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DESIGN OF A PRE-SERVICE TEACHER TRAINING UNIT TO PROMOTE SCIENTIFIC PRACTICES. *IS A CHICKPEA A LIVING BEING?*

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In this paper, we present the design of a teacher training sequence, emphasizing supporting pre-service teachers to reflect on their knowledge, skills, and emotions experienced when engaging in scientific practices. We consider such reflections being crucial in initial teacher training because they can make pre-service teachers aware of the cognitive, procedural and emotional process that their students are bound to experience in the class. The importance of this work lies in the fact that emotions, even though important, are relatively underexplored. Furthermore, the way the sequence is developed can be used with students, both to promote scientific practices and explore their emotions, to give evidence to pre-service teachers of the effectiveness of this, and make them reflect on how scientific practices work, and the advantages of learning science implementing scientific practices.

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INTRODUCTION

Numerous research projects and reports (Erduran & Yan, 2009, National Research Council, 2011, Osborne & Dillon, 2008, Worth, Duque, & Saltiel, 2009), show the disparity between research and teaching practice in the classrooms (Cronin-Jones, 1991), and reveal that results from research are not transferred in actual teaching practice.

Often, science educators criticize this disconnection between research and practice without recognizing their own role in not address this gap even in their own teaching practice throughout the preservice teacher training (Blackburn & Moissan, 1987). This has been reported for more than 30 years, as well as we also detected it in recent interviews with Spanish science education researchers, internationally recognized, all of the teacher trainers, to whom we asked: "Which evidence do you considered relevant to know whether the initial teacher training you develop really works?". Most interviewees responded considering aspects such as the satisfaction confessed by their students, comments from former students postgraduates, their feelings or perceptions based on years of experience training future teachers, and only a small percentage, based their responses on the foundation of the design and its effectiveness (Martínez-Chico, López-Gay & Jiménez-Liso 2014).

This made us substantiate the design of our sequences. We focus on making pre-service teachers experience scientific practices and reflect on what they learned, as well as how they have learned and what emotions they felt. Our goal is to ensure that pre-service teachers appreciate asking students

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to engage in practices not only to develop an understanding of the disciplinary core ideas but mainly to acquire procedural and epistemic understanding (Osborne, 2014). The design of teacher training programs aiming to promote ways that can potentially engage students with science and scientific practices (Evagorou et al., 2014).

Per Duschl, Maeng, & Sezen (2011), engaging in scientific practices apart from linked to promoting interest in science, is connected to the fact that science learning involves participating in the epistemic goals of scientific work, objectives related to the construction of knowledge. Developing pre-service teachers' understanding of the epistemic basis of science—how we know what we know—requires them to be engaged in the common practices of science (Duschl & Bybee, 2014). Only then they will begin to understand how scientists establish credibility for the claims that they advance (Osborne, 2014), and they will consider it essential in their future instruction.

Consequently, the design of sequences on improving teacher training should include the ability to identify scientific questions, as well the ability to investigate them, the skill to use scientific models to explain phenomena, and the ability to use evidence to assess knowledge (Jimenez-Liso, Martinez-Chico, Avraamidou & López-Gay, 2019). Thus, teachers' understanding of scientific practices can be enhanced when they are actively engaged in an innovative learning process through an approach that serves as a methodological model to teach alternative to that experienced when they were taught (Abd-el-Khalick, 2012; Akerson & Hanuscin, 2007; Wandersee, Mintzes, & Novak, 1994). In this way, we will contribute to narrow the gap as mentioned earlier when they become in-service teachers, referring to the lack of proper scientific practices in primary school classrooms (Ebenezer, Kaya, & Ebenezer, 2011; Jorde, Lenzen, Walberg-Henriksson, & Hemmo, 2007).

Based on the argument that teachers will rarely adopt an instruction based on scientific practices if they have not experienced it in their training, we designed a teaching sequence placing emphasis on pre-service teachers experiencing scientific practices as learners and reflecting on their experience. This design case aims to describe the development of this teaching unit, with an emphasis on the challenges and decisions taking place throughout this process.

The purpose of our program is to promote teacher training with an emphasis on scientific practices and self-reflection on learning and emotions experienced by pre-service teachers.

CONTEXT

The authors work as teacher trainers and researchers on professional development in two European countries. The Programme for International Student Assessment (PISA) 2015 framework adopted by both countries provides a description and rationale for the basis of the instrument to assess scientific literacy, which requires promoting some Competencies: Explain Phenomena Scientifically, Evaluate and Design Scientific Enquiry, and Interpret Data and Evidence Scientifically.

