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Estimating the Competence of Preservice Primary Teachers to Use Inquiry and Their Willingness to Apply It in the Classroom

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Abstract

Inquiry as a strategy for science teaching has become widespread in the classroom and has various applications. But whether teachers are sufficiently trained to carry it out in pre-university classrooms would need to be determined. The objective of this study is to determine the inquiry knowledge of preservice primary teachers and their ability to use it before and after experiencing it for themselves on their degree programmes. The study was carried out over three academic years (2018–2021) with students from the Experimental Sciences course on a Bachelor's Degree in Primary Education at a teacher training centre in Spain. A total of 579 students participated and the study was divided into two phases. In the first phase, students answered a questionnaire about a hypothetical situation in which they had to apply inquiry, and in the second phase, they worked in groups on problematic situations in which they had to solve them or propose solutions through inquiry. The results indicate that students have a general ability to follow inquiry procedures, which improves after instruction, although they still need training in didactic content on inquiry methodology. Students were also asked about their willingness to apply inquiry in their future work, as well as the difficulties they consider they will encounter. A number of recommendations are made to address the shortcomings and to overcome the difficulties expressed by students in applying inquiry in their future teaching work.

Keywords Assessment · Inquiry · Preservice teachers · Primary education · Scientific skills

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Introduction

Alternative methodologies to the traditional transmissive methods used in science teaching became very relevant in the twentieth and twenty-first centuries. One of these strategies is inquiry, but it should be asked whether this term is considered equally in all settings (Lederman et al., 2014). Since the National Research Council (NRC, 1996) considers inquiry to be the way in which scientists observe and study natural phenomena and provide explanations based on their work, it can be applied to different contexts, leaving the exact definition of the term unclear. Garritz (2010) points out the difficulty of specifying the concept due to its broad meaning and Buck et al. (2008) express this difficulty by highlighting that the meaning of the term depends on the person using it and to whom it is applied, an example of this being the comparative study by Lee et al. (2020). In any case, the common feature of all meanings is the use of serial procedures based on the steps on which the scientific method is based (Garritz, 2010), or activities that promote it which are closely related to the competences of scientific work (Crawford, 2014; French & Russell, 2002; Khan, 2007; NRC, 2000; Pedaste et al., 2015). A good example is the activities proposed from the Next Generation Science Standards (NGSS, 2022).

The diversity of meanings of the concept implies that the types of inquiry are considered differently depending on the authors addressing the issue. Martin-Hansen (2002) and Bell et al. (2005), among others, propose different types of inquiry depending on the role of the teacher: confirmatory inquiry, structured, guided, open-ended, coupled, etc. Barrow (2006) considers three meanings of inquiry that can be carried out in the classroom: inquiry as science content, inquiry as what the learner needs to understand about scientists' methods, and inquiry (IBSE) as a didactic model. Within the framework of the next-generation science standards, inquiry is considered for the integration of the three dimensions of science education (3D learning), specifically in the "Practice" dimension (NGSS, 2013). Romero-Ariza (2017) refers to *quality inquiry* as the need for the type of questions used to have a strong scientific orientation that encourages students to build models and theories that support the evidence, in an environment of reflection and reasoning without neglecting evaluation as a means to verify the conclusions and results (Osborne, 2014).

In any case, since "inquiry" encompasses a multitude of actions in the classroom that hinder a consensus around the term (Abd-El-Khlick et al., 2004; Anderson, 2002), it would be appropriate to adopt an encompassing and synthetic term. Therefore, in this study, and without going into detail about what "inquiry" is, we will consider the concept of inquiry in accordance with the Barrow (2006) in order to use inquiry in the classroom, i.e., as a teaching strategy for students to learn and develop problem-solving skills using scientific procedures, thereby emulating the work of scientists. Also, the meaning considered in this paper is parallel to the meaning considered in the dimension 1 (practice) within the Next Generation Science Standards (NGSS, 2013).

Furthermore, there seems to be no consensus among the scientific community on the success of inquiry as a teaching methodology, and there are also numerous papers in the literature arguing one way or the other. It is often difficult to extrapolate the results due to the different contexts in which the studies have been carried out, or even the relatively limited production of studies on inquiry in some educational stages (Morales et al., 2018), limiting the general diagnosis. Mayer (2004) and Kirschner et al. (2006) strongly criticised inquiry-based and discovery-based learning. In contrast, and without going into detail, the review of studies, meta-analyses and experiences by Furtak et al. (2012), Lazonder and Harmsen (2016), and Wang (2020) show that some improvement in learning is observed, but that it depends on how inquiry has been applied, the objectives set and the role of the teacher.

In primary education, the competence level of teachers also plays a key role in bringing inquiry into classrooms. The lack of this level of competence could lead to a lack of use of *quality inquiry* as a teaching strategy by practising teachers. This inadequacy could be attributed to their lack of knowledge about teaching research (Capps & Crawford, 2013) or to their low level of scientific knowledge (Murphy et al., 2007). However, it is the same in-service teachers who are demanding initial training to address these gaps in order to be able to effectively transfer inquiry and research-based methodologies to the classroom (Martínez-Chico et al., 2013). Therefore, it is necessary to focus on initial teacher education where problems and gaps in the application of inquiry are also observed (Lee et al., 2020; Toma et al., 2017).

