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Use of Data Obtained in the Field and its Contribution to the Process of Construction of the Geological Change Model by Preservice Elementary Teachers

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ABSTRACT

Background: Science education should encompass enculturation in science which implies performing scientific practices such as use of data and modelling, in authentic contexts like the field.
Purpose: This work aims to determine how preservice elementary teachers (PETs) use data obtained in the field, and how these data contribute to the process of building a model of geological change.
Sample: 41 Preservice Elementary Teachers (PETs) participated in the study.
Design and methods: A mixed methods design was used. The data from the conversations of 9 groups during the 6 sessions following a field trip were categorized by constant comparison according to how the data from the field were used. The cases of field data used for modelling were further categorised through the Modelling Model Diagram framework. The PETs´ perception was examined by means of an open-ended question.
Results: PETs did use field trip as a learning resource and appealed to it without being explicitly required to. Seven groups used the data for the modelling process, mainly for creating and testing the model. Data were used in four of the groups as evidence for evaluating the validity of models. PETs perceived the field trip to be useful. Specifically, they acknowledged its usefulness whilst carrying out operations related to the creation of the model but they showed lack of awareness about the usefulness for performing other important operations.
Conclusion: The findings suggest that the field trip may be a valuable resource for developing scientific practices such as use of data and modelling in science education. The positive perception of the PETs about the usefulness of the field trip for the learning process may foster their involvement in the design and implementation of such field trips in the future.

Keywords: field trip; Geology; modelling; preservice elementary teachers; use of data

Introduction

The development of scientific competences (OECD 2019) in science education needs the enculturation of students in science (Brown, Collins, and Duguid 1989), that is, the incorporation of scientific practices and authentic activities in the classroom (Jiménez-Aleixandre and Crujeiras 2017; NRC 2012).

Scientific practices are the practices scientists develop in their endeavour to understand the natural phenomena, that is, while they investigate the world, develop explanations and evaluate those explanations using evidence (NRC 2012; Osborne 2014). Modelling and argumentation are two of the fundamental scientific practices (Jiménez-Aleixandre and Crujeiras 2017). Modelling has a variety of definitions. One broad and extensively used definition is: the process of construction, use, evaluation and revision of scientific models (Schwarz et al. 2009). Models have been defined as partial representations of reality that try to explain and predict scientific phenomena (Gilbert, Boulter, and Elmer 2000), or as epistemic artifacts whose purposes are related to a multitude of scientific practices (Gilbert and Justi 2016). Whilst importance is given to the predictive potential of models (Gilbert, Boulter, and Elmer 2000), in Geology 'retrodictive thinking (‘prediction’ of the past)’ (King 2008, p. 188) also has to be taken into account.

Argumentation can be defined as the use of evidence to assess knowledge (Jiménez-Aleixandre and Crujeiras 2017) and its practice implies the justification of the claims being formulated (NRC 2012). Argumentation and modelling are closely related, for example, the construction and evaluation of scientific models requires the development of evidence-based justifications.

The incorporation of scientific practices in the classroom depends to a large extent on teachers (Bybee 2014; Driver, Newton, and Osborne 2000). A change in science teaching that aims to incorporate science practices requires changes in teacher training to improve teachers' knowledge of what science practices are and strategies to use with their students (McNeill et al. 2016; Osborne 2014). In that sense, ‘beginning teachers need to experience what it means to learn science concepts deeply and conceptually in ways that are consistent with how they will eventually be asked to teach’ (Zembal-Saul 2009, p. 696). Indeed, as Windschitl (2003) found when analysing the implementation of inquiry activities by trainee secondary school teachers, the key factor was that they had carried out science inquiry activities themselves, for example, in their initial training. However, teachers often have little or no experience of the scientific practices they are supposed to promote and have difficulties in carrying them out (McNeill et al. 2016; Vo et al. 2019). McNeill et al. (2016) assessed secondary school teachers' PCK in argumentation. One of the difficulties they encountered in defining PCK was the lack of studies analysing teachers' difficulties in using evidence and arguing. Similarly, Vo et al. (2019) highlighted the lack of studies on primary school teachers' difficulties in modelling and promoting modelling. In their findings, McNeill et al. (2016) highlighted that teachers with little experience in argumentation tended to focus on superficial aspects of argumentation, such as language, and not on more central aspects, such as the epistemic goals of argumentation. Giving teachers opportunities to engage in authentic experiences of argumentation may be one of the keys to moving them away from such a conception. The need for such experiences, namely experiences of theorising from data, was underlined by Crippen (2012), who observed that of a group of 42 practising secondary school teachers, none drew on their own data when formulating a conclusion. They tended to use external data such as those obtained from the web, lacking confidence in their skills or in their data, according to themselves. Sampson and Blanchard (2012) also expressed concern that very few of the teachers they interviewed used data when constructing arguments to evaluate different explanations of a phenomenon.

Duncan, Chinn, and Barzilai (2018) suggested the use of authentic (multiple, low-quality, complex) evidence in science classrooms. The field constitutes a source of authentic data to be used as evidence to theorise as suggested by Crippen (2012), for modelling.

The main objective of this work is to address how data collected in the field are used by PETs and specifically how PETs use the data to theorise, to construct the geological change model. This study contributes to the knowledge of how teachers develop the use of data competence, specifically how they approach the process when starting from an authentic context such as the field. In addition, it contributes to the knowledge about the possibilities of fieldwork to foster the development of scientific practices in the context of geology.

Competence for Using Data

The use of evidence to assess knowledge is one of the fundamental scientific practices (Jiménez-Aleixandre and Crujeiras 2017; NRC 2012) and scientific competences (OECD 2019) and has acquired relevance in science education.