In Europe, the current emphasis on innovation in science education has been placed on promoting *Inquiry-Based Science Education* (IBSE) approaches, a complex process of sense-making and constructing new understandings such as coherent conceptual models, by engaging students in (1) authentic, problem-based learning activities where there may not be one correct answer; (2) experimental procedures, experiments and "hands-on" activities, including searching for information; (3) self-regulated learning sequences where student autonomy is emphasized; and (4) discursive argumentation and communication with peers ("talking science"). This is how IBSE is defined in the Report to the European Commission of the expert group on science education 'Science Education for Responsible Citizenship' (Hazelkorn et al., 2015), where the need to close the gap between what we have learned from science education research and classroom practice to obtain positive results is emphasized.

This recommendation is in contrast with a reality into which outcomes of science education research are not embedded, as in most schools, science is taught through lectures and generally focused on teacher's lectures and books content, memorizing, and presenting in this way a naïve picture of scientific activity. Therefore, although both, European and national educational laws and reforms establish as requirements a science education oriented to promote scientific literacy, through inquiry-based approaches, teachers do not do it because they are not prepared to do it. This can be due to the scarce pedagogical content knowledge they have to adapt their instruction to a more student-focused and inquiry-based instruction. Furthermore, there is a lack of accessible resources and materials, such as previously evaluated teaching units that can scaffold teachers through inquiry-based approaches.

DESIGN MOTIVATION

As teacher trainers, our main purpose is preparing future teachers to be competent in teaching sciences through inquiry-based approaches that incorporate both, scientific practices, and conceptual contents. Furthermore, as researchers, we are worried about the gap between the objectives of educational research and the real teaching of science in classrooms. These are the reasons that have determined this design-case.

As research, and our own experience, has shown people who have experienced inquiry-based, collaborative science become enthusiastic promoters of inquiry-oriented learning

(OECD, 2015). Therefore, to support teachers' preparation the training we promote includes two necessary aspects to face both, their lack of knowledge and effective units designed: the need for future teachers to experience inquiry-based sequences oriented towards the construction and use of models, as well as the construction of descriptive knowledge, and reflect on the experienced learning. To question their spontaneous pedagogical knowledge, they need to have learning experiences, alternative to their previous experiences that serve as reference to teach science (Martínez-Chico, Jiménez-Liso, López-Gay & Romero-Gutiérrez, , 2017), while they are *learning by doing* (Haefner & Zembal-Saul, 2004) and acquiring an appropriate vision of scientific activity, increasing their self-confidence to transfer these practices to their instruction. Furthermore, as science-based learning processes are not merely cognitive but are highly charged with feelings and self-regulation they should not be reduced to metacognitive aspects, but also be extended to the affective dimensions (Costillo, Borrachero, Brígido & Mellado Jiménez, 2013); and we cannot ignore the common negative emotions towards science and teaching science (Evagorou et al., 2014).

The complete teacher training program is gradual in terms of the roles adopted by preservice teachers: from teachers as learners (to promote changes on epistemological, psychological, methodological approach, etc.), teachers as thinkers (to prepare them as critical consumers of "good" units already designed), to the role of teachers as designers.

Frequently, the designs of sequences are presented as the final product already tested with positive results of their effectiveness. Nevertheless, for teacher professional development it is important that teachers and researchers explain step by step how we have obtained a sequence based on the research to facilitate the construction of a design, which generally is a very complex process.

In this paper, we want to "bare" such a process with a sequence focused on the living being model to show the different drafts produced and the motivations of the improvements incorporated.

Furthermore, by orienting the design of the unit in this way, we try to overcome the common critics from in-service and pre-service teachers of the training programs for being too abstract and theoretical (Darling-Hammond & Bransford, 2007).

After many implementations and reviews that permitted improve and complete the design of the sequence by two of the authors, we realized that, although the activities were focused on inquiry-based science education to construct a model, there was a great potential for working on argumentation too. Then, the opportunity for one of the authors (Martinez-Chico) of doing a research stay with an expert on argumentation (Evagorou) allowed the last modifications that would turn the sequence into the final design.

Thus, the final teacher training sequence is closer to promoting the 3 scientific competencies defined by the PISA 2015 framework (OECD, 2013; 2015) and corresponding to the three broad practices of the NRC framework (NRC, 2013): Evaluate and design scientific inquiry (*inquiry*), interpret data and evidence scientifically (*argumentation*), and explain phenomena scientifically (*modeling*).

