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Developing prospective primary teachers' learning-to-learn competence through experimental activities

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Abstract

A qualitative study was made of how the learning-to-learn competence is favoured in prospective primary education teachers when they participate in an ad hoc designed experimental activity (ExA). The ExA was on the germination of seeds. Its objective was for the prospective teachers to learn how to (i) design and execute a school scientific inquiry, and (ii) reflect metacognitively about their experience with the ExA and what they had learnt. This latter objective is analysed in the present study. To this end, a category-descriptor instrument was designed for the learning-to-learn competence. This allowed the moments and actions to be analysed, as well as the prospective teachers' cognitive and metacognitive strategies during the ExA. The participants were organized into small work groups, and the information analysed was drawn from the records of the ExA in the notebooks which those groups prepared. In general, the results are indicative of the positive effect of the proposed ExA on the development of cognitive and metacognitive strategies in the prospective teachers' learning processes. Especially important were the moments of idea confrontation, reflection, and whole-class sharing since they let the prospective teachers become aware of and control these strategies. The scope, limitations, and implications of the study are discussed.

Keywords: experimental activity; teacher training; learning-to-learn competence; inquiry; metacognition.

Learning science as inquiry with experimental activities

In science education, there is broad consensus on the advisability of promoting inquiry-based learning strategies to develop scientific competence (Abd-El-Khalick et al., 2004). Experimental activities (ExA's) play an important role in this framework (García-Carmona et al., 2018). They are conceived of as being classroom activities in which students are challenged with stimulating questions to observe, investigate, and develop an understanding of the physical world through direct experiences with the phenomena, or by manipulating objects and materials (Science Community Representing Education [SCORE], 2013).

In Spain's educational context, the Primary Education science curriculum explicitly suggests the promotion of ExA. In particular, within the block "Initiation into scientific activity" the following learning standard is proposed (Ministry of Education, 2014): "[the students] carry out simple experiments and small research inquiries, setting out problems, stating hypotheses, selecting the necessary material, carrying out the activity, drawing conclusions, and communicating the results" (p.18; brackets added).

The development of ExA poses significant didactic challenges for the students, especially when the topics of inquiry are more open in nature. In this regard, education research shows that students often have difficulties in identifying researchable questions (Cruz-Guzmán et al., 2017) and formulating scientific hypotheses (Oh, 2010). They also have difficulties regarding the identification and management of variables (Schwichow et al., 2016), the design of experiments (García-Carmona et al., 2017), as well as drawing conclusions through an argued interpretation of the data (Rönnebeck et al., 2016). Nonetheless, with appropriate instruction, they can improve their ability to perform these scientific practices, for example, when the ExA is implemented as a guided inquiry (García-Carmona, 2020).

Despite the didactic potential of ExA, its incidence in Spanish primary education classrooms is still far from desirable (Cañal et al., 2013). In general, little attention is paid to the inquiry-based didactic approach in basic science education. When an attempt is made to address it, it is usually in a somewhat distorted manner, i.e., as if it were simply a matter of following a series of ordered steps like following a "cooking recipe" (McLaughlin & MacFadden, 2014), without the students reflecting on what they are to inquire into, why, and how to do so (García-Carmona et al., 2017). For this reason, this approach needs to be dealt with adequately in initial primary science teacher training (Cañal et al., 2016). A good way would be through these students' own participation in ExA, reflecting on its didactic value (García-Carmona et al., 2018). The prospective teachers would then be able to experience school science inquiries first-hand, which in addition will serve them as referents for their own inquiry-based teaching designs (Cortés & Gandara, 2007; García-Carmona et al., 2017).

For years now in Spain, the inquiry-based didactic approach has been used from the initial training of primary education teachers onwards (e.g., Cortés & Gándara 2007; Cañal et al., 2011). Nonetheless, there is still a recognized need for its further development and implementation (Vílchez & Bravo, 2015; García-Carmona et al., 2018). In particular, there have been few studies analysing how prospective teachers go through the different stages of an ExA that is set out as a scientific inquiry (García-Carmona, 2020).