Students need to be given opportunities to work with data in order to develop the ability to use evidence in science. Data are the facts that individuals involved in argumentation can appeal to in support of their claim (Driver, Newton, and Osborne 2000). In that case, when data are used to support a claim they become evidence (Duncan, Chinn, and Barzilai 2018; Duschl 2008). Students, therefore, should interpret data and turn them into evidence so they can extract conclusions.

Interpreting data and using them as evidence are complex operations. The relationship students establish between data and evidence is formed, among other factors, by their scientific knowledge, which makes a given piece of information to be considered evidence to support an explanation (Koslowski et al. 2008).

Duschl (2008) proposed considering the evidence-explanation (E-E) continuum in order to establish "dialectical discourses about data representations, data and conceptual models, evidence, explanatory theories, and methods″ (p. 279) in the classroom. He indicated that, in science learning, conversations should mediate the following transitions from evidence to explanations: a) selecting or generating data that are to become evidence; b) using evidence to establish patterns and models; c) employing the models and patterns to propose explanations.

These operations performed with data are central for evaluating the ability of using data. Ryu and Sandoval (2012) considered four epistemic criteria to characterize scientific argumentation, one of which was the citation of evidence. For this criterion, they established four levels (0-3) to evaluate the work of primary school students: not citing any data (0), citing only one (1), presenting several (2), giving all relevant data in support of conclusions (3). Ageitos, Puig, and Colucci-Gray (2019) adapted these levels to analyse oral discussions in groups of secondary school students who had to find the relationship between two diseases based on data provided to them. Three levels were established, from merely mentioning data up to using them as evidence to support conclusions.

The consideration of evidence by children in Early Childhood Education was analysed by Monteira and Jimenez-Aleixandre (2016). To do this, researchers studied how children formulated conclusions based on the observation of snails. They distinguished two use-of-data levels, based on the E-E continuum (Duschl 2008). They found that more than half of the statements were from the lowest level, close to raw data.

Fieldwork in Science Education

Many studies show the benefits of field trips in cognitive and affective domains (Aflalo, Montin, and Raviv 2020; Easton and Gilburn 2012; Fedesco and Cavin 2020; Lavie Alon and Tal 2017; Orion and Hofstein 1991, 1994). Yet, outdoor learning seems to be losing attention compared to computer-based learning, despite, as Aflalo, Montin, and Raviv (2020) concluded, outdoor activities promote scientific knowledge and can facilitate the perception of the topic as relevant to children´s lives. To promote a greater role for field trips in science education, teachers need, among other things, to understand that their benefits are worth the effort of designing them. Scott, Boyd, and Colquhoun (2013) conducted a qualitative study with 210 elementary school students who participated in outdoor lessons in environments close to the school. Teachers were hesitant at the beginning, but at the end of the activities the feedback was positive, both from teachers and students with respect to motivation, communication and relationships. In fact, it has been highlighted that field trips are contexts that favour the development of authentic learning experiences, in which students can act as active subjects (Behrendt and Franklin 2014; Orion and Hofstein 1994); and facilitate the interrelation between the diverse elements and multidisciplinarity (Schiappa and Smith 2019). However, as Carrier, Tugurian, and Thomson (2013) showed, teachers, constrained by time and content requirements, carried less field trips than intended because they did not see their potential as a learning resource. Teachers need to experience fieldwork to be aware of this potential. Nugent et al. (2012) compared the performance of two groups of preservice teachers, one participated in a field course and other followed a classroom-based course. Their results showed that the ones in the field course performed higher in conceptual knowledge, confidence in teaching science, attitudes toward science, differentiation between observations and inferences, critical thinking, and cooperative learning. Teacher should design the field work appropriately to make use of its potentialities. Thus, it is important to prepare students before going to field, reducing the novelty, by sharing the objectives of the field trip and giving them information about the place to be visited (Orion, 1994). During the field trip, teachers should surrender their expert status (Scott, Boyd, and Colquhoun 2013) and give students the opportunity to take an active role (Orion and Hofstein 1994), to enable them to feel autonomous and competent (Fedesco, Cavin, and Henares 2020). This could be done for example by engaging students in inquiry based activities (Behrendt and Franklin 2014; Nugent et al. 2012), in which they could raise hypotheses (Almquist et al. 2011) and contrast them in groups (Scott, Boyd, and Colquhoun 2013).

In the framework of situated learning, in order to learn a discipline, one has to enter into its practice and culture (Brown, Collins, and Duguid 1989). Field trips are a reference context for this enculturation and practice, particularly in Geology (Donaldson et al. 2020; Petcovic and Stokes 2014). This was stated by the research carried out by Kortz, Cardace, and Savage (2020) to address what factors influence students' intention to persist in geoscience degrees. As they found, the field experience was very valuable for students to imagine what a geoscientist does.

One of the reasons why Geology is so closely linked to the field is that it is an historical and interpretative science (Frodeman 1995), as it approaches phenomena of the past through the interpretation of geological structures from the present. Instead of conducting experiments, geologists use data collected in the field that are spatially and temporally fragmented to build models (Balliet, Riggs, and Maltese 2015). Moreover, in the field, the studied object is often observed from an internal spatial viewpoint, that is, the observer is immersed in it, so the perspective achieved is unique (Mogk and

Goodwin 2012). This was also appreciated by Fedesco and Cavin (2020) in their qualitative study on the benefits of fieldwork in various college degrees. Geology students reported that fieldwork allows them to see the "*bigger picture*".