INITIAL DESIGN PROCESS

The design process began with an activity centered on a key question whose effect suggested the need to continue with a sequence that completes the sequence.

Design decision 1: "Good questions" to promote talking science.

The initial motivation that triggered what would later become a sequence of activities was the posing of a "good question" that really favored "talking science" and engage students in expressing their ideas, conceptions, believes...: *Is a chickpea a living being? What is your evidence?*

The chickpea works as a border element between living and inert beings. The characteristics of this question, of allowing a balance between "skill/challenge", because it makes sense for the apprentices, is daily, but its response is not obvious, they allow learners to be engaged in the communication of their answers and the expression of their reasonings. In the discussions that were generated, the learners had to justify their answers based on their own knowledge, which sometimes referred to their own experience, to popular daily knowledge, or to contents constructed previously in their school years. It was necessary to have criteria that were valid to identify a chickpea as a living or inert being, which ultimately means having a living model.

Design decision 2: Question to favor the construction of scientific models

After posing the question in Secondary School classrooms and with Preservice teachers, we realized its potential as a resource to promote, not only learners' conceptions expression, but also the construction of scientific models (Roca, Márquez & Sanmartí, 2013), specifically the living being model, that matches with the national curriculums (MEC, 2014).

The initial responses of the students to this question (whether it is a living being or not, and why) constituted their initial models.

The emotional climate created in the classroom after asking the question led students to focus their efforts on the search for suitable criteria to identify living beings, so that one could

WHAT CAN ONE DO EACH OF THEM, THAT THE OTHER ONE DOES (OR NOT)?	
CHICK	**CHICKPEA**
It can be eaten	It can be eaten
It comes from a chicken? (a living being)	It comes from a plant? (a living being)
It flees from predators, follows her mother → Reacts to stimuli	Under the right conditions it can germinate → Reacts to stimuli
It needs food	It needs food
It grows	It grows
It can lead to other chicks	It can lead to other plants
It needs to breathe	It needs to breathe????

TABLE 1. Comparison between a chickpea and chicken

work on the construction of this model among all, from a specific case, and not as usually occurs in science classes, in which the teacher provides the finished model and give some examples to be memorized.

To guide students in finding the right criteria, we proposed to compare the characteristics of a being that we are sure is alive (e.g.. a chick) and those of our chickpea, to identify common aspects and differences. The purpose of this activity is to engage the preservice teachers in the process of identifying common characteristics from concrete cases, to get the aspects that can be generalized for every living being, a model.

This table that gathers all the ideas that come up was presented unfilled and learners were asked about what each of them can do that the other cannot.

To review the features that are unique to living beings and not, the instructor questioned their statements. E.g.; *All things that can be eaten, are a living being?* Based on this definition, an ice cream should be a living being, but it is not. Or, if something comes from a living being, it is also a living being? Then, the urine coming from our body would also be living things. On the other hand, everything that grows is a living being? According to this statement, then the hair the nails or the water level of a river would be living beings. So, the criteria we consider exclusive from living beings were identified.

Nevertheless, this search for criteria to classify our chickpea required a key aspect in the process of constructing scientific knowledge: the consideration of evidence.

Design decision 3: Inquiry-based activities to promote evidence-based knowledge construction

The different parts of the sequence made it adopt a structure that responded to a teaching approach based on inquiry (as defined in the "context" section). Therefore, we decided to transform it into activities with its own entity that made the process of inquiry explicit, thus responding to the demands of educational reports and regulations to initiate students in scientific activity.

In the search for evidence to check whether the chickpea complied with the established criteria, some of them were clear to the students: Chickpeas receive environmental stimuli and responds to them, for instance when they "decide" to germinate (relation); they come from another living being and can reproduce and transfer their characteristics to their offspring (reproduction), as learners remember from a typical experiment they do when they are children; they exchange material and energy, so that they modify the environment (nutrition) ... But there was an aspect of nutrition that was not so clear... Do they exchange gases with the environment? *Do the chickpeas breath?* Then, we addressed this new question, making the learners represent their hypothesis and including the use of sensors to check them.