Taking into account all of the above, the purpose of this study is to answer the following questions:

- What level of knowledge of inquiry do preservice primary teachers have prior to studying inquiry on their degree programme?
- Are they willing to apply a methodology based on inquiry with their future students?
- What difficulties do they think they will encounter if they try to apply inquiry in a classroom situation?
- Has the competence to apply inquiry improved after receiving instruction or training on it?

Methodology

Study Overview

The study is a semi-quantitative mixed quasi-experimental study carried out over 3 academic years with an empirical-analytical basis (Hernández & Fernández, 2000). It was carried out over two phases. A first phase of a prospective nature in which information was collected on the prior knowledge of preservice primary teachers related to inquiry before receiving instruction on inquiry. A second phase assessed the inquiry competence acquired by the preservice primary teachers after receiving instruction on inquiry in the classroom and carrying out inquiry-based work. For this purpose, the preservice primary teachers were organised into 70 groups of between four and six members to produce a work report in which they were given problematic situations applicable in a primary education classroom to which they had to respond by means of inquiry procedures. This type of work has a similar structure and methodological and conceptual basis to what Rosa (2019) called "inquiry activities or practical research work". They are based on Caamaño's (2012) consideration for this type of activities because they allow students to act in a similar way to how scientists work to solve problems, by acquiring knowledge about science procedures through inquiry in the classroom.

Instruments

In the first phase, a survey was conducted using a questionnaire that is presented in Appendix 1 and was modified from the one used by Greca et al. (2017) with nine questions (a, b, c, d, e, f, g, h and i) with open answers about a problematic situation (defined as "an everyday circumstance in any person's environment in which questions arise that require answers based on scientific evidence or reasoning"). Some examples of problematic situations are listed in Appendix 2. A question "k" was added to the questionnaire, consisting of a first part on the trainee teachers' intention to apply inquiry in their professional future and a second part on the difficulties they think they will encounter when applying inquiry in the classroom.

In the second phase, the report made by the different groups was evaluated using a rubric structured in domains that is presented in Appendix 3 and was adapted from Rosa's (2019) modification of the NPTAI instrument by Ferrés et al. (2015). Based on the total score of each task or inquiry-based work, the groups were classified into categories on levels of inquiry competence using Rosa's (2019) NCI instrument defining the inquiring character of the groups ("inquirers", "partial inquirers", "incipient inquirers", "non-inquirers" and "unscientific").

Application and Reliability of Instruments

First Phase Instrument

For the evaluation of the responses to the questionnaire in the first phase, these were categorised following techniques for analysing content (Schreier, 2012) according to criteria based on the level of scientific thinking involved in the responses and their scientific value (Crujeiras & Jiménez, 2015; Ferrés-Gurt, 2017; Ferrés et al., 2015; Sardá & Sanmartí, 2000) as well as being scientifically coherent responses and reflecting scientific competences (Bybee, 2004). A reference answer to the questions was sought by consensus among three people linked to the area of Didactics of Experimental Sciences. Two of them did not teach the subject, while the other one has more than 30 years of experience in the field of Didactics of Experimental Sciences. For doubtful student responses, agreement was sought between the three assessors as to whether they matched or were close to the reference response.

The result of the categorisation was summarised in three values: 1, 2 and 3. Value 1 corresponds to answers matching the reference answers. Value 2 was assigned to answers which, although close to the reference answer, did not meet some of the criteria considered in the categorisation (e.g. definition of the problem using colloquial terminology but taking into account factors, partial statement of hypothesis with a mixture of two factors, partial identification of variables, interpretation based only on some of the data or partially argued conclusions). Value 3 was assigned to answers that did not meet the predefined scientific criteria and have a significant deviation from the reference answers (e.g. definition of the problem without taking into account factors, erroneous statement of hypotheses indicating observations instead of possible solutions, confusion between types of variables, interpretation not based on data but description of observations, conclusions not supported by data). Appendix 1 presents some examples of correct and incorrect answers given by respondents to the questionnaire.

Responses from the part of question “k” on willingness to apply inquiry in the classroom were binary categorised as “yes/no”, and responses from the part concerning difficulties were grouped by commonality or similarity of meaning.

Second Phase Instruments

The result for each domain in the reports was scored according to a scale of 0 to 3 points from incorrect answer (0) to fully correct answer (3). The instrument with the characteristics of the scores in each domain is presented in Appendix 3. With regard to the reliability of the application of this instrument, we proceeded in the same way as with the first instrument.

Furthermore, using the total score of the tasks by adding up the score in each domain, these were classified into categories on levels of inquiry competence using Rosa’s (2019) NCI instrument so that groups with scores between 10 and 18 points were considered to be inquirers, from 7.36 to 9.99 points as partial inquirers, between 5 and 7.35 points as incipient inquirers and between 2 and 4.99 points as non-inquirers.

Sample

The sample is made up of students of the subject Didactics of Experimental Sciences in the 3rd year of the Degree in Primary Education at a teacher training centre in Spain between 2018 and 2021.

The sample spectrum for the first phase survey consisted of 173 students, of whom 138 were female and 35 male. Approximately 90% are under 25 years of age and the rest are between 26 and 40 years of age. In the academic year 2018–2019, 56 students participated; in 2019–2020, there were 71 students; and in 2020–2021, there were 46 students.

Furthermore, for the inquiry work (second phase), the sample consisted of 376 students, of which 68 belonged to the 2018–2019 academic year, 129 to the 2019–2020 academic year and 179 to the 2020–2021 academic year. Approximately 80% are under the age of 25 and the rest are between 26 and 40 years old. Out of the total number of students, 259 are female and 117 are male.