The field is a key site where a large part of the data are collected, interpreted and utilized to formulate hypotheses (Almquist et al. 2011), which is related to the *creation* of the model (Gilbert and Justi 2016). Data obtained in the field can constitute a reference for the model *representation*. In Geology, the aim of the model is to reconstruct the geological processes that occurred in the past and whose consequence is reflected in the materials and structures observed in the field, so those materials and structures are part of the representation (Egger 2019). The data collected in fieldwork can be used to conduct thought experiments and as evidence in group discussions to convince colleagues and *test of the model* (Blanco-Anaya, Justi, and Díaz de Bustamante 2017).

The college students who participated in the research carried by Balliet, Riggs, and Maltese (2015) developed an individual field trip in which they were confronted with an unknown area and asked to model how it was formed. Students followed different strategies of modelling, some focused on one model and its validity, while others considered several models. The latter proved to be the most successful due to the flexibility it gave students in accommodating and interpreting new data. Indeed, it is the interpretation and use of the data from the field, the argumentative process inherent in modelling (Böttcher and Meisert 2011; Mendonça and Justi 2013; Passmore and Svoboda 2011; Schauble 2018) which has to serve to evaluate the models. As Egger (2019) states, the field is in fact the cornerstone, 'the criterion for judging any map, climate model, visualization of change over time or reconstruction of the past' (p. 97).

Research questions

The specific objective of this work is to understand how data collected in the field are used by PETs and contribute to the stages in the modelling process. In order to do so, three research questions are posed:

(RQ1): How did PETs refer to the field trip in the subsequent activities, and how did they use the data obtained in it?

(RQ2): In the cases that PETs made use of the data obtained in the field, how did the use of fieldwork data contribute to each of the stages of the modelling process as defined by Gilbert and Justi (2016)?

(RQ3): Which is the perception of PETs about the contribution of the field trip to their modelling process?

Methods

Given the nature of the research questions, the research was mainly based on the interpretative analysis (Erickson 1986) of data of a qualitative nature. The data used to address RQ1 and RQ2 were conversations among PETs. RQ3 was adressed through an open-ended question.

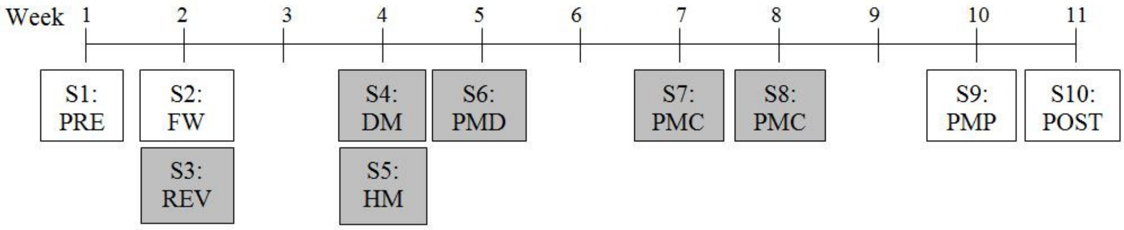
Participants and Context

The teaching sequence took place during the first four-month period of the 2018/2019 academic year with 41 PETs (33 women and 8 men) from a 4th year (22 years old) class of the Primary Education Degree at a Spanish university. They worked in 9 groups (named A, B, C, D, E, F, G, H and I) of 3-4 people. The names of the PETs were replaced by pseudonyms starting with the letter corresponding to the group.

Groups were created by PETs themselves; and, in terms of prior knowledge, there were no major differences, since all PETs had taken the same subjects in the three previous years. Two of the subjects were on science education, and, in one of them, three years before the study, they had all worked on some geology concepts such as plate tectonics and geomorphology processes.

The modelling sequence lasted 10 sessions (19 hours in total), was based on the reconstruction of the geological history of Orduña valley (Basque Country, Spain), and included a field trip. The sequencing of the sessions is summarized in Figure 1.

Figure 1. Sequencing of the sessions. (PRE: pretest, hypothesis formulation; FW: field work; REV: revision of the field work; DM: addressing diapir question; HM: addressing hydrodinamics question; PMD: physical model design; PMC: physical model construction; PMP: physical model presentation; POST: postest and collection of opinions). The grey shaded squares correspond to the sessions in which the conversations of the groups were audiotaped.



The first session (S1) was devoted to a pre-test and the formulation of hypotheses while viewing photographs of the area. The aim was to reduce novelty and prepare students cognitively, geographically and psychologically for the field trip (Orion, 1994). Two main questions were posed to guide the reconstruction of the geological history of the site to be visited. *Why does the river have water even when it does not rain?,* to deal with hydrodynamics, related to the external geodynamics model, and *How have the strata been placed vertically?*, to discuss diapir formation, related to the internal geodynamics model. The field trip was carried out in the second session (S2), with the aim for the students to collect the necessary data to reconstruct the geological history of the site. The valley (Figure 2) has a circular morphology becouse there is a diapir where the gypsum and clay of the Keuper *facies* of the Upper Triassic emerge. The upper rocks are Turonian and Coniacian limestones, arranged in sub-horizontal and karstified strata, and they form the rugged reliefs of Sierra Salvada mountains. These mountains contain a karstic aquifer that drains into Nervión river. This river rises here and has eroded the mountain into a large canyon.

Stops made in the field trip have been located on the map in Figure 2 and are described in Table 1.

Figure 2. Geological map of the Orduña valley with the 4 stops (1-4) of the field trip (edited from Zamorano, Del Pozo and Tomás, 1978). The oldest unit is formed by clays and gypsum of the Upper Triassic Keuper facies, located in the centre of the valley, at the lowest elevations, in pink (a). Upper Cretaceous units, which form the highest reliefs, are represented around it: limestones and marls of the Turonian in yellow (b) and higher up, limestones of the Coniacian in darker green (c). The canyon formed by the River Nervión is easily visible at the bottom of the map.