It was an opportunity to raise a new question or problem in which we focus later, in order to make students' knowledge of breathing explicit. First, we ask them to write how they think the exchange of gases occurs, so, we will develop on a new set of inquiry-based activities. Then, students are asked for using graphic language to show what they think happens to the gas (CO2 and O2) surrounding the chickpea. They had to think about the experimental design to plan and carry out the experiment to check their responses, considering the importance of controlling variables. This modern but simple technology lets perform the collection of large data sets in real-time, thus providing secondary sources for analysis.

In Figure 1, we present the design process, conducted during 2016-2017.

Design Decision 4: The structure of the unit to making "inquiry-based activities" explicit

Given the need to promote inquiry-based science education in primary school classrooms, we decided to clarify the activities so that preservice teachers clearly perceive the different practices of this approach in the sequence.

Table 2 presents the activities of Version 1, and the scientific practices promoted. As Table 1 shows, all activities were linked to a *Model-Based Inquiry* approach.

DESIGN MOTIVATION	DESIGN DRAFTS	DATES
QUESTION	Martinez-Chico and Jiménez-Liso design a question to engage pre-service teachers on talking science (A1)	January 14
MODELING	Authors A and B identify criteria on living organisms and design activities to construct the model of living beings through comparison between a chickpea (the border element challenged) and something we are sure it is alive (A2, A3 and A4)	February 15
INQUIRY (LOOKING FOR EVIDENCE)	Authors A and B incorporate the search for real-time evidence (with sensors, A8) and activities for prediction and graph interpretation, previous and after the data collection (A5, A6, A71, A72, A9, A10, A11)	February 15
SELF-REFLECTION	Self-report of learning and emotions (A12)	October 15
ARGUMENTATION	Authors A and C recognize the opportunity to work on argumentation in the sequence, and design activities to make it explicit	October 16

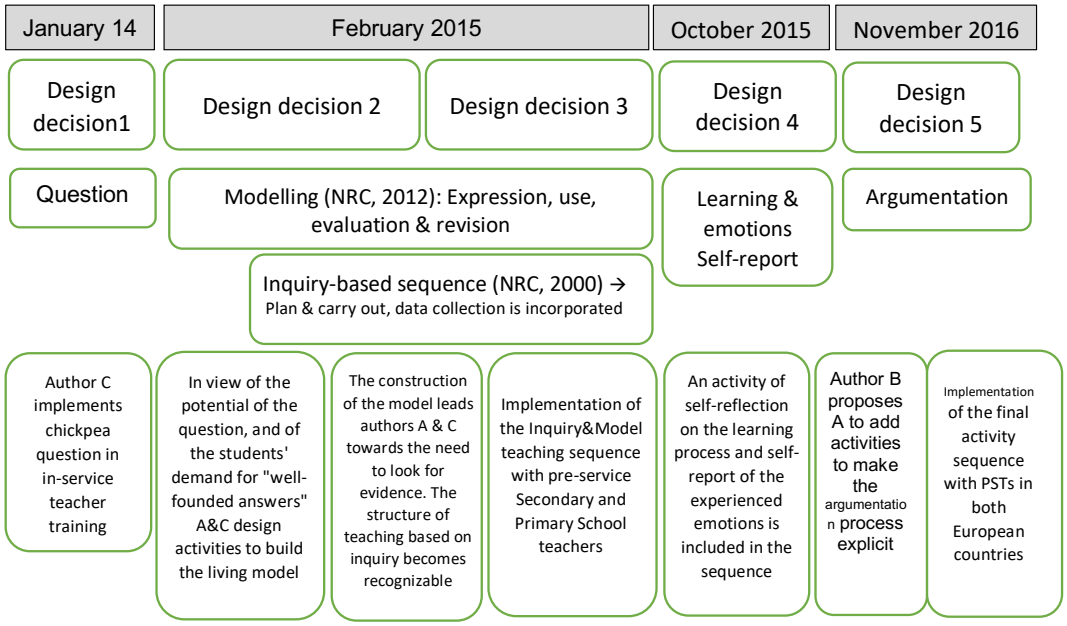


FIGURE 1. Summary of the process of design of the teaching sequence.

Design decision 5: Transform the implicit into explicit

We consider reflection as crucial in initial teacher training if we want PTs to be aware of the cognitive, procedural and emotional process that their students will experience.

