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Pre-service teachers' perceptions about the contributions of field work and construction of a physical model to modelling aquifers

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Abstract

Teachers are crucial to implement innovative activities in the classroom and to make them effective for their students' learning. Teachers' beliefs have been found to condition the extent to which and the way in which they carry out certain activities. This study analyses the beliefs of 73 pre-service teachers (two cohorts) about two resources (fieldwork and physical model) used in an aquifer modelling sequence in which they had participated. Their perceptions are compared with the hypothetical purposes of the resources in a modelling process. The data analyzed were the written reflections at the end of the activities. Both resources were rated very positively. Practically all participants referred to contributions to learning and many made metacognitive reflections. The results show that both resources met the expectations about their contribution to modelling. The implications for future design of modelling activities are discussed.

Keywords: field trip, modelling, perceptions, physical model, pre-service teachers

INTRODUCTION

Teachers' beliefs have been found to have a strong influence on the decisions they make about what content to teach and how to teach it in the classroom. Beliefs about teaching make up an important part of teachers' thought processes (Fang, 1996), and, consequently, they influence teachers' practice by guiding their behaviors and decisions in the classroom (Vartuli, 2005). Specifically, it has been shown that beliefs in the value of a certain teaching practice support and predict the implementation of that practice in the classroom (Areljung et al., 2021; Ng et al., 2024; Yang et al., 2023), and ultimately affect his/her students' learning (Fang, 1996). For example, Areljung et al. (2021) examined 45 science class sessions of early childhood and primary school teachers in Sweden, and they found that the teachers' beliefs about the role of drawing in science learning are key. Thus, the few teachers who showed the perception that drawing is helpful for learning science, were the ones who used drawings for science learning in the classroom. Yang et al. (2023) also concluded that the belief system of the teacher conditions the opportunities given to students. They observed and interviewed two teachers' mathematics teaching and found that only when the teacher has strong beliefs about student-centered and inquiry-based learning, students encounter opportunities to develop critical thinking and construct their own understanding of mathematics. Ng et al. (2024) also found a relationship among the beliefs of 187 elementary teachers about teaching basic writing techniques and their use while teaching writing to low socio economic status students. Most teachers believed that writing instruction for those students should focus on teaching writing mechanics and not advanced techniques and did so. Nevertheless, the results of their study showed that this link between beliefs and practices was moderated by self-efficacy perception, and that when this was high, more opportunities were given to students despite the limited beliefs.

It has been noted that teachers' experiences in their training contribute to the shaping of beliefs about the contribution of specific teaching methods (Carrier et al., 2013; Maiorca et al., 2023; Windschitl, 2003) but also the beliefs about self-efficacy and the construction of a professional identity (Maiorca et al., 2023). Windschitl (2003) studied the implementation of inquiry activities by trainee secondary school teachers and found that the key factor in implementing them was that they had experienced inquiry activities themselves, for example,

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Contribution to the literature

- While previous studies address teachers' beliefs about the contributions of particular strategies, none have addressed perceptions of such tools in a modelling process in which they have participated. This study addresses pre-service teachers' (PSTs') perceptions about the contribution of the fieldwork.
- It addresses PSTs' perceptions about the physical model to the whole process of modelling the formation and functioning of an aquifer.
- Given that modelling involves moving from the particular reality to the model and to the general theory (and vice versa), the study analyses how PSTs perceive that the fieldwork has contributed to moving from reality to the model and how they perceive that the representation in the form of the physical model has contributed to the creation of the mental model.

in their initial training. Similarly, Zembal-Saul (2009) pointed out the need for novice teachers to experience learning scientific concepts in the way they will have to teach them. Such experiences should include scientific practices (National Research Council [NRC], 2012; Osborne, 2014), including modelling.

Modelling can be defined as the construction, use, evaluation and revision of scientific models (Schwarz et al., 2009). Models can be defined as representations of reality used for explaining and predicting scientific phenomena (Gilbert et al., 2000). The representation of the mental model is one of the stages of the modelling process (Gilbert & Justi, 2016; Schwarz et al., 2009). It is intentional, and the intention can be communicative, cognitive or operational (Adúriz-Bravo et al. 2005), and can be made by five modes according to Gilbert (2005): concrete or material (e.g., a plaster representation of a section through geological strata), verbal (spoken or written description of the entities and the relationships between them in a representation), symbolic (e.g., chemical symbols and formula and equations), visual (diagrams, graphs, and virtual models), and gestural (body movement, embodiment).

Three-dimensional models are extensively used in model-based learning to mediate between world phenomena and theoretical models (Adúriz-Bravo et al., 2005; Oh & Oh, 2011). Bahamonde and Gómez (2016), Gómez et al. (2007), and Uskola et al. (2022) highlighted the effectiveness of building physical models for developing a models related to the living being (ecosystem and human digestion), and García and Mateos (2018) concluded that students who had built a physical model developed their ability to visualize human anatomy more than those who had visualized images. The use of physical models in geology has been found as particularly relevant (Dickerson et al., 2007; Donaldson et al., 2020; Miller & Kastens, 2018; Seijas & Uskola, 2022; Torres & Vasconcelos, 2016), as it is a discipline that deals with processes that are difficult to observe. In chemistry, Maia and Justi (2009) found that, throughout the modelling process, the physical models contributed to the expression and communication of the students' models and to the development of the mental model itself.