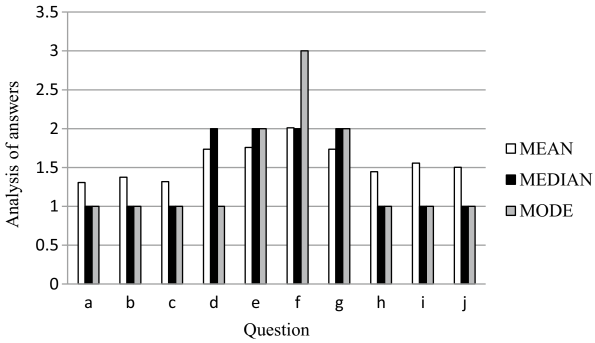


Fig. 1 Representation of the responses to the first phase questionnaire. *Note:* Value 1 as most favourable response and value 3 as most unfavourable response

Results and Interpretation

The results are presented as follows: first, the data relating to the first phase of the study, beginning with the analysis of questionnaire answers except for question "k", and then the answers to question "k" will be analysed. Secondly, the data from the second phase of the study are analysed and, thirdly, the comparison of the results between the two phases of the study is presented.

Data from the First Phase

Questionnaire Answers: Questions a, b, c, d, e, f, g, h, i and j

The answers to the questionnaire (some examples of correct and incorrect answers are listed in Appendix 1) were categorised and their descriptive statistical processing was carried out. In relation to the answers to the questions on the identification of the problem (question a and b), on the formulation of the research question (c), on the experimental design (question h), on the conclusions reached by the students (question i) and on the identification of the content involved (question j), Fig. 1 and Table 1 show that the mode and median are the same, with a value of 1. The mean, in these questions, does not exceed the

Table 1 Statistical processing of the survey responses from the first phase

	a	b	c	d	e	f	g	h	i	j
Mean	1.31	1.38	1.32	1.73	1.76	2.01	1.73	1.45	1.55	1.50
Standard error	0.05	0.05	0.04	0.06	0.04	0.07	0.05	0.05	0.06	0.06
Median	1	1	1	2	2	2	2	1	1	1
Mode	1	1	1	1	2	3	2	1	1	1
Standard deviation	0.61	0.68	0.58	0.79	0.47	0.88	0.61	0.72	0.75	0.76
Confidence coefficient (95%)	0.09	0.10	0.09	0.08	0.07	0.13	0.09	0.11	0.11	0.11

value of 1.55 which, together with standard deviation values between 0.09 and 0.11, indicates that in these questions, the answers were predominantly assigned a value of 1; i.e. the answers were valid according to the criteria of scientific value and congruence with the inquiry processes. It could be interpreted that teachers in training already have a high capacity related to the management and identification of inquiry processes. However, Table 1 shows that the mean value between 1.31 and 1.55 means that there were students who did not answer the questions correctly. Regarding question "j" on the identification of the contents involved in the problematic situation, the deviation between the mean (value 1.50) and the median and mode (coincident, with value 1) indicate that there were students who did not identify the content involved, which shows that they have conceptual gaps. This is unusual because students should already have mastered scientific content knowledge because they have studied it in previous years of the degree. However, there is evidence, along with data from other questions indicating poor science procedural skills, that preservice primary teachers have limited science training with significant conceptual gaps (a view concurring with Murphy et al., 2007).

The statistical data of the answers to the question on hypothesis formulation (question d) that are presented in Fig. 1 and Table 1 was shown a value 1 for mode and a value 2 for median with a standard deviation of 0.79. This difference between mode and median suggests that, although the majority of responses are assigned 1 (correct answer), there is a high number of incorrect or partially incorrect responses.

A different situation is observed with regard to the questions concerning the identification of variables (questions e, f and g). Here, it seems that the students are quite clueless as to what is being asked of them. In questions "e" and "g", on the variables and on the independent variable, the mode, median and mean values are similar, around 2. It appears that a high number of respondents did not respond adequately, either by missing a variable or incorrectly identifying the independent variable. More worrying is the data relating to the question on identification of the dependent variable (question f). Figure 1 presents this case where it is observed that the value for mode is 3, which indicates that a large proportion of students have not correctly identified the dependent variable, confusing it with the independent or control variable. These values should not be underestimated because they will be the starting point for the design and implementation of experimentation or research, as well as the basic pillar of the inquiry process. Nor can the diachrony between mode, median and mean in the questions on hypothesising (question d) and arguing conclusions (question i) be underestimated because these are questions which require higher order thinking and the application of scientific procedures with medium–high level research skills.

Based on these preliminary results, it can be interpreted that preservice primary teachers have sufficient ability to use inquiry satisfactorily in solving scientific problems or questions before receiving instruction in inquiry; however, they need to improve their skills to master inquiry-based methodology.

Questionnaire Answers: Question k

The questionnaire also asked the preservice primary teachers about their feasibility and willingness to apply inquiry in their future teaching (first part of question k). Eighty-three percent of the students in all three academic years answered in the affirmative while only 1% of the total number of students answered that they did not think they would be able to apply inquiry with their future students. Sixteen percent did not answer or answered that they did not know if they could apply inquiry. The data suggest that students have some confidence in new classroom methodologies and in their own education. This disposition is a relevant aspect as a fundamental element in students' metacognition, as well as its undeniable value in favour of positive attitudes towards scientific procedures. All this will contribute to more effective learning by students, facilitating the development of both scientific and degree-specific competences.