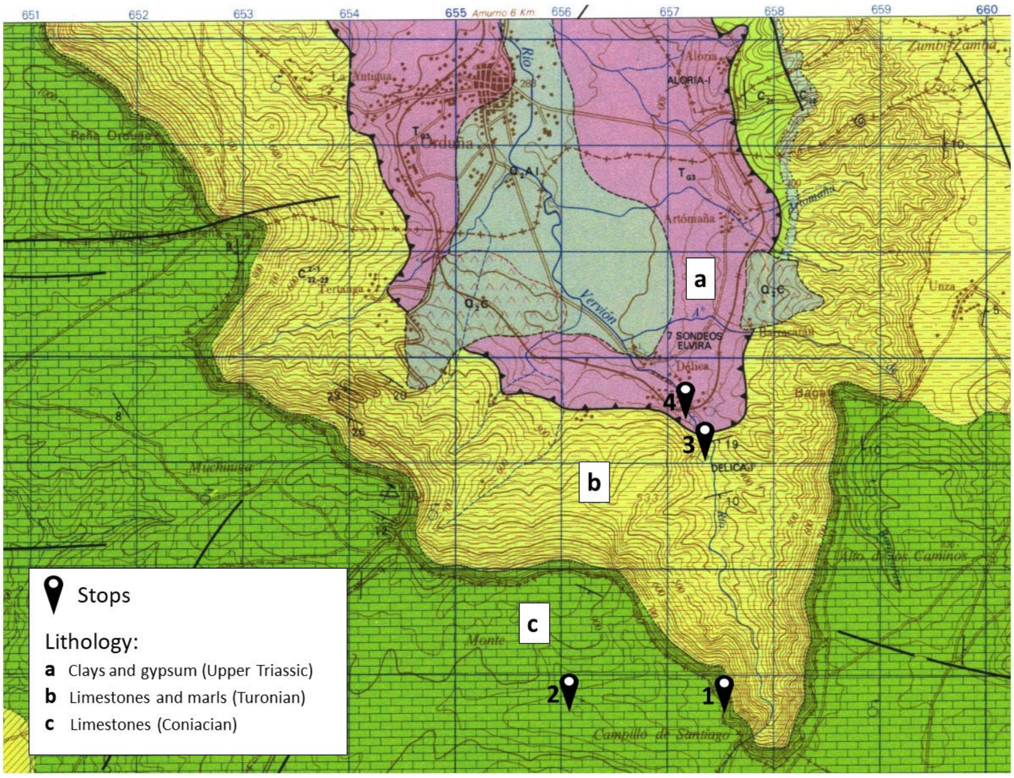


Table 1. Stops made in the fieldtrip and activities carried by PETs in each stop.

Stop number-location	Activities
1 Viewpoint	Observing the cut of the mountain (block of 500 metres high horizontal limestone-marl strata).
2 Karst structures	Searching for evidence to test the hypotheses from session S1 (formation of karst structures). Testing the hipotheses. Formulating hypotheses (how the river gets water).
3 River canyon (vertical marl and limestone strata)	Analysing the lithology. Observing the structure. Formulating hypotheses (vertical disposition of strata).
4 Delika town (outcrop of *Keuper* facies clays and gypsum)	Analysing the lithology. Formulating hypotheses (formation of the rocks; dating all the observed rock formation events in the valley; vertical disposition of strata in stop 3).

The field trip was performed at an early stage of the modelling sequence. For this reason, as Table 1 shows, most of the activities carried in the field aimed that PETs observed the rocks and structures and formulated hypotheses or new and more specific questions around the main two questions posed in the previous session in the classroom, in line with Almquist et al. (2011) about the field trip being a resource for formulating questions, interpreting information and raising hypotheses. The field trip was designed not to be a teacher gives explanation kind but to pursue an active role of the participant PETs (Orion and Hofstein 1994), so that students increase their autonomy (Fedesco, Cavin and Henares 2020). It can be said that they surrendered their expert status (Scott, Boyd, and Colquhoun 2013) and guided PETs to engage in inquiry based activities

(Behrendt and Franklin 2014; Nugent et al. 2012). For this purpose, teachers continously asked PETs to observe, to formulate hypotheses, teachers did not give the answers to the main questions nor explained what they were observing.

In the session following the field trip (S3), PETs ordered the data collected in the field trip spatially and temporally, and represented them on a topographic map of the area. In sessions S4 and S5, the groups constructed an explanatory model for each of the questions (the second question in S4 and the first one in S5). Subsequently, in S6-S8, five groups (B, C, D, G and H) constructed 3D models that addressed the external dynamics (hydrodynamics) model and four (A, E, F and I) did the same for the internal dynamics (diapir) model. The researchers are analysing all the artefacts produced by the PETs before, during and after the sequence to assess the evolution of the models. The results found so far show that the models evolved in a positive way, and that, for example, in the case of the hydrodynamics model, at the end of the sequence, the PETs took into account more material elements, represented more adequately the water in the system, and considered the various flows and interactions in the system (Uskola and Seijas 2019).

Instruments and Methods of Analysis

The data used to deal RQ1 and RQ2 consisted of recordings of the conversations and group discussions of the nine groups in the post field trip sessions (sessions S3 to S8). The average conversation time for all groups was 5h 47 minutes (minimum 4h 37 minutes and maximum 6h 37 minutes).