Physical model-based modelling promotes not only the learning of the elements and the structure, where they are located, but also the related relationships and processes (García & Mateos, 2018; Steer et al., 2005). Three-dimensional representations help students reason spatially about the topic (Dickerson et al., 2007), establishing relationships between system components and representing unobservable mechanisms in an observable way (Forbes et al., 2015). Searching for correspondences and non-correspondences between the physical model and reality is "an often overlooked component of modeling practice" (Miller & Kastens, 2018, p. 641). The field trip has been found to constitute a very valuable educational resource in order to compare the physical model with the Earth system (Fedesco et al., 2020; Mogk & Goodwin, 2012; Seijas & Uskola, 2022; Uskola & Seijas, 2023). Data from the real Earth can be obtained during field work (Almquist et al., 2011), which affective and cognitive potentials have been addressed (Aguilera, 2018; Behrendt & Franklin, 2014). Besides, fieldwork gives a unique opportunity to visualize the reality to be modelled. The element studied in the field is observed from an internal spatial position, as the observer is spatially immersed in it. When students physically move into the object of study, they get a unique and irreproducible perspective (Mogk & Goodwin, 2012). Thus, geology students in the study of Fedesco et al. (2020) indicated that fieldwork allowed them to see the "bigger picture". For Egger (2019), 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).

Despite this potential of physical models, most of the time that they are used in teaching, especially in geology, they are not constructed by the students as expressions of their mental models but are rather physical models that the teacher shows in an expository manner (Gray et al., 2011; Torres & Vasconcelos, 2016). Moreover, when students construct physical models they use them to communicate ideas, but not to create knowledge, although "some of the most profound learning opportunities arise if and when students critically examine the correspondences and non-correspondences between the classroom model and the Earth system" (Kastens & Rivet, 2010, p. 122).

As noted, teachers' perceptions and beliefs play an important role in their professional practice. With regard to field trips, it has been found that after doing them, in-service and PSTs value their importance more highly (Behrendt & Franklin, 2014), feel more confident to go on them and to carry them with students (Carrier, 2009; Nugent et al., 2012). Sáez-Bondía and Cortés-Gracia (2019) found how reflective work carried out in several stages with videos of fieldwork they had conducted led a group of trainee teachers to deepen their pedagogical considerations about the use of fieldwork.

Regarding the use of modelling, Vo et al. (2019) highlighted the lack of studies on primary school teachers' difficulties in modelling and promoting modelling. In a three-year longitudinal study, they followed four primary school teachers. They found that they provided few opportunities to evaluate models compared to opportunities to use them, and that this corresponded with their conception of modelling. Their conception and practice changed as a result of the training they received, although even in the third year they still showed shortcomings, such as a lack of consideration of the role of evidence. As Guy-Gaytan et al. (2019) pointed out, there is a difference between "learning models" and "engaging students in modelling". They detected some "pseudo-modelling" practices and concluded that teacher training should prepare and support teachers for situations that typically occur in the classroom, for example, the appearance of erroneous but useful ideas, so that teachers can take advantage of them and not just ignore them. In the study by Jiménez-Tenorio et al. (2016), PSTs rated the usefulness of various analogue models for learning and teaching. They valued the three-dimensional models more than the computer models, which the authors attributed to the possibility of manipulation and the feeling of being the protagonists. Miller and Kastens (2018) also addressed the development of knowledge and beliefs of teachers, in their case, according to the use of physical models. They analyzed the difficulties in developing modelling sequences during an academic year with secondary school teachers, and after a training program during the summer, they analyzed the improvement in teaching practice in the following year. They found that during the first year, teachers used the models only as a tool to demonstrate their previous explanations of natural phenomena. Sometimes students were asked to manipulate the models, but only as part of a prescribed activity that the students had to replicate in order to see what they were supposed to see. After the teacher training program in the summer, the teaching methods improved substantially: Teachers emphasized that students should make connections between the model and the reality, use the models to answer questions about the phenomena, as well as to interpret new data, and use the models as a way to learn about the phenomena.

While the studies mentioned above address teachers' beliefs about the contributions of particular strategies, none have addressed perceptions of such tools in a modelling process they have experienced. This study addresses PSTs' perceptions about the contribution of the fieldwork and the physical model to the whole process of modelling the formation and functioning of an aquifer. That is, given that modelling involves moving from the particular reality to the model and to the general theory (and vice versa) (Sensevy et al., 2008), it analyses how PSTs perceive that the fieldwork has contributed to moving from reality to the model and how they perceive that the representation in the form of the physical model has contributed to the creation of the mental model. The research questions addressed are:

RQ1. What are the perceptions of PSTs about the field trip and the physical model made in a modelling sequence?

RQ2. How do the contributions of the field trip and physical model perceived by PSTs relate to their hypothetical contributions to the modelling process?