In the second part of question "k" in the questionnaire, students were asked to indicate the difficulties they felt they might encounter when trying to apply inquiry in the classroom. The responses were classified into 9 categories as described in Fig. 2. Most students do not encounter any difficulties (category *0* with 34 answers). Moreover, the main obstacle they encounter is the difficulty that school pupils may have in understanding content (category *2* with 29 responses), followed by lack of resources (category *1* with 25 responses) and, further down, lack of time (category *5* with 8 responses), organisation (categories *4* and *6* with 8 responses together) and safety in the classroom (category *8* with 7 responses).

From the responses collected, there is an apparent confidence of preservice primary teachers to apply inquiry in the classroom, with a majority of respondents saying that they will not encounter difficulties, which coincides with the few responses on the difficulty of understanding and teaching methodology by teachers (categories *3* and *7*). This statement seems consistent with the results obtained in the initial questions (a, b, c, d, e, f, g, h, i, j) of the questionnaire in which the preservice primary teachers seem to have a discrete (albeit limited) command of inquiry methodology, indicating self-confidence.

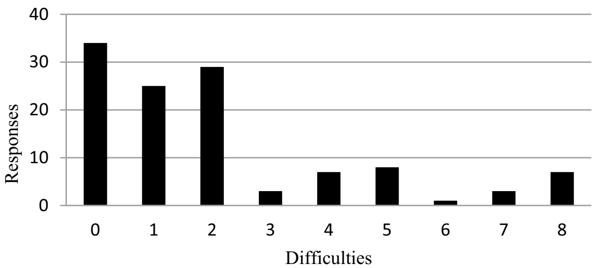


Fig. 2 Difficulties that preservice teachers think they will encounter when applying inquiry. *Note*: 0 no difficulty, 1 lack of resources in the classroom, 2 difficulty of school students to understand concepts or the procedure, 3 difficulty of teachers to understand concepts or the procedure, 4 number of students, 5 lack of time, 6 context of the environment, 7 difficulty of teachers to teach the methodology, 9 aspects related to student safety (accidents with heat, breakage of materials, etc.)

Regarding the lack of resources as a difficulty mentioned by preservice primary teachers (category *1*), this opinion coincides with that expressed by active teachers as an obstacle to deciding to use this methodology (Chichekian et al., 2016).

In any case, the data suggest that preservice primary teachers express certainty in applying inquiry-based methodology in the classroom and the difficulties they report in doing so are consistent with the concerns that a future professional teacher may have.

Data from the Second Phase

In the reports for each inquiry task or inquiry-based work, the degree of execution of each domain was analysed according to the characteristics of the answers by applying the rubric that is presented in Appendix 3 from the second phase of the study. The value of 3 was the most favourable or coincided with correct answers from the scientific point of view, and 0 corresponded to completely incorrect answers.

Figure 3 shows the evaluation of the 70 inquiry works where it can be seen that for the mode coinciding with the median, in all 6 domains the most frequent score is 3, indicating that the majority of the working groups have a reasonable capacity to use inquiry-related procedures after having received training in this area. Compared to the mode and median, Fig. 3 shows that in all domains, the value of the mean is around 2.5, which means that there are tasks that have difficulties in some aspects on the basic stages of scientific work. For instance, in the domain on *problem identification* (domain 1), the obstacle detected, and which may have led to low values for the question, is related to the students' difficulty in formulating the research question correctly, as it does not refer to variables or how to give a scientific answer to the problem.

Regarding domain 2 (*hypothesis formulation*), the lower mean value with respect to the mode and median is derived from the incorrect formulation of hypotheses by some working groups. These groups did not formulate the hypotheses taking into

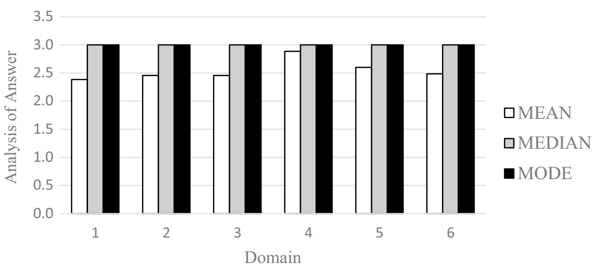


Fig. 3 Assessment of inquiry tasks (mode, mean and median data in each domain). *Note:* Domains: 1, identification of the problem and correct statement; 2, formulation of hypotheses; 3, identification of variables; 4, design of experiment or strategy to obtain information; 5, collection and representation of data; 6, interpretation and conclusions. Scoring: 0, incorrect answer or answer not related to the question; 1, correct part of the answer but very far from the scientific value and the problematic situation; 2, partially valid answer; 3, valid answer and coherent with the scientific value of the question

account the factors involved in the problematic situation or issued a solution without considering them or with no basis on them.

Regarding the *identification of variables* (domain 3), the most common error detected was confusion between variables or, in some cases, failure to indicate the correct variable (dependent or independent), which explains why this was not so in all the tasks.

In domain 4 (*design of experiment or strategy of obtaining information*), there is less deviation between mean, mode and median, indicating that the experimental design or planning of obtaining information was carried out satisfactorily by most of the working groups. Perhaps this was motivated by the procedural or executive character of the stage, which is less complex from the conceptual point of view than other stages.