The recordings were divided among the researchers, who identified and transcribed all explicit references to the field trip. Each researcher transcribed all the references and labelled them taking into account theoretical considerations and previous studies about the competency of use of data, and using constant comparative method to establish categories throughout the data analysis (Lincoln and Guba 1985).

The categories were discussed and reelaborated among the researchers and finally the categories shown in Table 2 were defined. Finally, the categorization of all references was revised to detect inconsistencies. Given that one aim was to assess the impact of the field trip, all the occasions on which a reference appeared, even if repeated, were taken into account. The lowest level (level 0) corresponded to merely mentioning the field trip. References at this level help to get the footprint left by the field trip in PETs, but not their ability to use the data. Level 1 corresponded to a mention of the field trip data, but without either interpreting them or relating them to statements. Ageitos, Puig, and Colucci-Gray (2019), Ryu and Sandoval (2012) and Kelly and Takao (2002) established equivalent lowest levels. In this case, the data obtained in the field trip that could be used for modelling were: a) for the hydrodynamics model: the rocks, dry waterfall, karst structures, water upwellings; b) for the diapir model: the rocks, vertical strata, location of *Keuper* facies with respect to vertical strata. The highest levels corresponded to the most advanced transformations of the Duschl (2008) continuum, that is to say, the use of such data to establish patterns and models, and to propose explanations. In this case, a distinction was made between the references related to the target models (hydrodinamics and diapir) (level 2b), and those that established patterns or were used in discussions unrelated to the target models (level 2a). Examples of the above are shown in Table 2.

Table 2. Categories of use of data from the field in PET group discussions

Level	Example

2b	Establish patterns and explanations (target models)	*Edurne, S5:* Didn't you notice that when we were there [the water] was coming out of the stone? *Garazi, S3:* We first saw this. Then we went down and saw the vertical [strata]. Then we went to the bus and there was plaster and shale. As we found them below, they are older.
2a	Establish patterns and explanations (others)	*Coral, S5:* After all, fields that have less water do dry out. What we saw [the dry waterfall] had no water.
1	Mention data	*Beñat, S3:* As they reacted less than the limestone, we concluded that it was marl.
0	Mention field trip	*Ander, S3:* Let's see, those that were in stop 3.

To address RQ2, each of the references related to the construction of the target models (level 2b) was assigned to one of the stages of the modelling process. The modelling process can be divided into several stages, but different authors use slightly different structures. We used the Modelling Model Diagram (MMD) (Gilbert and Justi 2016; Justi and Gilbert 2002), used in the literature as a reference for both the design of sequences and the analysis of the process followed by the students. Based on MMD, the modelling process is an individual process that includes the definition and/or understanding of the objectives of the model and the interpretation of information to *create* the mental model, the selection of the representation form and its *expression*, the expressed model *testing* through mental or empirical experiments, and the identification of the limitations and scope of the model (*evaluation*).

All transcribed references were analysed separately by two researchers, who identified the modelling operations PETs were making and to what stage of the process they corresponded, that is, if they were formulating hypotheses and creating an initial model, or testing the hypotheses using data from the field, or were involved on deciding how to represent it or discussing its limitations. The assignment of an operation to a stage is not always straightforward, as they can overlap. As most operations were found to be in creation stage, when an action had any feature that fitted into another category, it was highlighted. The identification made by researchers was discussed reaching consensus in the few cases of disparity (less than 15%). Since the objective was to evaluate the role played by the references, repetitions were not taken into account.

With regard to RQ3, the data consisted of the opinions written by PETs about the contribution of the field trip to their learning. The 32 responses were analysed by both researchers. First, we analysed whether PETs simply rated the contribution as good or bad or whether they elaborated on the response, making specific references to the learning process. In the cases in which they extended their response, a content analysis was made by each researcher to identify units (in this case, sentences in which PETs stated the contribution that the field trip had made to their modelling process) and label them according to the operations corresponding to the modelling stages proposed by Gilbert and Justi (2016). The disparities (around 10%) among the researchers were discussed and resolved by reaching consensus.

Results

Use of Data Obtained in the Field Trip

A total of 86 mentions to the field trip were recorded. Their distribution by group is shown in Table 3.

Table 3. Number of mentions to the field trip per group and per level.

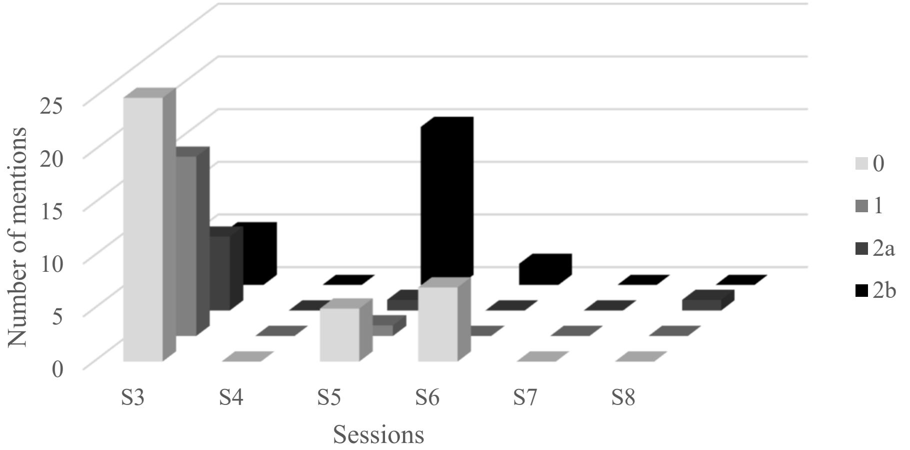
Level	A	B	C	D	E	F	G	H	I	Total
2b	1		1	8	6	2	3	1		22
2a			4		3		2			9
1		4			3		10	1		18
0	1	2	3	11	6	2	8	3	1	37
Total	2	6	8	19	18	4	23	5	1	86

In Table 3, it can be seen that all groups made at least one explicit reference to the field trip. Six of them made less than 10 explicit references, while D, E and G stood out with about 20.