MATERIALS & METHODS

This section describes the sequence designed and the methodological aspects of the analysis. The research was mainly based on the interpretative analysis (Erickson, 1986) of qualitative data (written reflections of PSTs).

Participants & Activity Sequence

The activity sequence was carried out during the first term of the academic years 2018/19 (year 1) and 2019/20 (year 2). The participants were 41 and 39 PSTs, respectively, with an average age of 22 and working on the subject 'new trends in science didactics' of the 4th year of the primary education degree. The first author was the teacher. PSTs worked in groups of three-five people (nine groups in year 1 and eight groups in year 2) and spent 16 hours in class, four hours on field trips and time outside class to complete assignments. All PSTs 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 worked on some geology concepts such as plate tectonics and geomorphology processes. The participants were selected for convenience, and they were those that gave their consent for their productions to be used for research in the context of a research project M10_2019_146 approved by the university ethics committee. Since the teacher was one of the researchers involved in the project, the committee made it a condition that the students' informed consents for the use of the data be kept confidential until the subject file was closed. The condition was fulfilled. The project includes a data treatment declaration that fulfills European Union legislation on data protection. Participants' names were replaced by pseudonyms: PST1-1 to PST1-41 for those in year 1 and PST2-1 to PST2-39 for those in year 2.

The sequence was designed by both authors that played overlapping roles of researchers and educators (Bulterman-Bos, 2008) and included a field trip and the construction of a physical model. The valley visited in the field trip has a circular morphology because 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 certified strata, and they form some 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.

This context was used for developing understanding about diapir formation and the aquifer model. In year 1, the first session was devoted to the formulation of hypotheses while viewing photographs of the area. The field trip was carried out in the second session. Teachers asked PSTs to observe, to formulate hypotheses, teachers did not give the answers to the main questions nor explained what they were observing. Following the field trip, PSTs sorted the data collected in the field trip spatially and temporally and represented them on a topographic map of the area. Subsequently, the groups constructed physical models. The most significant modifications in year 2 sought to address the issue that in year 1 there were few opportunities for PSTs to revise the physical models and also to use them to make predictions and revise their mental models. In contrast, in year 2, the groups started to build a physical model at the very beginning. Therefore, on the field trip, they were asked to evaluate and revise this first 3D model. In addition, the teacher asked each group to constantly evaluate and revise their physical model in the subsequent sessions, focusing their attention on the evidence from the field and on the previous representations (drawings) that they had previously made themselves.

Research Data & Analysis

The data consisted of the opinions written by PSTs about the field trip and the physical model. Specifically, in line, PSTs were asked to reflect on the contribution of the activities to their learning process. Thus, at the end of the sequence, participants were administered a questionnaire that included open-ended questions in which they expressed their final models and two open-ended questions in which they expressed their perception about the contribution of the activities to their learning process answered the questions, in line with the proposals of Hatton and Smith (1999) and Mena-Marcos et al. (2012): "Q1: In this sequence we have done, how do you think the trip has helped you to learn?", "Q2: In this sequence we have done, how do you think the model has helped you to learn?" The answers of 32 and 35 PSTs in year 1 and year 2, respectively, for question Q1, and 38 and 35 PSTs, respectively for Q2, have been considered. The difference in year 1 is due to the fact that six PSTs who answered Q2 had not attended the field trip.

All responses were read and analyzed by two researchers. To address RQ1, each response was classified as a positive or negative rating. A response was considered positive when it contained adjectives or validations that indicated that the activity was valued as a learning facilitating activity. Responses were classified attending to the strength of that validation. Thus, the use of superlatives or the use of the first person (Granit-Dgani et al., 2017) were considered. Positive statements included the use of adjectives such as *useful, valuable, relevant* (positive 1), sentences in the first person indicating that it had been helpful (positive 2), adjectives and expressions in superlatives such as *essential, very significant, fundamental, necessary, the best way* (positive 3). The responses in which participants did not use any of the mentioned expressions but indicated that the activity had contributed to learning were also considered as positive (positive 0). Negative responses were those in which participants stated that the activity had not contributed much or that they would have learnt better in another way.

Allusions to the learning process (e.g., seeing, understanding, analyzing, representing, and drawing conclusions), to metacognition, to knowledge of a resource for teaching in their professional future, and others (e.g., improving group work and motivation) were identified. In those related to learning, verbs and operations corresponding to the revised Bloom's taxonomy (Anderson & Krathwohl, 2001) were identified. The categories and examples used are shown in **Table 1**.

With regard to RQ2, the operations that, according to Miller and Kastens (2018), scientists perform when using dynamic models to construct knowledge were considered. These researchers pointed out that scientists make observations, which they then interpret as outcomes of processes that they represent in dynamic models. The models are then tested, evaluated and improved through comparison with the data obtained.

Regarding the field trip, it should play a role in various of the operations mentioned by Miller and Kastens (2018), for example, in data collection (F1 in **Table 2**) and interpretation (F2) of the phenomenon to be modelled (Sensevy et al., 2008), and in the comparison of the representation with reality, being a reference for constructing the physical model (F3) and for evaluating it (F4). Thus, the operations listed in **Table 2** were identified in the students' perceptions of the usefulness of the field trip.