However, in domain 5, relating to *data collection and representation*, and judging by the deviation of the mean from the mode and the median, there are groups that did not adequately develop the stage. Despite being a procedural and executive task, like the stage corresponding to domain 4, which should not generate complications for students, it seems that some groups had difficulties developing it correctly. This may be due to the linkage with other areas where implementation was found to be inadequate, as is the case for domains 1, 2 and 3. Thus, if some groups have started with errors in the previous stages (domains 1, 2 or 3), it is possible that the data processing and information gathering in domain 5 will also contain errors. Regarding domain 6 (*interpretation and conclusions*), the deviation of the mean compared to the median and mode is attributed to the fact that some groups have not adequately or correctly drafted conclusions, have done so partially or not based on the data, with little argumentation, or the interpretation is more about observations and description of the data than real analysis.

Furthermore, by representing in Fig. 4 the sum of the total scores of the tasks, it can be seen that almost all of the tasks are in the range between 10 and 18 points. Indeed, the statistical data presented in Table2 show that the mode has a value of 18, the median 16 and the mean was very similar (15.27). Together with the standard

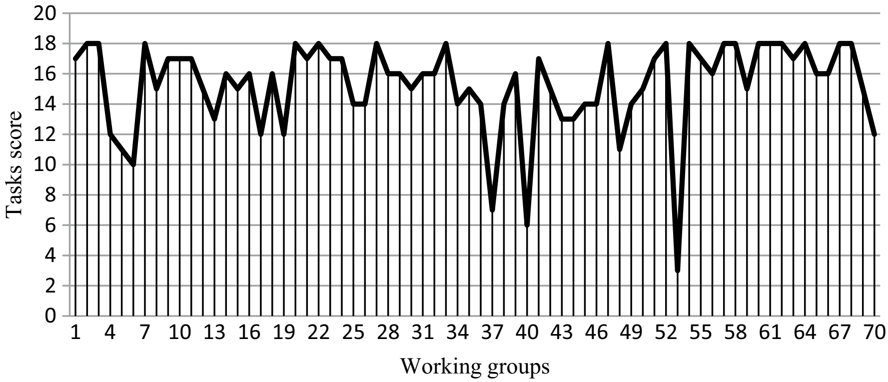


Fig. 4 Representation of the total score of each inquiry task

Table 2 Inquiry task scores

Mean	15.27
Standard error	0.36
Median	16.00
Mode	18.00
Standard deviation	2.98
Confidence level (95.0%)	0.71

deviation and confidence level data, they indicate that a high number of tasks have high scores.

When applying Rosa's (2019) NCI scale on the inquisitiveness of working groups, the result is that 67 of the 70 tasks have a total score that would include them in the range corresponding to inquirers groups, while the other three deviate greatly from the rest of the scores. Based on its score, one of these tasks (no. 37) can be described as partially inquirers (score 7), another (no. 40) as incipient inquirers (score 6) and a third (no. 53) as not inquirers (score 3).

According to the data recorded, it would appear that most of the working groups have mastered the inquiry methodology after experiencing it through practical work and after having received instruction on inquiry.

Comparison of Results Between the First and Second Phase

In order to be able to make a comparison between trainee teachers' ability to apply inquiry between the two phases of the study, it is necessary to unify the presentation of the results in both phases. The data obtained for the different stages of inquiry are considered. Since the first phase stages were structured through nine questions (a, b, c, d, e, f, g and i) from the questionnaire presented in Appendix 1, while in the second phase, they were structured in six domains presented in Appendix 3; it was necessary to correlate the questions from the first phase with the domains of the second phase and vice versa. The criterion to correlating the stages of both phases is based on the equivalence of meaning, object and purpose between the questions (or set of questions) of the first phase and the domains of the second phase of the study. Table 3 presents the correlation and it is as follows: domain 1, questions a, b and c; domain 2, question d; domain 3, questions e, f and g; domains 4 and 5, question h; domain 6, question i. To make the comparison, we used the mean, median and mode data from the first phase shown in Fig. 1 and Table 1 and the data from the second phase shown in Fig. 3, unifying the scales and assigning in both cases value 1 as most favourable and value 3 as least favourable, presenting the results in Table 3, Fig. 5 and Fig. 6.

Looking at the results in detail in Table 3, in relation to domain 1, there does not seem to be any change between the first phase, whose data are represented in Fig. 5, and the second phase, whose data are represented in Fig. 6. It seems that students still have the same ability to identify and formulate the scientific problem involved in the proposed problematic situation. Regarding domain 2, there are improvements in

Table 3 Comparison of statistical data on students' inquiry skills in the two phases of the study

Domains	Questions	Mean		Median		Mode	
		First phase	Second phase	First phase	Second phase	First phase	Second phase
1	*a* *b* *c*	1.3	1.3	1	1	1	1
2	*d*	1.7	1.4	2	1	1	1
3	*e* *f* *g*	1.8	1.3	2	1	2	1
4	*h*	1.5	1	1	1	1	1
5			1.1		1		1
6	*i*	1.6	1.5	1	1	1	1

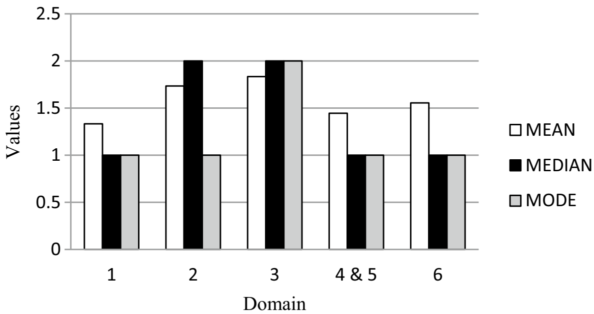
Value 1 most favourable and value 3 less favourable

the second phase. Although the mode has the same value in both phases, in Table 3 and Fig. 5, it is observed that the median decreases from 2 points in the first phase to 1 point in the second phase, presented in Fig. 6, which is considered the correct answer. Mean values also decrease slightly. This change is important because it refers to a greater readiness to make hypotheses, an aspect that will positively influence the rest of the stages of the inquiry.