With the aim of making PTs aware of what they have learned (conceptual knowledge -model- and scientific practices) along the sequence, we considered the need to reflect on the contents learnt and the activities developed. The importance of this activity lies in ensuring that this knowledge does not go unnoticed and that the learners self-regulate their own learning process. This is the reason we spend time in making explicit these scientific contents by reflecting on the process lived, not only and the conceptual contents learned. Therefore, this activity is included: *A12. What have we learned along the lesson?*

First, the instructor can ask PTs, and then go to completing what they have lacked to say, in case they do not consider all the contents and practices:

- Chickpeas (seeds) made a gaseous exchange with the environment → They breathe! They are living beings because...
- They have characteristics that match with living beings:
  - They need feeding and breathing, thereby modifying the environment
  - They respond to environmental stimuli

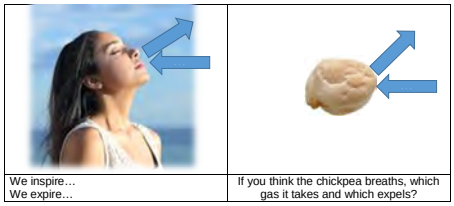
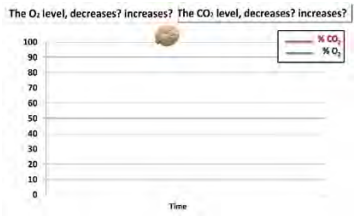
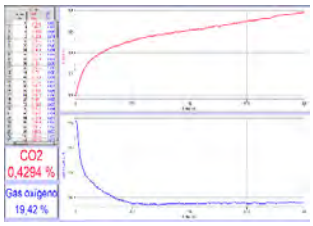
ACTIVITIES	PURPOSE / SCIENTIFIC PRACTICE
A1. Is a chickpea living being? Explain your reasoning	To identify scientific questions and formulate PTs' initial explanations or models, by embedding the scientific contents in their ongoing experiences
A2. Which criteria have you proposed to identify living things? Communicate your responses and justify them.	To communicate and justify PTs' ideas, so that they define their models, being conscious of the different thoughts from their partners and the common aspects
A3. Do your explanations or models really let us to distinguish between living and nonliving beings?	To identify the invalid criteria by making PTs think critically and consider their explanations logically
A4. Is there any difference between a chickpea and a chicken? If yes, how do they differ?	To identify common characteristics from concrete cases, to get the aspects that can be generalized for every living being, a model
There is a characteristic that effectively the chicken has, but that at the time of associating it to the chickpea is especially problematic and uncertain: *Does a chickpea breathe?* **A5.** Breathing involves a gases exchange with the environment. What do you think the chickpea does? Does it breathe? How? In each case indicate by arrows what happens.  We inspire… We expire… If you think the chickpea breaths, which gas it takes and which expels?	To raise a new question in order to make PTs' knowledge on plants' breathing explicit.
A6. How do you imagine CO_2 and O_2 varies around the chickpea? Draw them. 	To represent graphically PTs' ideas about the evolution of both gases surrounding the chickpea and interpret their partners thoughts.
A7.1. How could you know if your hypothesis conforms to reality? Details the experimental design to follow and discuss with members of your group the results you expect to get (notice that we have a sensor that measures CO_2 and O_2). **A7.2.** To know if your hypothesis conforms to reality, connect the sensors to the laptop and collect real data.	To plan and carry out investigations
A8. Observe what happens and analyze the data. Does it match your prediction? Does the chickpea breathe? How does it do it? 	To collect, analyze, and interpret the collected data, considering in which aspects, the obtained results confirm PTs' hypothesis, and in which do not, reflecting on that discrepancy

TABLE 2. First version of the teaching sequence. (Continued on next page)

ACTIVITIES	PURPOSE / SCIENTIFIC PRACTICE
A9. Communicate your conclusions. Could we say that a chickpea is a living being? Why? Justify your answer	To identify living beings' characteristics (based on evidence), by using the model of living being constructed to answer the question posed at the beginning.
A10. If we consider only these criteria, then, a human cell would be a living being. Is it? And a set of cells?	To evaluate the model and modify it by incorporating another characteristic or criteria to complete our model: Autonomy.
A11. Apply what we have learned on these other contexts: • Death by poisoning is common in enclosed spaces with lots of seeds as silos. What could be causing it? • Many farmers produce their own seeds by allowing some plants to mature and collect them. Saving seeds allows farmers to re-grow plants. How should be they stored? • The study of plants' breathing shows that: - Plants and animals breathe consuming O_2 and giving off CO_2, the same way, day and night - Plants breathe only at night - Plants breathe during the day backwards animals, because to do so, they take CO_2 and give off O_2	To use the model or the constructing explanations, so that the PTs apply the scientific knowledge constructed on other contexts

TABLE 2 (CONT). First version of the teaching sequence.