The learning-to-learn competence in experimental activities

For students to achieve meaningful learning, it is necessary for them to put into practice *cognitive* and *metacognitive* strategies that will help them regulate autonomously the construction of such learning (Campanario, 2000; García-Carmona, 2012). Cognitive strategies refer to the skills that students bring into play to encode, memorise, and recall information; while metacognitive strategies comprise skills that allow them to understand and monitor their cognitive processes. (Schraw et al., 2006, p. 112). Both strategies are essential so that students gain awareness of how they learn, the obstacles they face and how these can be overcome to achieve the educational objectives that they have been set. This is known as the "learning-to-learn" competence (Cornford, 2002). Below, it is exposed a brief review of some background information on the development of this competence in the context of inquiry-based science learning.

Brief background review of the literature

The benefits of engaging in inquiry-based activities to improve students' metacognitive skills have been verified in numerous studies (Kipnis & Hofstein, 2008; Schraw et al., 2006). For example, in a quasiexperimental study with high school students, Huang and Chang (2013) verified that those students who practiced collaborative discussions during the development of an *online inquiry* improved their metacognition skills with respect to those who performed the same inquiry without such collaborative discussion moments. Chang et al. (2020) found that the school inquiry model based on the *metacognitive learning cycle*, which provides opportunities for students to reflect on their learning, significantly improved high school students' metacognitive skills while learning abstract biology concepts. A similar conclusion is obtained by other authors, such as Nunaki et al. (2019) when implementing the 4-D (Define, Design, Develop, and Dissemination) inquiry model with high school students; or Divrik et al. (2020) by applying metacognitive strategies with 4th grade students while learning with the inquiry-based learning method.

In the training of prospective science teachers, the effectiveness of inquiry-based activities in improving their metacognitive skills has also been verified. For example, Erenler and Cetin (2019) found that argument-driven inquiry-based laboratory activities helped preservice secondary science teachers improve their metacognitive awareness and science writing skills. In a study that analysed the development of science inquiry skills in preservice primary teachers, it was found that the metacognition practiced by participants in teamwork was essential for this purpose (García-Carmona, 2019). Overall, Schraw et al. (2006) comprehensive review of the issue highlights the positive relationship between the performance of metacognitive strategies and the improvement of science teaching/learning using inquiry-based learning contexts and other similar approaches, such as problem-based approaches. However, there are hardly any known studies specifically focused on developing the learning-to-learn competence through participation in ExA in prospective primary school teachers. Hence the relevance of the present study.

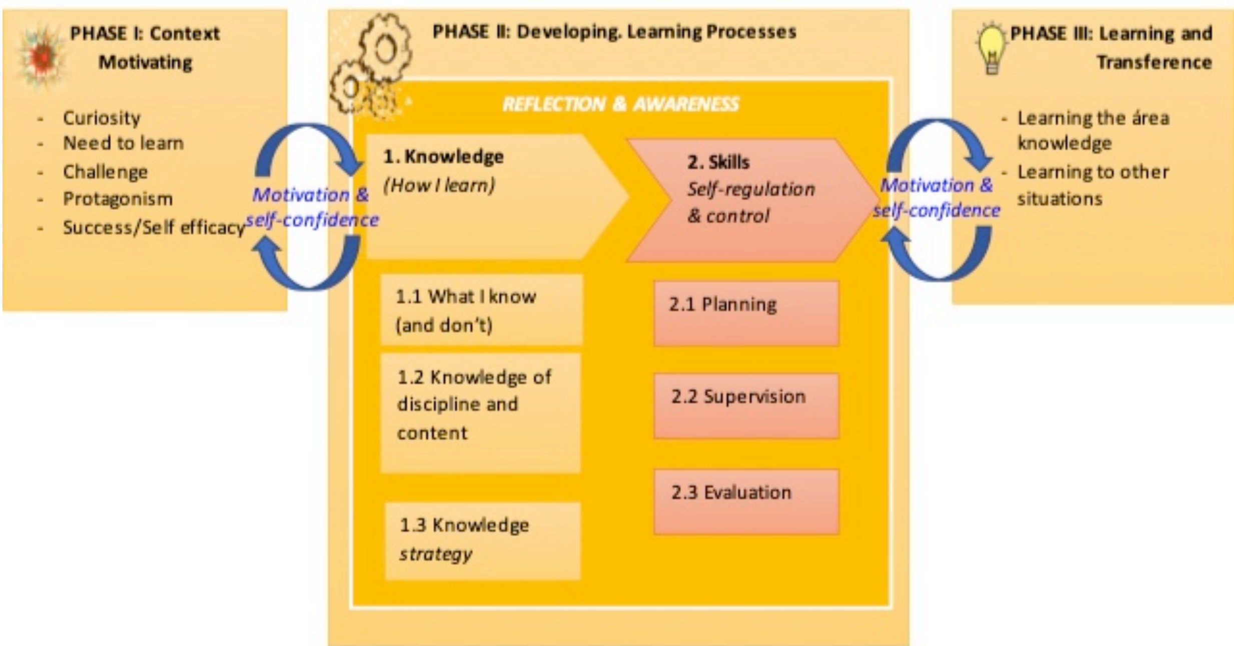
A model for the development of cognitive and metacognitive skills