Table 1. Categories for analysis of contributions of physical model & field trip as perceived by PSTs

Category	Example
Learning	
AK1 remember	PST1-10 (field trip): (…) It has been useful to learn new things and to remember things I already knew.
AK2 understand	PST2-11 (physical model): (…) Also to learn what water table is & why it forms at one height or another. In addition, I have realized that river level & water table are directly related to each other.
AK3 apply	PST1-9 (physical model): The part of the physical model has been essential, to really put into practice what we have learnt. In my case, I had to represent the strata, and it was a real headache to do it, because we wanted the whole process to turn out well, respecting the diapiric process (…).
AK4 analyze	PST2-4 (physical model) It has helped me to draw out my ideas, to analyze and put into practice what I have learnt, to come to new conclusions.
AK5 evaluate	PST1-6 (physical model): Physical model, apart from having fun & working in a different way in a group, it gave me option to test my knowledge. It was an excellent way to test my knowledge of subject.
AK6 create	PST2-9 (field trip): (…) At first I thought that the mountain was made up of soil but after the trip to Orduña I realized that it is made up of rocks.
Metacognition	PST2-28 (field trip): After the field trip, I was able to see what limestone looks like and what changes it can undergo. Before doing the activities, I thought that the limestone was impermeable and that the water passed through pipes in the mountain. I also thought that the aquifers were holes in the middle of the mountain and that water accumulated there. Now I know that aquifers are places where water accumulates on top of clay or impermeable material.
Resource for teaching	PST1-15 (physical model): Making physical model has been very useful, both for a better understanding of scientific concepts, & to see how important it is to do this type of work with our students in future.
Others	PST2-4 (field trip): To look for methods of knowledge construction (didactics). In future I want to use a dynamic method. In addition to developing learning, it also serves to improve classroom climate.

Table 2. Contributions of field trip related to modelling in PSTs' perceptions

Contribution	Example
F1 observing, collecting data, & getting closer to reality	PST2-16: (…) Different types of rocks, clays and limestones, which are permeable and impermeable. In addition, we were able to observe how the layers are formed when we were at the first viewpoint, i.e. we could see that the layers were horizontal. In addition to this, at the third stop it became clear to us that there may be groundwater.
F2 interpreting data on processes	PST1-14: (…) Field trip helped us to see these situations in reality, and to reflect on what we see today and to draw conclusions. From my point of view the field trip leads you to think, to think about why things are the way they are and to clarify the ideas you have in mind.
F3 reference for making physical model	PST2-23 (…) Within this sequence, the field trip was useful to analyze & observe rocks well, & also to observe well the materials that appear in reality of physical model that we had to make.
F4 reference for evaluating physical model	PST1-8: I would say that the field trip has been useful, because it has given us the option to, through it, be able to relate what we have worked on in class both before going and after going to a real model (…)

Table 3. Contributions of physical model related to modelling in PSTs' perceptions

Contribution	Example
M1 understanding to represent	PST1-1: After all, understanding the process was fundamental, in order to be able to represent it, to be able to reflect on the options given by the materials and to be able to represent the process live (to put it into practice with real water). (…)
M2 representing to communicate	PST1-13: It's not so easy to embody what you have in your head. This was the biggest difficulty. Through the physical model I could explain what I understood.
M3 representing to understand	PST1-3: (…) In my opinion the physical model was more useful than the field trip. In fact, by representing in the physical model what you have learned, you realize the process, and also what you do not understand. This is very important for meaningful learning.

Regarding the physical model, it has been studied whether PSTs perceived it solely for knowledge communication (M2 in **Table 3**) as found by Kastens and Rivet (2010) or whether they refer to the relationship between representation and knowledge construction (M1 and M3), as corresponds to a modelling process (Adúriz-Bravo et al. 2005; Gilbert et al., 2000; Maia & Justi, 2009; Miller & Kastens, 2018).

Table 3 shows the categories identified. **Figure 1** is a schematic representation of the hypothetical contributions of the field trip and the physical model to the modelling process.

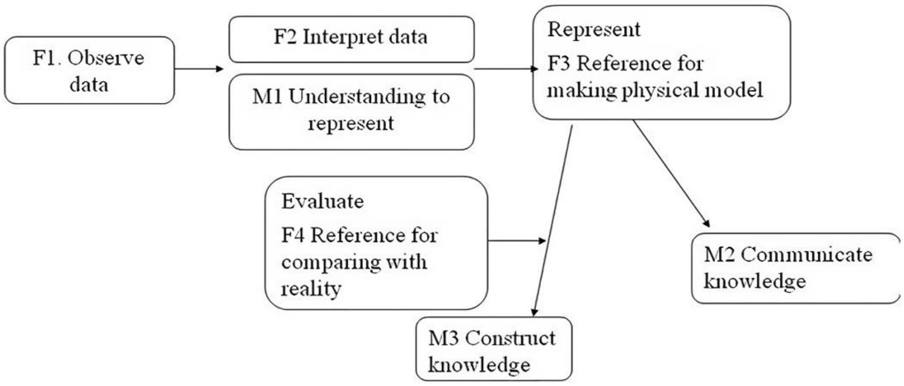

Figure 1. Diagram of hypothetical contributions of field trip &e physical model to modelling process (adapted from Miller & Kastens, 2018)