Regarding the typology of the references, all groups mentioned the field trip (level 0) and/or data from it (level 1), and all except B and I made use of such data (levels 2a and 2b). C, E and G used data to identify patterns and as evidence in arguments unrelated to the construction process of the target models. A, C, D, E, F, G and H used them to construct the external or internal dynamics models. There were differences among the groups. As an example, among the three groups with the most references (D, E and G), G did them mainly (78%) in the lowest levels, that is, mentioning the data or just the field trip. In contrast, groups D and E used the data in about 50% of the references.

The distribution of references by session is shown in Figure 3.

Figure 3. Number of mentions to the field trip, by session and category.



As can be seen in Figure 3, session S3, in which the field trip data were reconstructed, presented the highest number of references to the field trip (54 mentions, 63% of the total). In sessions S4 and S5, PETs had to construct explanatory models. In S4, no mention to the field trip was made, while in S5 there were 22 (26% of the total). In S6, on 3D model planning, the field trip was mentioned 9 times, while in S7 and S8, on 3D model construction, it was hardly mentioned at all (one mention).

In session S3, in which most mentions were made, these were at the lowest levels (78% at levels 0 and 1), while the use of field trip data for model construction stood out in S5 (68% at level 2b).

Contribution of the Use of Field Trip Data to Modelling

Table 4 shows the references in which field trip data were used to build the model (level 2b), classified by session and by stage of the modelling process.

Table 4. Number of references in each stage of the modelling process (Gilbert and Justi 2016) by session

Session	Creation	Expression	Test	Evaluation
S3	4 (E, F, G)			
S5	3 (C, D)		5 (A, E, G, H)	
S6	1 (D)		1 (E)	
TOTAL	8 (C, D, E, F, G)		6 (A, E, G, H)	

In session S3, four mentions were differentiated, all of them for *creating* the model. The groups were arranging the field trip data and they focused mainly on building an explanation for the formation of the mountain range. They observed sedimentary rocks strata and group E formulated a prediction related to a hypothesis of how the sedimentation had took place:

> Edurne: You could see the mountain, sedimented all the same. So below it would be all the same.

Based on the position of the strata, group G formulated a hypothesis on their relative age:

> Garazi: We first saw this. Then we went down and saw the vertical [strata]. Then we went down to the bus and there was plaster and shale. As we found them below, they are older.

Groups E and F mentioned that the limestones were formed in an underwater environment.

In session S5, there were eight spontaneous mentions of construction of the hydrodynamic model: three for *creating* the model and five for *testing* it.

The three *creation* stage mentions were in groups C and D. In group C they remembered that the waterfall had no water (‘Coral: What we saw had no water’), which forced them to think about other origins for the river water. Then they tried to formulate hypotheses about how the water passes through the mountain by remembering the spring and sinkhole observed in the field.

> Coral: Imagine that there is a cave, which is what we saw.

Group D also mentioned up to four times the spring and sinkhole to raise their hypothesis of how water circulates in the mountain. On the other hand, they referred three times to the limestone pavement visited, in which several tests had been carried out, in order to incorporate the process of rainwater infiltration into the model.

> David: The gaps between the stones were not because...
> Diana: Yes, the water went in.
> David: Yes, because not only did the water come in through the cave.

The other five references in session S5 were for *testing* the model through mental experiments.

Group A faced difficulties to draw how the water flows from the river to the sea, as they found it challenging to determine where the river emerges. While discussing this, they turned to the memory of the waterfall to test and discard the hypotheses that the river emerged from the waterfall.

In group E, PETs posed many questions in their conversations, and they formulated hypotheses to explain why the river carries water. When they asked themselves where the water came from, they formulated one hypothesis, remembered the field trip and used the data (water coming out of the rocks) to test and validate their hypothesis.

> Elena: From among the stones. The last thing we saw on the excursion was water falling between the stones, right?

The discussion continued, some members had difficulties in assuming that water seeps into the rocks, so the field trip was again recalled to convince peers about the validity of the hypothesis.

> Edurne: Didn't you notice that when we were there [the water] was coming out of the stones?

Group G raised a hypothesis of water being accumulated underground and carried out mental experiments to test it, using the field trip data, the waterfall that had run dry.

Holga formulated a hypothesis based on groundwater. Group members then tested this hypothesis by applying it to what they had seen in the field trip, the spring.

> Holga: Isn't it because there will be groundwater and it comes from somewhere?
> …
> Haizea: Does water always come out of that cave?

In session S6 groups were planning 3D models and two model construction references were given.

Group D worked on the hydrodynamics 3D model. When they began to design it, they went back to the field trip data, tried to make sense of it, organized it and wondered about the formation of the mountain range. This reflected their need for a model, so it was considered to belong to the *creation* stage.

> Daniel: So we went to this waterfall, and we saw that the mountain was all cut off and then we saw the different layers of the sediments, right? And then we were at the bottom of it, which was like the oldest layer. How did that happen? How is it possible that we were in the oldest layer of all and at the top there were newer ones?

Group E was designing the 3D model of diapirism. They tried to link the mental model they had to the visited area. They had constructed the mental model in S4, in which they did not mention the field trip. In S6, they contextualised what they had learnt in S4 on diapirism and in doing so they *tested* their model using the real data from the field.