In domain 3, the change is remarkable as the mode and median values decrease from values of 2 points in the first phase to values of 1 point in the second phase. At the same time, the mean goes from values close to 2 points to values around 1.3 points. The improvement in this domain is significant because it indicates that the preservice primary teachers have become more proficient in the identification of variables, suggesting that they have a good understanding of the scientific problem and the factors involved. This allows for correct experimental design or adequate planning of the search for information in the event that the experiment cannot be carried out.

In domains 4 and 5 together, although the mode and median values are the same, the mean values indicate a slight improvement from values close to 1.5 points in the first phase to values close to 1 point in the second phase. The data are presented in

Fig. 5 Values from the first phase responses by adapting the survey questions to the domains of the second phase. *Note:* Value 1 most favourable and value 3 most unfavourable



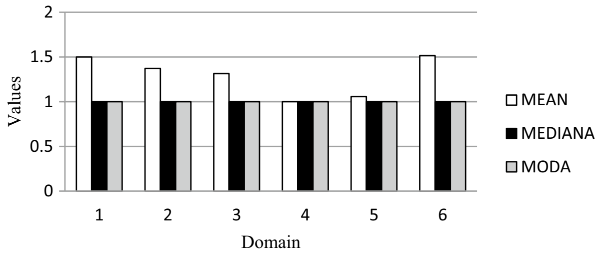


Fig. 6 Values from the inquiry tasks by domains from the second phase. *Note:* Value 1 most favourable and value 3 most unfavourable

Table 3, Fig. 5 and Fig. 6. The results indicate that they slightly improve the procedural skills of the trainee teachers.

Finally, with respect to domain 6, the values of the mode and median are the same in both phases, while the values of the mean decrease very slightly from 1.6 points to values of 1.5 points. Although the data suggest improvement, the change is irrelevant. The ability of preservice primary teachers to argue and draw evidence-based conclusions is very similar in both phases.

The results of both phases seem to indicate that the trainee teachers' knowledge in applying inquiry is adequate but improves after receiving training in inquiry methodology. The comparison seems to indicate that there is an increase in inquiry competence, which suggests that students have acquired or strengthened the minimum skills necessary to use inquiry as a methodology in the classroom.

Discussion and Conclusions

The discussion will be carried out by answering the questions posed by the objectives of the study through the results obtained in the two phases of the study and their subsequent comparison.

What Level of Knowledge of Inquiry Do Preservice Teachers Have Prior to Studying Inquiry on Their Degree Programme?

The first phase of the study (answers to questions a, b, c, d, e, f, g, h, i and j of the questionnaire in Appendix 1) provided data that allow us to ascertain that the level of knowledge about inquiry prior to receiving instruction was acceptable. The results suggest that the preservice primary teachers are sufficiently proficient in scientific procedures to approach a problem from an inquiry perspective, coinciding with the conclusions expressed by García-Carmona (2019) in a study also with preservice primary teachers. Despite this, in the first phase, it is worth reflecting on how teachers in training faced the problematic situation, which was designed to be used with primary school students. In these circumstances, the results should have been much better as it is understood that a trainee teacher, as an adult, already possesses sufficient scientific literacy to face a problem and try to solve it from a scientific point of view. However, the results suggest that there are a discrete number of students who do not demonstrate sufficient ability to provide scientifically reasoned answers. This is reflected in the fact that not all students recognised the content involved in the problem situation and were not able to recognise what the actual scientific problem was. Or worse still, they failed to hypothesise the problem (it is difficult to suggest a possible solution or explanation to the problem if it has not been properly identified and formulated). The situation is more worrying when looking at variable-related responses, where the data indicate that they fall far short of what is expected of a sufficiently scientifically literate learner. Regarding the design of the experiment (as an executive process) and the interpretation and conclusions, the results are acceptable but could be improved, including the quality of scientific discourse, as it seems that there are preservice primary teachers who do not have a good command of this scientific domain. Thus, it can be stated that some of the preservice primary teachers who participated in the study, prior to learning inquiry content, lack the basic skills required in any inquiry process. Preservice primary teachers have a discrete capacity for inquiry, with less ability in the stages where intermediate or higher order cognitive processes are required, such as the formulation of hypotheses and in the definition of variables, which is something that conditions the correct development of later stages.

Are They Willing to Apply a Methodology Based on Inquiry with Their Future Students?

The answer to this question is based on the data extracted from first part of question "k" in the first phase survey presented in Appendix 1. The results obtained show that preservice primary teachers are willing to use inquiry with their future students. Although the inquiry skills of many of the preservice primary teachers surveyed could be improved, almost all of them stated that they would apply inquiry as a methodology in the classroom. This is a very positive aspect because in terms of attitude they are inclined to use a methodology that is new to them. The positive disposition will reinforce and facilitate their learning about inquiry-based methodology.

What Difficulties Do They Think They Will Encounter if They Try to Apply Inquiry in a Classroom Situation?