In the Spanish educational curriculum, one of the key competences is learning-to-learn, defined as the ability to initiate, organize, and persist in learning (Ministry of Education, 2014). It can be subdivided into three types of knowledge: "What I know and what I don't" (knowing), "The strategies I use to learn" (knowing “how to do”), and "The sensations and emotions associated with the learning process" (knowing “how to be”). In order to evaluate the acquisition of the learning-to-learn competence, these three types of knowledge can be re-interpreted in the form of four progressive phases during the development of this competence (European Commission, 2012): "Why I learn" (motivations and attitudes), "What I learn" (objective and planning), "How I learn" (organization and management), and "I reflect on my progress" (reflection on learning progress). This phase breakdown is interesting because it helps to see to what extent this competence is acquired with some specific activity or learning experience.

In accordance with the above, and with a focus on the possible phases in attaining the learning-to-learn competence, Figure 1 summarizes the moments and elements that need to be promoted during educational practice. The first phase involves creating the motivational environment or context, presenting the students a problem to solve that is interesting and close to them. This phase is the one that tries to hook the students onto the problem and generate in them a need to learn. Some elements that should be fostered are curiosity about the problem, the students' protagonism, and for the activity to be challenging as well as approachable. The second phase invites the students to ask themselves what they do know and what they don't, as well as what possible strategies and resources they need to solve the problem. Then the planning of the activities to be developed begins, as well as the execution and supervision of the different tasks. Finally, the third phase is aimed at contrasting the achievements made during the educational experience, and transferring this knowledge to other contexts and/or problems.

It is worth noting that this model for the promotion of learning-to-learn competence is in line with previous models on the development of metacognitive skills, such as the one proposed by Schraw (1998, cit. in Kipnis & Hofstein, 2007, p. 606). His model establishes two essential components: *knowledge of cognition* (declarative knowledge, procedural knowledge, and conditional knowledge), and *regulation of knowledge* (planning, monitoring, and evaluating). It can be said that both components are integrated in phase II of the model shown in Figure 1. In addition, in this framework, motivation is assimilated as the set of beliefs and attitudes that affect the use and development of cognitive and metacognitive skills (Shraw et al., 2006).

Figure 1. Phases for the development of cognitive and metacognitive skills (the authors).



Likewise, within the ExA framework, this scheme (Figure 1) can also be considered to promote the learning-to-learn competence. On the one hand, for the students to attain this competence it is necessary for them to put into practice other educational capacities. And on the other, learning science through ExA as inquiry requires the ideas, data, and/or results obtained to be permanently (re)evaluated and (re)formulated, as well as confronted, discussed, and reasoned about in group contexts (Angulo, 1998; Cornford, 2002). In this sense, self-regulation and control competences (planning, supervision, and evaluation) are processes that not only have links to cognition and metacognition, but also are involved in the inquiry processes (White et al., 2009). Therefore, ExA's require constant cognitive and metacognitive exercise. This makes them ideal to promote the learning-to-learn competence.

