following question to investigate surface tension is an example:

> Having a glass with oil and water, what happens to a drop of ink when it passes through the oil? And when it passes through the water?

Other physics content was referred to with high-order questions. Examples were the buoyancy of bodies, gravitational acceleration, the force of the wind, propagation of light, the influence of temperature on solutions, and the main changes of state. All of this was possibly because they are phenomena that, in principle, lend themselves to experimental manipulation in the school classroom. Examples:

> How does water's salinity affect a body's buoyancy?
>
> Does an object's buoyancy in water depend on its density?
>
> Which reaches the ground first, a lead ball or a cork ball?
>
> Does the strength of the wind have an influence on the fall of leaves from the trees?
>
> What determines the shape of our shadow?
>
> Does the milk's temperature affect the complete solution of chocolate powder?
>
> How do temperature changes affect the natural state of water?

We found that, except for those referring to physics content, descriptive and comparative questions were scarce or non-existent. This reflects a deficiency that needs to be addressed in the training of the EPTs since, in the early educational levels, these types of question are essential to carry out inquiries aimed at explaining what an object, material, or organism is like (García-Carmona, Criado, et al., 2014; Martí, 2012).

Moreover, none of the questions formulated dealt with aspects of chemistry, earth science, or life sciences, even though the EPTs were free to choose the subject for their proposals. It should be noted that they were not influenced with the previous instruction they had received, since the examples that had been used covered different scientific areas. For example, one proposal had been the identification of the independent and dependent variables in the relationship between the consumption of calcium and bone density, and an inquiry ExA had been presented about the effect of acidic water used to irrigate plants.

With regard to this last part of the study, it has to be noted that the topics selected by the EPTs for their ExAs, and therefore the inquiry questions that they formulated, were coherent with the various types of content of a primary education science curriculum. Therefore, it is not possible to compare the present results with those of other studies such as Hofstein et al. (2005), Roca et al. (2013), and Ferrés et al. (2015) since these addressed classroom scientific inquiry into specific topics of science so as to analyse their educational effectiveness.

Conclusions, limitations, and implications for teacher education

One of the basic competencies for teaching through inquiry is to know how to formulate scientific questions that are appropriate for the pupils and which they themselves can check. Up to now, research on the formulation of inquiry questions had essentially been carried out for pre-university educational stages, and within the separate subjects of secondary education science. It was therefore reasonable to extend this type of analysis to other contexts such as initial teacher education, and in particular to that of EPTs in order to help them develop skills that they will use to foster inquiry-based science learning from the early stages of education onwards (Harlen, 2014).

This study has analysed the quality and the type of the questions formulated by a sample of EPTs after they had received explicit instruction on the topic. The main conclusions that can be drawn are that:

- Explicit instruction on the formulation of questions to initiate school science inquiry was shown to be effective overall. A major part of the EPTs composed quality questions that established relationships between variables. Also, although to a lesser extent, they posed questions which demanded a check or a prediction, and they did not pose any questions of a causal explanatory type which would not promote scientific inquiry. There were few descriptive and comparative questions. Certainly, all phases of the teaching intervention conducted in class were fundamental for achieving these results. But if we had to highlight one of such phases, this would be the process of peer assessment whereby each group assessed the quality of the inquiry question posed by another group in order to make its suggestions for improvement. This phase was decisive for EPTs to reconsider their initial questions and to improve them according to the established criteria for asking a good question to initiate an ExA as inquiry.
- With respect to the school science content selected for the inquiry questions, physics content was the most frequent in the high-order questions. There were only a few questions related to biology content, although most of these were of high order. Content relating to chemistry, environmental sciences, health sciences, and so on was not considered. One possible reason for this may have been that, although they are themes that may be of interest to the EPTs, they did not offer any clear possibilities for interesting inquiry questions that could be approached through primary school classroom ExAs, unlike what was observed with the physics content.
- Regarding the rubric employed in the study (Table 1), it has been shown to have a good validity to analyse the questions formulated by the EPTs. The novel taxonomy exposed in the rubric (i.e. *quality of question* – clear and coherent, concrete and approachable problem, and relating variables – ; and *type of question* – low order [conceptual, exploratory/descriptive, comparative and causal explanation] and high order [checking, predictive and relationships] –) has been built on the basis of previous contributions to this research line, although it has allowed us to categorise the questions in a more broad and refined way than those other taxonomies. The categorisation of questions that was obtained in this study appears to be useful in order to guide plans for teacher training in the design of ExA as inquiry.