Considering the answers to second part of question "k" from the questionnaire used in the first phase survey presented in Appendix 1, the majority of preservice primary teachers say that they do not think they will encounter any difficulties in applying inquiry in the classroom. This assessment is consistent with the trainee teachers' predisposition to use inquiry in the classroom discussed in the previous question.

Other preservice primary teachers believe that the main difficulties they will face are related to the lack of resources and problems of understanding concepts and procedures by primary school pupils. The lack of resources as a difficulty mentioned by preservice primary teachers is a view that coincides with that stated by practising teachers as an obstacle to deciding to use this methodology (Fang, 2021), which is relatively easy to overcome. Moreover, the problem of the possible lack of understanding of the content and inquiry procedures by their future school pupils denotes a lack of confidence in their prior knowledge and in their logical-mathematical reasoning ability. It could also indicate a hidden lack of confidence in their own ability to teach and transmit knowledge properly. A suggestion to increase their confidence in this aspect is to receive greater training in both scientific and didactic content from teacher training centres by designing curricula and intervention appropriately.

Has the Competence to Apply Inquiry Improved After Receiving Instruction or Training on It?

The answer to this question is drawn from the results obtained in the second phase of the study and from the comparison between the results of the two phases of the study. By comparing the level of preservice primary teachers' ability to use inquiry before (first phase of the study) and after receiving inquiry training (second phase of the study), the answer is that competence in applying inquiry has improved. It seems that their scientific inquiry skills have increased after the practical work and have improved after the instructional intervention. However, although there is positive progress in their competence in relation to inquiry procedures, deficiencies remain in the problem identification and variable identification stages. It is clear that these aspects need to be reinforced by drawing attention to the fact that these difficulties are not exclusive to the preservice primary teachers in this study but have been identified in other contexts, as for example, the inability to correctly identify variables in pre-university students (Crujeiras & Jiménez, 2015: González & Crujeiras, 2016), the lack of skills for formulating hypotheses and researchable questions in preservice primary teachers (Ferrés-Gurt, 2017) or the difficulty in defending conclusions, also in preservice primary teachers (Vílchez & Bravo, 2015).

It is recommended to pay attention to how inquiry is treated or what kind of inquiry is intended to be taught to trainee teachers. It would be desirable for their training to be carried out in a framework of *quality inquiry* (in the sense of Romero-Ariza, 2017) that facilitates their transposition to primary education classrooms. It would also be desirable for this training framework to lead to a methodology as close as possible to Barrow (2006) third meaning (inquiry as a didactic model).

In summary and by way of conclusions, it can be affirmed that, although the preservice primary teachers have an acceptable ability to deal with scientific content through inquiry, they still show deficits in this ability, mainly in procedures related to problem identification and hypothesising. This shortcoming, together with the deficiency of critical thinking in the scientific field reflected in the limited ability to argue and draw conclusions based on evidence, requires a training reinforcement in inquiry methodology. For this reason, it is recommended to intensify and increase the scientific training of preservice primary teachers in inquiry-based methodology, thereby strengthening the initiatives already in place (Godoy et al., 2014).

Likewise, this educational reinforcement would be ineffective if the insufficiency in elementary or basic scientific content persists, which is why it is necessary to insist on adequate scientific training in disciplinary content (nature of science, physics, chemistry, natural sciences, etc.). Furthermore, in order to strengthen and consolidate the learning of preservice primary teachers in their future teaching work, it is also relevant to convey to schools that they should provide the necessary resources to deal with science content in an effective way. It is also recommended to implement in-service teacher training programmes on inquiry-based methodology.

Limitations and Future Research

Despite the limitations, or precisely because of them, possible avenues for future research are open. One is to continue to gather information on inquiry-related knowledge from preservice primary teachers in different teacher education institutions. Another line of research is to find out how inquiry is used in the classroom at pre-university and university levels. It would also complement the findings of Tierno et al. (2020), who analysed the use of inquiry in Experimental Science subjects and in Primary and Early Childhood Education degrees in some universities in Spain, based on data extracted from their teaching guides. This line of research will allow us to learn about the reality of the classroom in these degrees, by obtaining information about the use and application of inquiry in the training of preservice primary teachers and how they will be able to apply it in their future teaching work. It provides an idea of how experimental science students are trained in relation to inquiry and their competence to carry it out in the classroom. The prospective is justified in order to contribute more data to the study on the issue carried out by Morales et al. (2018), who point out that research on the subject (inquiry-based teaching) is incipient in Spain. A third, longer-term avenue of inquiry is to learn how active teachers apply inquiry in the classroom.

The information obtained through these avenues of research will be very useful for teacher educators to evaluate our teaching design for inquiry methodology. It will allow changes to be made that will increase the efficiency and effectiveness of instruction so that it has an impact on improving students' learning in relation to inquiry.

Appendix 1 Questionnaire for the first phase of the study and examples of answers.

Modified from Greca et al. (2017).