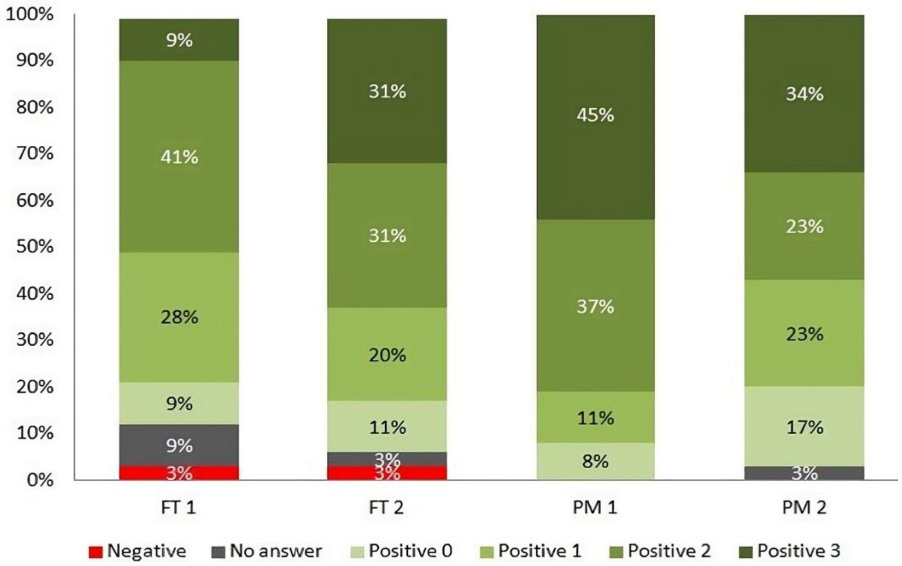

Figure 2. Percentage of PSTs that showed a certain opinion on physical model & field trip each year (PM 1: Physical model year 1 & FT 2: Field trip year 2) (Source: Authors' own elaboration)

RESULTS

PSTs' Opinions About Field Trip & Physical Model (RQ1)

Figure 2 presents the overall ratings of the physical model and the field trip in both years. As can be seen, both activities were rated very positively with only one negative opinion each year regarding the field trip. The ratings that used superlatives when mentioning the physical model (both years) and the field trip in the year 2 were used by more than one third of PSTs.

Figure 3 shows the percentage of PSTs who, for each activity and year, mentioned each of the categories of the activities' contributions. As can be seen, almost 100% of PSTs mentioned that both physical model and the field trip contributed in some way to their learning process.

Figure 4 shows these categories ordered according to the revised Bloom's taxonomy (Anderson & Krathwohl, 2001). The next category was metacognition, with percentages around 20% and with an increase in the model in year 2 compared to year 1.

Few references were found to other types of contributions, such as motivation, improvement of climate, group work and even less to being a resource for teaching.

PSTs' Perceptions About Contribution of Field Trip & Physical Model to Modelling (RQ2)

Figure 5 shows the percentage of PSTs that each year referred to the various hypothetical contributions of the field trip to modelling.

As can be seen from **Figure 5**, the main perceived contribution of the field trip to modelling was the *observation* and collection of data, the experience of the phenomenon and the approach to reality.

About half of PSTs (slightly less in year 1 and slightly more in year 2) mentioned *interpreting* such data, looking for explanations, making hypotheses. The responses of PST1-30 and PST2-13 show how the questions posed by the teacher and some of the observations, respectively, led them to do so:

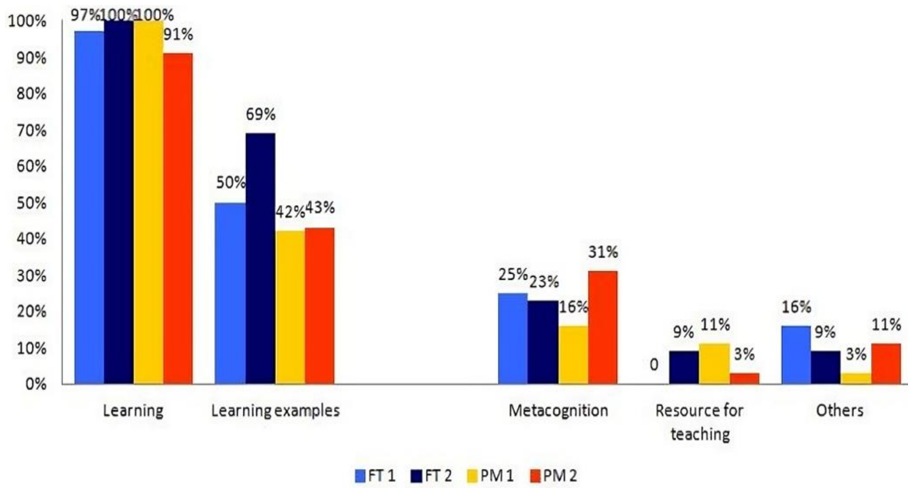

Figure 3. Percentage of PSTs in both years in each of contribution categories (PM 1: Physical model year 1 & FT 2: Field trip year 2) (Source: Authors' own elaboration)