> Enara: But then, the volcano was where we were, all that?
> Elena: From where we were at the waterfall there was a hole.
> Edurne: And has it disappeared because of salt?
> Enara: In other words, the…, what's there right now, the town, was it all salt or were there other layers?

PETs' Perception of the Contribution of the Field Trip

The 32 PETs indicated that the field trip had contributed positively to their learning and all of them expanded on the response by explaining in what way. It is noteworthy that 26% of PETs mentioned what they saw in the field in order to answer questions related to conceptual knowledge in the final questionnaire.

The number of PETs who indicated the operations of the stages of modelling is indicated in Table 5. The cases in quotation marks refer to cases where they came close to referring to a certain stage, but, as explained below, the explanations were incomplete.

Table 5. Number of PETs indicating operations of each of the stages of modelling

Creation	Expression	Test	Evaluation
31	"3"	"4"	0

As seen in Table 5, 31 PETs commented that the field trip had been useful for the creation stage operations of the modelling process (Gilbert and Justi 2016). For example, they mentioned that it had been helpful for introducing themselves to the topic (three PETs), asking themselves questions (two PETs). 9 highlighted specific data they had observed in the field (rocks, arrangement of strata), and most (27) mentioned that it had helped them to understand the process. Six mentioned that the field trip had helped them to visualise, an important operation in the *creation* stage, especially in Geology (Mogk and Goodwin 2012), linked to that of *expression*.

Regarding the stage of *expression* in the modelling process, no answers were found in which PETs explicitly argued how the field trip had been useful to them in choosing the modes of representation or defining the codes of representation they would use. However, three PETs (*Amaia, Bea, Heidi*) mentioned that it had been valuable for them while making the 3D model.

> Heidi: Interiorising concepts. Getting to know the area so as to be able *creation*
> to understand and make the 3D model better. *"expression"*

The same can be said about the operations of the testing of the model stage. Four students (Ainhoa, Bea, Coral, Helena) mentioned that they had established relationships or connections between what they had discussed in class afterwards (Bea referred specifically to the 3D model) and what they had seen in the field. However, none of them explained how they had made these connections.

> Helena: I would say that the field trip has been useful, because thanks to it
> I have been able to relate what we worked on in the classroom before "*test*"
> and after the field trip to a real model. That is, we have seen how they
> happen in reality, and that has meant that we have a model in mind. *creation*
> Thus, I have interiorised better the concepts we have worked on.
> Bea: The approach to reality always helps to see that the concepts are *creation*
> useful and real. At first it was difficult to make relationships, but when
> I made the 3D model I tried to relate it to what was seen in reality and I *"expression", "test"*
> understood the process more easily and better. *creation*

No reference to the evaluation phase was identified.

Discussion

This work provides some evidence to state that the field trip carried out at the beginning of a modelling teaching sequence during a PETs training program was a valuable resource for developing scientific practices such as use of data and modelling. The first research question (RQ1) focused on how PETs referred to the field trip throughout the subsequent activities. Every group referred to field data in their discussions without being explicitly required to. 86 mentions may seem small quantitatively, but qualitatively they are proof of the role of the field trip in the learning process and that it was not a mere social act as it is often the case (Orion and Hofstein 1991). The data were not only mentioned but they were used while constructing explanations, indeed 7 of the 9 groups made mentions at the highest levels for performing this practice (Duschl 2008), that is, they used the data to establish patterns, develop arguments, and use them in explanations. Using data and transforming data into evidence is challenging (Ageitos, Puig, and Colucci-Gray 2019; Monteira and Jiménez-Aleixandre 2016; Ryu and Sandoval 2012), even for teachers (Crippen 2012; Sampson and Blanchard 2012), specially in the case of authentic (multiple, low-quality, complex) data (Duncan, Chinn, and Barzilai 2018) as the data collected in the field can be. This study makes a contribution to the broader research about how teachers use data and what difficulties they face, requested by researchers (i.e. McNeill et al. 2016). Many authors have pointed out that teacher education should provide opportunities for teachers to engage in authentic inquiry, modelling and data use activities (i. e.Windschitl 2003; Zembal-Saul 2009), including opportunities to theorise from data (Crippen 2012). In our work, PETs were given the opportunity to use data from the field as evidence, to theorise from data, to build models from data.

This study is a case study and the results are not generalizable. Nevertheless there are some results that deserve to be highligted and discussed, so that they can be considered by science educators.

First, the performance for the competence of data use showed differences along the groups and sessions. Let´s take the different results in S4 (diapirism) and S5 (hydrodynamics) each of them designed for addressing one question posed in the field trip and creating a first group model. In S4 no reference was made to the field trip, while in S5 6 of the 9 groups made 22 references, 68% of which were used to construct the external dynamics model. Although the time dedicated to small group work in S4 was half that of S5, this difference does not account for the total absence of references. In the case of diapirism (S4), PETs used the maps produced in S3 based on direct field data. In the case of hydrodynamics (S5), PETs used the data observed in the field. There was no previous elaboration of data, so this may explain the higher reference to first hand data in S5. Another difference lies in the processes involved in the models. The process of diapirism is often unknown to laypeople. At the end of session S4, students acknowledged that they had not heard about it. In the extract from group E in S6 it can be seen that linking the theory to what they had seen was demanding for them, whereas for the hydrodynamics model, data from the field where used at an initial stage of the modelling process by PETs to *create* the model. Differences in data use performance due to the different nature and complexity of the topic were also found by Sandoval and Millwood (2005). Indeed, Sadler and Fowler (2006) proposed a Threshold Model according to which there are at least two thresholds that correspond to minimum levels of knowledge necessary to reach a certain level of argumentative quality.