Problematic Situation

María and Pedro are classmates in the 5th year of Primary Education. Every day for breakfast, they follow the same routine in their respective homes: (i) they put a big cup full of milk in the microwave; (ii) they turn it on and after a while they take the cup out carefully so as not to burn themselves and put it on the kitchen table; (iii) they add sugar by stirring it with a spoon and drink all the milk and eat some biscuits;(iv) finally, they leave the cup in the sink, noticing that some days there is still sugar at the bottom of the cup.

a Identify three **scientific problems** from the previous everyday situation so that Mary and Peter can address them using a process of inquiry to give reasoned answers.
b From the three problems above, choose the one that contemplates the most scientific factors or variables to provide an adequate answer.
c Now try to formulate the above problem in one of two ways:
What factors (or variables) does it depend on? Or what factors (or variables) influence what?
d Indicate the **hypotheses** for the problem formulated in c
e List all the **variables** (or factors) that you think are involved in the problem being formulated.
f What is the **dependent** variable?
g What are the **independent variables**?
h Describe the **experimental design** you would do to test your hypotheses (from section d).
i What do you think the **conclusions** would be?
j What **scientific content** is being worked on in this inquiry?
k Do you think that inquiry processes similar to the previous one can be carried out in primary education classrooms? Describe the difficulties you encounter.

Examples of correct answers from students to some of the questions in the questionnaire:

Question a: Why does the sugar stay at the bottom of the cup?
Question c: On what factors does it depend that the sugar remains at the bottom of the cup?
Question d: If the milk is warmer, the sugar will not appear in the cup.
Question i: The higher the temperature of the milk, the better the sugar dissolves. The warmer the milk, the more sugar you have to pour in order for it to stay in the bottom.
Question j: Solutions, solute, solvent, solubility, variables, experimentation, observation.

Examples of incorrect or partially correct answers to some questions:

Question a: *Are the density of milk and the dissolution of milk and sugar directly proportional?* This refers to the explanation or cause, but it is not the problem they have to identify from observation.
Question c: *On what factors does stirring with a teaspoon depend?*
Question d: *In the cup there is little milk and a lot of sugar* (partially correct because it is not well formulated by not specifying how the factors influence). *Stir so the milk tastes sweet.*

Question i: *It will not dissolve completely and will do so after a considerable time. You'll notice when the sugar dissolves and when it doesn't.*
Question j: *Volume, mass, degrees, variables.*

Appendix 2 Example of problematic situations

Example of problematic situations proposed for carrying out the inquiry work.

1. John has to buy a kitchen towel and his mother has told him to get the most absorbent one, but he cannot figure out how to assess which one is more absorbent. Can you design a series of experiences that will help him understand the phenomenon of absorption and be able to make choices?
2. On her way to school every day, Sofia notices a bush growing in the rubble of a half-ruined building. Sofia does not understand how the plant has been able to survive at the bottom of the collapsed building where there was no light and has grown into the sunlight through the cracks. Help Sofia to resolve her uncertainty.

Appendix 3 Rubric for the second phase of the study.

Modified from Rosa's (2019) instrument.

Domain 1: Identification of Investigable Problems

- Does not identify problems or does not raise problems or raises unapproachable problems: 0 points.
- Does not clearly identify the problem and the formulation is ambiguous or poorly formulated: 1 point.
- Identifies the problem but it is not well formulated: 2 points.
- Identifies appropriate research problems and specifies questions: 3 points.

Domain 2: Hypothesis Formulation

- Does not state hypotheses or does not identify hypotheses or states hypotheses that make no sense: 0 points.
- Makes ambiguous or logically flawed or poorly formulated hypotheses or only makes predictions: 1 mark.
- Puts forward hypotheses that fit the research problems but does not formulate them as a deduction: 2 points.
- Puts forward hypotheses that fit the research problem and with reference to the model but does not formulate them as an inference: 3 points.

Domain 3: Identification of Variables

- Does not identify variables or does not know how to specify design: 0 points.
- Confuses independent variable (IV) and dependent variable (DV) or proposes IV and DV that do not fit the hypotheses formulated: 1 point.
- Identifies IV and DV but in an unspecified or imprecise way: 2 points.
- Identifies and defines appropriate IV and DV, which fit the hypotheses: 3 points.

Domain 4: Research Planning

- No experimental design or no experimental design proposed: 0 points.
- The methodological design does not allow to verify the hypotheses: 1 point.
- The methodological design only allows a partial verification of the hypotheses: 2 points.
- The methodological design offers an adequate verification of the hypotheses, with replicas and control: 3 points.

Domain 5: Data Collection and Processing

- Has not collected research data either in experiments or in data sources: 0 points.
- Incomplete data collection, lack of precision, inadequate or incomplete data processing, graphs without titles or with inaccuracies: 1 point.
- Collection of data with errors or inaccuracies, but with adequate processing of the data and the graphic representation: 3 points.
- Methodical, adequate and sufficient data collection with good understanding and execution of techniques and measurements, good mathematical and graphical processing of the data: 3 points.

Domain 6: Data Analysis and Conclusions

- No data analysis: 0 points.
- Poor analysis and conclusions not based on data: 1 point.
- Conclusions very similar to the results, without interpretation or analysis of data. Does not coordinate theoretical justifications with empirical evidence. Barely scientific discourse: 2 points.
- Well-founded data analysis and evidence-based conclusions. Coordinates theoretical justifications with empirical evidence. Consistent and relevant responses. Scientific discourse: 3 points.

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Declarations

Disclosure and ethics statement No potential conflict of interest was reported by the authors. This study did not require formal ethics approval because the data was completely anonymous with no personal information being considered (apart from age and a record of informed consent). The data was not considered to be sensitive or confidential in nature and was used for a purpose which falls within the remit of the original consent provided by subjects. The issues being researched were not likely to upset or disturb participants. The subject matter is limited to topics that are strictly within the professional competence of the participants. Vulnerable or dependent groups were not included.

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