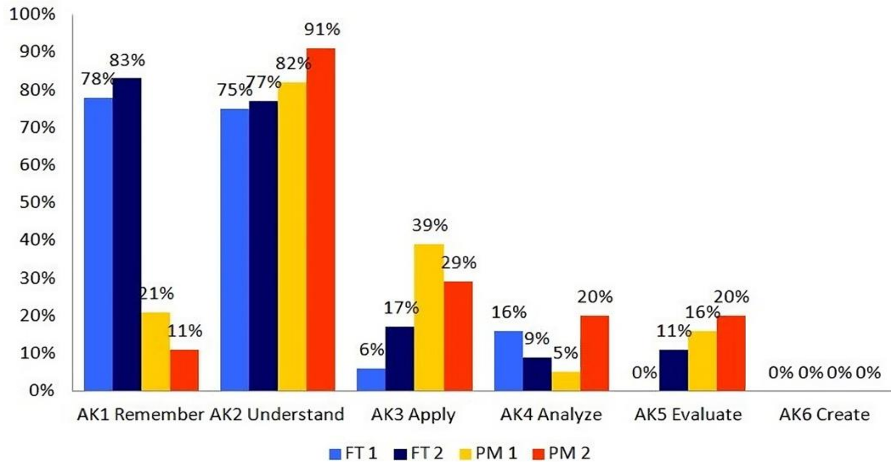

Figure 4. Percentage of PSTs from both years in each of categories of revised Bloom's taxonomy (Anderson & Krathwohl, 2001) corresponding to learning contributions in PSTs' perceptions (PM 1: Physical model year 1 & FT 2: Field trip year 2) (Source: Authors' own elaboration)

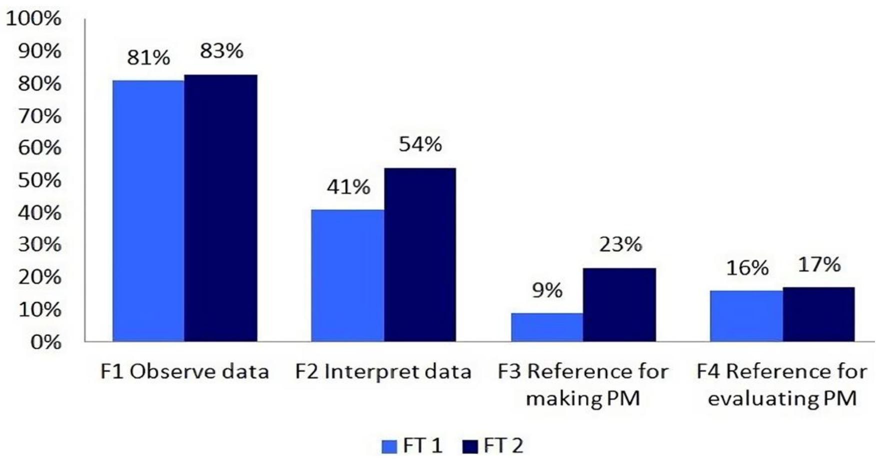

Figure 5. Percentage of PSTs that each year referred to various hypothetical contributions of field trip to modelling (PM 1: Physical model year 1 & FT 2: Field trip year 2) (Source: Authors' own elaboration)

> "I had already been there, but the first time I only saw the landscape and what is visible. The second time, however, when I went with the class, [the teacher] raised a lot of questions and I saw things in a different way. We tried to make sense of the questions and for that we used evidence and the scientific method (…)" [PST1-30].

> "(…) Finally, seeing the dry waterfall has led us to take a deeper look at the reasons why the river holds water" [PST2-13].

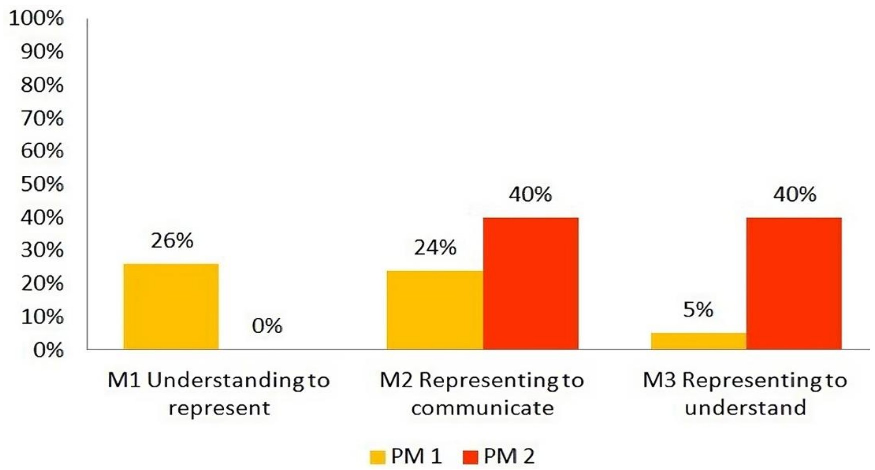

Figure 6. Percentage of PSTs that each year referred to various hypothetical contributions of physical model to modelling (PM 1: Physical model year 1 & FT 2: Field trip year 2) (Source: Authors' own elaboration)

Smaller percentages alluded to what was seen in the field trip as a *reference for making the model* (e.g., PST2-21) or *for evaluating it* (e.g., PST1-21).