- They come from another living being and can reproduce transferring characteristics to their offspring
- Plants breathe like animals (inspire O2 and expel CO2) always (during the day than at night)
- Addressing a scientific question
- Formulating and justify ideas or explanations
- Look for evidence to test hypotheses
- Analyze results and draw conclusions
- Build consensus and based criteria
- Communicate and share ideas
- And we found that sometimes there are ideas that are transmitted in society that do not match scientific ideas

Furthermore, as part of the reflection process we consider the emotions that take place during the teacher training as important. The majority of studies in the field of science education report that positive emotions and enjoyment from learning science play a significant role in the learning outcomes and serve as a driving force for self-learning, and retaining knowledge (Alsop & Watts, 2003; Järvenoja & Järvelä, 2010). So, as the processes of learning and teaching science are not merely cognitive but are highly charged with feelings, the importance of emotions in teaching and learning advocates the need to consider the cognitive and affective dimensions, and metacognitive regulation should be expanded to include not only cognitive but also emotional regulation (Costillo, Borrachero, Brígido & Mellado, 2013, Sutton & Wheatley, 2003). In the case of PTs, the emotional aspect is especially critical at this stage due to, on one hand, the first teaching experiences (that occurs during teaching practices) are emotionally very strong and can be traumatic for future teachers, which are especially vulnerable; and on the other hand we cannot ignore that they usually have negative emotions towards science and teaching science (Evagorou et al., 2014; Evagorou & Mauriz, 2017), which is another barrier to overcome.

Then, the way the sequence is developed can be used both, to promote scientific practices and explore their emotions, and to give evidence to the PTs of the effectiveness of this approach as well, by making them reflect on how scientific practices work, and the advantages of learning science implementing scientific practices. Therefore, the unit can be completed with the next activity: *A13. What were your emotions during the implementation of the unit? Considering the following feelings and emotions indicate in each case whether you felt them and if so, describe briefly what situation (activity) you remember having felt it*: *Rejection, Attentiveness, Insecurity Interest, Boredom, Confidence, Satisfaction Dissatisfaction, Shame.*

Design decision 6: Include argumentation as an explicit part of the unit

The idea of bringing together these three scientific practices (Inquiry, modeling, argumentation) as part of this design came from Martinez-Chico and Jiménez-Liso, who were conscious of the opportunity that this sequence offered to do it and the necessity of making it explicit.

Then we were given the opportunity to work together with Maria Evagorou in September 2016 when Maria Martinez-Chico visited Evagorou under a Spanish government-funded research grant. Even though the initial concerns and ideas were discussed over several months, the teaching unit, as

presented here started being developed during Martinez-Chico's visit when we had the opportunity to have several work meetings and develop our ideas.

After discussing Martinez-Chico's implementation with Evagorou, the potential of the unit to work on argumentation was confirmed, and the inclusion of "how to construct good arguments" explicitly was considered. Then began the transformation of the sequence that led to the final version of this.

Jiménez-Liso had experience in engaging elementary school students in modeling and used their models to present and support their arguments about their decisions (Nicolaou, Evagorou & Lympouridou, 2015).

The modifications that were made aim the PTs to learn in what a good argument consists and how to build it based on tests, besides knowing the different kinds of evidence that can be used. To do this, once they had answered the initial question, and had communicated on what basis their responses, they are asked: *Do you consider your arguments as "good" arguments?*

To answer this question is needed to know what "a good argument" means. We take this opportunity to work on what a good argument contains with PTs: Claim, Evidence, Reasoning, Rebuttal. To learn about argumentation, we decided to propose a different example of the question that guides the sequence in this way, they will be able to build the necessary knowledge to later be able to apply it to their answers about the chickpea. The example was: *Are women smarter than men?*

After discussing they realised, they need evidence to support their responses, and we asked*: What is evidence? Consider the argument you provided before and state, which is your evidence. Do you have sufficient evidence?*

We then move the construction of "good arguments" to another issue related to climate change. A complete example of the different characteristics that this argument should present was shown.

To delve into the different types of tests, and in the structure of a good argument, we focus on another issue related to vaccines:

CLAIM: FLU VACCINES DO NOT PROTECT YOU FROM GETTING SICK.