The second result to be discussed is how the data where used for modelling. The field took place at the beginning of the modelling process, and the activities carried in the field where in the *creation* stage. Nevertheless, PETs were expected to use field data in the subsequent stages. The results show that, when PETs used field data for their model building process, they did it mainly in operations related to the *creation* stage but also in the *test* stage defined by Gilbert and Justi (2016).

It seems that the objective of the field trip being a resource for formulating questions, interpreting information and raising hypotheses (Almquist et al. 2011) was fulfilled. Although possibly all the groups bore in mind what they had observed while creating their model, the results show that more than half of them did so explicitly. But they also used data to *test* the hypothesis they were formulating. Field data were in some cases used for testing models as the results of four groups show. In all those cases one of the components of the group went to what observed in the field when the group was facing some kind of difficulty, such as disagreements or doubts, in order to build arguments to convince their peers of a certain hypothesis being valid or not. That is, PETs used the field data as evidence for judging their models, as claimed by Egger (2019). The results show that some of the data observed in the field were key: the waterfall not carrying water and the water coming out from the rocks in the case of hydrodynamics model. The first put PETs in the need for searching for another origin for the river, the second gave them a clue of water being filtered inside the rock formation.

Among the modelling operations, the lack of operations in the *expression* stage is noteworthy. Although the materials and structures observed in the field were part of the representation (Egger 2019), no operations of the expression of the model were identified in group discussions. It is possible that the groups took into account the observed materials and structures while choosing materials and deciding how to build the 3D model, but no evidence was found in the group discussions devoted to those issues. Indeed, PETs hardly justified their decisions at all, and their conversations were focused on purely manipulative issues. In the future, PETs should be required to make explicit their justifications for their decisions about the 3D model.

Finally, the perception of PETs about the usefulness of the field trip for their learning process was addressed by RQ3. PETs perceived it as useful for the model construction process. This is coherent with the results obtained in the study by Orion and Hofstein (1991), in which the oldest students (17 years old) did value the field trips for their learning process, compared with the youngest (14 years old), that valued them as social events. In fact, 97% of PETs indicated the field trip being useful for understanding objectives, asking questions, interpreting information, visualising and understanding the processes, that is, for *creating* the model. As previously discussed, these operations were indeed carried out. Concerning the *expression* stage, the fact that only three PETs referred to the 3D model in a vague way is consistent with which has been discussed for group discussions. In the case of the operations to *test* the model, PETs did not show a high degree of usefulness. The failure to mention operations of *expression* and *test* stages may show that PETs had a limited understanding of the modelling process, especifically that they did not sufficiently appreciate the importance of the use of evidence in the process. A limited understanding of modelling was also observed by Vo et al. (2019) in a three-year longitudinal study with four primary school teachers. They found that teachers offered few opportunities to evaluate models compared to opportunities to use them, and that this corresponded to their conception of modelling. Their conception and practice changed as a result of the training they received, although, even in the third year of the study, there was no consideration of the role of evidence. The relationship of models and evidence is strong, the model is built on the use of evidence, and the information available becomes evidence in the light of the model (Koslowski et al. 2008). In fact, modelling is, as several authors say (Böttcher and Meisert 2011; Mendonça and Justi 2013; Passmore and Svoboda 2011), an inherently argumentative process, but considering the role of evidence is, as Vo et al. (2019) observed, challenging even for teachers.

Evidence-based testing of the model in this sequence of activities was partly done through mental experiments in which students converted the field data into evidence, but they did not show awareness of this. The results of the study increase the evidence to claim that it is necessary to incorporate scientific practices in teacher training (Bybee 2014; McNeill et al. 2016; Vo et al. 2019; Windschitl 2003) but also that these practices are accompanied by critical reflections to improve PETs epistemic knowledge and considerations. The students' reflections on the modelling process have already been pointed out as scarce compared to their reflections on the models (Schauble 2018). The same could be said about using data. Reflection on the framework proposed by Duncan, Chinn, and Barzilai (2018) on the nature of evidence or on the transformations from data to explanation (Duschl 2008) could help improve epistemic knowledge about evidence and give value to the use of authentic evidence, which can be obtained, for example, from field trip data.

More studies should be carried out to highlight the possibilities offered by field trips for the development of scientific practices, but the results show that the modelling process carried out by the PETs was enriched by the authentic data from the field that they used as evidence. PETs not only referred to the data from the field trip, but also used it in group discussions when they were creating the model or even testing it. Furthermore, they used data from the field as evidence without being explicitly required to, but because they felt it was necessary, because they considered the field to be a valuable criterion for evaluating the knowledge that they were constructing. Thus, the results of this study provide further evidence to claim, along with other studies (e.g. Fedesco and Cavin 2020; Mogk and Goodwin 2012), that field trips are useful for understanding and visualizing geological phenomena. Nevertheless, results also show that the chance for PETs to use the data from the field trip for modelling depends on the phenomenon to be modelled. That is, PETs need to be minimally familiar with the phenomenon to be able to use the data (Sadler and Fowler 2006). Moreover, results show that PETs did perceive the field work as valuable for their learning, so it can be the case that in the future they carry outdoor activities despite the costs of money and time (Carrier, Tugurian, and Thomson 2013). Experiencing field trips during their training can help teachers develop the knowledge and confidence to use this valuable context in their future (Nugent et al. 2012; Tal and Morag 2009). Despite the limitations, the study provides evidence to claim that the field trip was more than a social event, that it constituted a resource for the development of scientific practices such as use of data and modelling.

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