> "(…) In addition, it gave us the opportunity to see how to make our physical model. In fact, the field trip was the way to make our final product, to get the knowledge there personally" [PST2-21].

> "(…) At first I did not see the relationship very well, but when I made the physical model I tried to relate it to what I saw in reality, and I understood the process more easily and better" [PST1-21].

Figure 6 shows the percentage of PSTs that each year referred to the various hypothetical contributions of the physical model to modelling. As can be seen from **Figure 6**, in year 1 the main idea in PSTs' opinions was that having to represent (whose objective 24% relate *to communicating* knowledge) makes it necessary *to understand* the processes prior to representing them. This is observed in the response of PST1-33.

> "(…) Before starting to build the physical model, it is necessary to be clear about what and why you want to represent, and this leads to work and internalize these concepts in a manageable way" [PST1-33].

References to the contributions of the *representations to both communicating and constructing* knowledge were more abundant in year 2 than in year 1. In fact, references to *representing to construct knowledge* increased from 5% to 40%. In the response of PST2-15, it can be observed that at the beginning PST2-15 relates the physical model *to communicating knowledge*; but later PST2-15 recognizes that some of the knowledge was constructed thanks to the model. These two ideas are also reflected in the reflection of PST2-33. PST2-16 specifies how the concept of water table emerged only after making the model, in line with a perspective of *representing to construct knowledge*.

> "By making the physical model, I have been able to capture what I have internalized in this process. It is true that I have understood some concepts after making the model, and that at the beginning I had some misconceptions. For example, I was not very clear about the functioning of an aquifer, but after making the physical model I have had the opportunity to understand how it works" [PST2-15].

> "Making the physical model has helped me a lot. It is true that until we finished the model I did not understand how the aquifer mechanism works. In fact, although I knew how I wanted to represent the physical model, I knew what parts it had to have, and I understood why I had to do it that way, I did not understand it until I finished it and saw it with my own eyes" [PST2-33].

> "The physical model has been useful for us to know what really happens. The physical model was also useful to be able to correct the previous knowledge we had. To know what an aquifer is, the term water table also appeared after making the physical model, a term that I had forgotten" [PST2-16].

DISCUSSION

This study has addressed teachers' assessments of the contribution of the field trip and the physical model and their perceptions of their contributions to modelling. Regarding the first research question, the results show that PSTs rated both the field trip and the physical model very positively. In fact, more than a third of the participants used superlatives such as essential, necessary, very useful in their reflections to describe the physical model in both years and the field trip in year 2.

This is not surprising as other studies also found that participants rate these resources positively (e.g., Jiménez-Tenorio et al., 2016; Nugent et al., 2012). What is more remarkable is that PSTs went to make explicit what contributions the activities had made to them.

In terms of the contributions expressed, it stands out that practically 100% of PSTs mentioned that both the physical model and the field trip contributed in some way to their learning process. This is in line with the results obtained by Orion and Hofstein (1991), who observed that the oldest students did value the field trips for their learning process. This was supported by the fact that PST also gave specific data on what they had learned (40% of PSTs in the case of the physical model in both years, and 50% and 70% in the case of the field trip in year 1 and year 2, respectively). This contribution to learning is also supported by the fact that about 20% made metacognitive reflections in which they not only expressed that they had learned a certain concept, but also referred to what they thought prior to the activity and what they knew afterwards. As for the type of learning-related operations to which they alluded, none were found that would correspond to the highest level in reviewed Bloom's taxonomy (Anderson & Krathwohl, 2001), *creating*; but all the others were found. Thus, the lowest level, *remembering*, was mentioned by more than 75% of PSTs in both years in the case of the field trip, but by 10-20% in the case of the physical model. *Understanding*, on the other hand, was the most mentioned operation overall: more than 75% in the case of the field trip and more than 80% in the case of the physical model, with higher results in year 2 in both cases. The higher levels were mentioned less frequently, but in the case of the physical model, the mentions of *applying* and *evaluating* in both years (about 30% and 20%, respectively) and *analyzing* in year 2 were notable.

It is somewhat disappointing, on the other hand, that less than 10% included in their reflection allusions to the possible use of the resources for teaching, to the knowledge of a resource to be used in their professional future. It is true that the question was aimed at assessing the contribution of the resource to their learning process, but it would have been positive if they had mentioned it. In the future, this issue could be asked directly or, as Sáez-Bondía and Cortés-Gracia (2019) observed, could arise through a reflective work with PSTs in their training, for example video-analysis of the activity and its subsequent discussion.