Evidence from experience

> *I know that because my friend was vaccinated, and she still got the flu.*

Evidence from authority

> *I know that because my doctor told me so*

Scientific evidence

> *(a) Secondary sources*
>
> *I know that because, in a medical study with 150 participants who were vaccinated, 125 of them still got the flu.*
>
> *(b) Primary sources (e.g., experiment)*
>
> *I know that because in our group we did an experiment in which 150 participants who were vaccinated, 125 of them still got the flu*

Another modification that was incorporated was at the end of the sequence because the PTs were asked to respond to the initial question using a "good argument" based on what they had learned.

This last version was put into practice by the third author, with a group of twelve postgraduate students, with the common background of having studied to become elementary school teachers, when the first author was doing the research stay there. This implementation allowed us to know the effectiveness of the sequence to engage the learners, to improve their science content knowledge. After incorporating little modifications, author A implemented the final sequence in a Secondary School teacher master's degree. The effect of the implementation was successful as the students' spontaneous reflections in an online diary showed. Some examples are:

> *The famous question that started one of the most interesting debates that we have had so far: Is a chickpea a living being? Yes / No Justify your answer (...) We got evidence to effectively check that the chickpea was performing all these vital functions, but there was one that we still were not very sure of, and was that of a chickpea breathes? And here came the most interesting thing about the class!!!! Let's check if the chickpeas breathe (...) we talked about whether there was an opportunity to speak /do science to our students, as well as we reflect on the typical high school instruction in which teachers repeat definitions of living beings and functions, a not suitable way of learning since our students will memorize the definitions for the exam, then they will memorize and later forget.*
>
> *(...)*
>
> *The class for me turned out to be very fun although I have to say that at the beginning I was lost! But the methodology follow made me realize that the important thing is not how it begins, but how it ends; and that it does not matter how silly I feel or the few previous ideas that I have, since at the end of the class I am full and satisfied with all the concepts and things that I have learned, because for once I can say; I have learned!*

DISCUSSION AND CONCLUSIONS

As the primary purposes of the paper were situating the design, describing the design, depicting the experience of

the design, developing trustworthiness through transparency, analysis, and reflection, we consider this article covers the definition of a design case (Howard, 2011).

Given the need to involve students in scientific practices (Osborne, 2014), and in the absence of these in primary classrooms (NRC, 2011), we focus our work on developing a preservice teacher training sequence that allows them to learn content through a different approach from the usual/traditional, offering them an alternative methodological model to teach to what they have experienced as students. The design incorporates reflection on the scientific contents learned (conceptual and procedural) and the emotions experienced throughout the sequence. The detailed design of each activity is presented, including the purpose in each case, practical indications for its implementation by the teacher, as well as expected student responses. This design is a result of multiple implementations and can be adapted to different levels (primary and secondary school), although can be considered especially useful in teacher training.

In this paper, we have tried to develop a design case as a specialized and critical form of design knowledge, including the experienced evolution of the product (the activity sequence) along the process of a collaborative construction. This design process has been possible thanks to the many discussions had by the authors and our intention of making explicit what was implicit in our instruction. This led us to translate it into specific activities with the aim of making the PST work on the three scientific practices more deeply: Modeling, Inquiry, Argumentation.

As can be seen in the text, the designer team has created knowledge through their own lived experience of creating that design for learning, a knowledge that is worth sharing with other designers, by acting the design case as a vehicle to share that knowledge (Boling, 2010).

To conclude, the sequence developed seems to encourage communication and exchange of ideas among students, and engage them in addressing scientific questions, letting future teachers be aware of the advantages of this approach in order to promote the science learning and emotions, as they experience themselves by performing scientific practices.

Furthermore, the implementation of the sequence let us identify some changes or implications for the design than could improve the proposal. Firstly, we need to work explicitly on each kind of scientific practice, in this case, we could focus on argumentation due to the possibilities that the sequence offers to work on constructing proper criteria to develop a proper argument. That's why we are reformulating some activities to really engage students in scientific explanations, because of its benefits (McNeill, 2011) Understand science content, develop 20-century skills, use evidence to support claims, reason logically, consider and critique alternative explanations, understand nature of science. Moreover, we will modify the final activity of self-reflection on the emotions experienced to also incorporate the learning content and the type of activities undertaken So they will be aware of what they learned, what they were doing and what they were feeling (Martínez-Chico, Jiménez-Liso, López-Gay, & Romero-Gutiérrez, 2017).

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