In view of the results, there is a need to further improve the training of EPTs in the formulation of scientific questions that are researchable through ExAs. The following are some proposals to this end:

- Examples could be presented of well-formulated and of poorly formulated questions for scientific inquiry on specific problems, the aim being to generate discussion among the EPTs, encouraging cognitive conflict, if necessary.
- It would be interesting to carry out a process of peer evaluation, applying criteria for the quality of inquiry questions, so that the EPTs get to analyse a variety of examples and cases proposed by their peers. Possibly in this way, when they have to assume the role of peer assessor, they would better understand how to avoid their own potential mistakes.
- The difficulty the EPTs had in proposing inquiry activities related to topics of biology, chemistry, or life sciences should condition the plans of teacher education courses in this regard. Examples of researchable questions about these areas of the school science curriculum could be put forward so that the EPTs familiarise themselves with them and design corresponding ExAs.
- When possible, the examples of inquiry questions should be of high order, although without ruling out some of low order, such as descriptive and comparative questions which, in the early levels of education, may be essential to subsequently be able to undertake ExAs of greater scientific scope such as those concerning the relationship between variables.
- Following the suggestion of Hofstein et al. (2005), it might also be interesting to start with a pre-inquiry phase, in which the EPTs are set a closed problem together with very specific instructions for its development. And then move on to the inquiry phase, beginning with the formulation of questions related to the phenomenon that they had been observing, for example, 'What questions do you have after the experiment?', 'Choose one of them as an inquiry question.'

Additionally, it is necessary to say that, although the study was performed with the rigour required in a qualitative research of its characteristics, this had limitations in order to obtain robust conclusions regarding the research questions addressed. Firstly, the sample of EPT involved in the study was chosen for convenience. Therefore, the conclusions cannot be generalisable to other contexts of EPT training.

Secondly, the limited scope of the results obtained requires further analysis with regard to certain aspects using different data sources. Thus, it will be necessary to analyse not only the type of questions formulated by EPTs when designing ExA as inquiry, but also the reasons they take to formulate these. It would help to identify the EPTs' difficulties or constrains to formulate the different types of inquiry questions (i.e. conceptual, comparative, predictive, relationships …).

Also, the EPTs should be asked to explain why they select certain topics and not others in designing their ExA as inquiry, and why they proposed certain types of questions and not others. This information would help to understand, for example, why the EPTs did not pose inquiry questions related to chemistry or geology; or why the most abundant questions were those related to physics, despite being one of science domains on which the EPTs show more understanding difficulties.

In addition, it will be interesting to require the EPTs that design one ExA as inquiry for each domain of school science (i.e. physics, chemistry, biology, geology …). It will allow us to identify possible relationships of dependence between the selected topic or domain and the type of inquiry question formulated to initiate the ExAs.

Consequenty, the conclusions of this study should be considered as tentative, although useful, in order to advance in the design of effective plans to train EPT in the formulation of questions with which to initiate school science inquiry. In addition, given that this research issue in the context of the EPT training had not been addressed until now, the present study can to serve as an interesting referent for undertaking new studies about it.

Finally, the authors of this study are aware of the difficulty of putting all of the above into practice in the training of EPTs. The principal reasons are their insufficient level of scientific competency (García-Carmona, Cruz-Guzmán, et al., 2014; Yoon, Joung, & Kim, 2012), the lack of self-confidence with which usually they approach their science teaching training (Appleton, 2008; García-Carmona & Cruz-Guzmán, 2016), and the complexity of training prospective teachers in the inquiry-based approach to teaching and learning (Crawford, 2007; Newman et al., 2004). But no effort should be spared if what is wanted is for EPTs to manage to learn how to teach science with approaches based on inquiry. As Zhang (2016) notes, although the challenge is difficult, it is worth attempting.

Note

1. Because the purpose was to develop scientific inquiry via experimentation (i.e. through experimental activities or experiments), we did not distinguish between inquiry questions and experiment questions.

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