Regarding the second research question, the perceptions about the contribution of the field trip and the physical model to the modelling of the aquifer model, the results show several remarkable things. In the case of the field trip, the results were better in year 2. PSTs perceived the field trip as fundamentally an approach to reality, an experience of the phenomenon to be represented (Adúriz-Bravo et al., 2005), i.e., given that modelling involves moving from the particular reality to the model and to the general theory (and the reverse) (Sensevy et al., 2008), in this case the field trip would fulfil the first part, moving from reality to representation, through observation (Miller & Kastens, 2018). This is in line with previous studies that see field trips as a unique opportunity to visualize the big picture to be modelled (Fedesco et al., 2020; Mogk & Goodwin, 2012) and to obtain data (Almquist et al., 2011; Uskola & Seijas, 2023). Furthermore, the results show that what was observed in the field trip made them ask questions about the processes involved and formulate hypotheses. In particular, some of the observations conflicted with PSTs' ideas, as they themselves acknowledged, for example, seeing the vertical strata at one of the stops, or seeing the dry waterfall, which forced them to rule out surface runoff as the source of the river water. Egger's (2019) perspective that the field is the criterion for judging, for evaluating any model in geology, is also present in the results, although to a lesser extent (less than 20% in both years).

The perception that what was observed in the field trip constituted the reference for making the physical model was quite low, especially in year 1. A similar number of PSTs indicated that what was seen in the field trip was a reference for making the physical model and that it was a reference for evaluating it, when the former was more explicit in the design of the sequence and the latter is a more difficult and higher level operation (Anderson & Krathwohl, 2001). Indeed, Miller and Kastens (2018) had alluded to the lack of the practice of comparing physical models with reality while Kastens and Rivet (2010) had pointed out its importance in the learning process.

With regard to the physical model, perceptions showed large differences between year 1 and year 2. Thus, in year 1 the main idea in PSTs' opinions was that it is necessary to understand processes prior to representing them, and that representation is used to communicate knowledge. This is in line with the usual practices in science classes with physical models, where they are used in an expository way (Gray et al., 2011; Torres & Vasconcelos, 2016). However, in year 2, the perception of PSTs reflects the desirable view according to Miller and Kastens (2018) of using physical models not only to communicate knowledge but also to construct knowledge, as Maia and Justi (2009) found in a chemistry lesson. That is, to use physical models to establish relationships between system components and representing unobservable mechanisms in an observable way (Forbes et al., 2015).

Numerous studies have also observed how diverse types of representations (mainly drawings and gestures) contribute to learning science (e.g., Prain & Tytler, 2012), and the relationship between representations and models constitutes one of the growing and future lines of research (Prain, 2019).

CONCLUSIONS

The study has limitations, on the one hand, by the limited number of participants. A larger number of participants and their corresponding opinions would undoubtedly increase the reliability of the results. This work is part of a larger project involving several researchers, and in the future the team plans to collect a larger number of PSTs' perceptions in order to further explore the issues identified in this study in relation to the contribution of various resources to modelling.

Even so, these results raise the question of what difference in the activities carried out in year 2 compared to year 1 can explain the differences in the perception of the contribution of the activities, especially the physical model, so that it can be considered in future sequence designs. The authors' hypothesis is that the better fitting between the perceived contributions and the desirable ones for both activities can be explained because of the physical model in year 2 being present throughout the sequence, from the beginning. As has been said, PSTs in year 2 made a physical model initially, prior to the field trip while in year 1 they constructed it after the field trip. During the field trip, in year 2 they kept this first physical model very much in mind and, in fact, in the last part of the field trip, they evaluated it and proposed modifications to adjust it to what they had observed, which they did in the subsequent sessions. In addition, although both years they were encouraged to use the physical models to visualize and explain the functioning of aquifers, the water table and how rivers are formed, in year 2, the teacher forced all of them to use real water and asked each group to constantly evaluate and revise their physical model, considering data from the field and the drawings that they had previously made. As the results show, these strategies, in addition to getting PSTs to build a more complete aquifer model (Seijas & Uskola, 2022), made PSTs aware of the modelling sequence as an integrated set of activities seeking the construction of the model. This confirms that teachers' experimenting methodologies, resources and strategies in their training is necessary for them to learn the methodologies they have to use (Zembal-Saul, 2009) and that experimenting them contributes also to shaping their beliefs about them (Carrier et al., 2013; Maiorca et al., 2023; Windschitl, 2003). Shaping their beliefs about methods of teaching and their contribution (in this case, believing that field trips and physical models can be effectively used for learning science) along the training of teachers is important since those beliefs can influence their educational practice in the classroom (Areljung et al., 2021; Ng et al., 2024; Vartuli, 2005; Yang et al., 2023). Furthermore, research has shown that reflective experiences in which PSTs participate as learners, and afterwards design and implement similar methods with students facilitates not only the shaping of beliefs about the methods but also about their own efficacy to teach (Maiorca et al., 2023), which also conditions the teaching practices (Ng et al., 2024). This link among beliefs about methods, perception about self-efficacy and practices, and the contribution that training experiences can have in shaping the beliefs constitute interesting issues for future research that would provide valuable insights for the academic community and for teachers.

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