An educational proposal that follows this line is that described by White et al. (2009) with inquiry activities based on role playing. In these activities, the metacognitive strategies that the students use during their learning are analysed. Nonetheless, even now more than a decade after that proposal, there is still little interest in carrying out educational experiences that promote the learning-to-learn competence in science classes.

Purpose of the study

In view of the above, the objective of this qualitative study was to determine the scope of cognitive and metacognitive strategies in prospective primary teachers, within the framework of an ExA. The general research question guiding the study was: To what extent do ExA's contribute to the development of learning-to-learn competence in prospective teachers? But, to operationalize this approach, the question was broken down into the following two research questions:

1. What moments and tasks of an ExA favour strategies for the development of learning-to-learn competence?
2. What strategies do teacher education students use as part of their learning-to-learn competence during the ExA?

The first question refers to the cognitive strategies, actions, and moments during the ExA that prospective teachers use during their learning. The second addresses the metacognitive strategies that they use in the management and conscious control of their learning. Therefore, the two questions are closely linked in the development of the learning-to-learn competence. In addition to exploring these two questions, this study hopes to provide an example of how an ExA can foster these cognitive and metacognitive strategies in initial teacher training.

Methods

Participants and context

The participants in the study were 68 students (31 men and 37 women, age range 19-22 years) who were studying science teaching in the 2nd year of the Primary Education bachelor's degree at the University of Sevilla. It was an incidental sample since the students selected were those who could be accessed at the time of the study. Furthermore, it should be noted that, prior to this, none of the students had received specific didactic training about either the inquiry-based approach or the metacognitive strategies for the self-regulation of learning.

Students who take this degree course tend to have low interest in science and its teaching (García-Carmona & Cruz-Guzmán, 2016). The vast majority come from educational itineraries related to the social sciences and humanities, so they arrive with a low level of scientific competence. They mostly opt for this university qualification to specialize in language teaching (English, French, or German), physical education, music education, or special education. Hence, science teaching is one of the areas of knowledge that arouses the least interest in them.

The science teaching course, in which the present study was carried out, is one-year (9 credits). Among its objectives is to introduce the students to the inquiry-based approach to science learning. This is specified in that firstly the students participate in an ExA to experience how to learn by inquiry about the phenomena of nature, and secondly they learn to design their own ExA as future science teachers.

The teaching intervention process

To develop the educational intervention under analysis, the students were organized into small work groups (11 groups in total). They had to carry out an ExA about the germination of seeds and the conditions that are necessary for their growth. This topic was selected because it is a common experiment in primary schools, usually carried out with bean seeds, cotton wool, and a yoghurt pot (Márquez & Pedreira, 2005). Nonetheless, the experiment is usually implemented for the students to acquire knowledge of the discipline (i.e., description and observation of the parts of the plant) through a process that is guided by the teacher (Márquez & Pedreria, 2005). It is therefore far removed from any inquiry approach, and any opportunity for the students to learn science by doing science in doing this experiment is lost. This is so much so that, when these students reach higher education levels, they have limited or inadequate knowledge about plant growth (Charrier et al., 2006).

An ExA can have different levels of openness (Martin-Hansen, 2002), ranging from an open inquiry in which the students propose, plan, and implement the entire process, to a closed inquiry in which the teacher sets out and plans the entire process (selection of the research questions, the data acquisition and analysis instruments, etc.). There are also intermediate approaches that can be denoted semi-open or guided inquiries. The present study proposes another option, which is termed here as flexible ExA. It is characterized by having a level of openness that is determined in accordance with the needs and demands of the students as the development of the ExA advances. In this way, the students progress through the different actions that need to be developed in each stage of the ExA, with the aid given to them by the teacher being adjusted to their pace and learning needs. Thus, the implementation of a flexible ExA means that the teacher has to be constantly observing and supervising the students' evolution so as to detect any difficulties or obstacles they encounter in order to provide the appropriate pedagogical support.

The prospective teachers were asked to carry out a flexible ExA framed around the main theme of germination. Each group had to define their own inquiry questions depending on what they wanted to analyse (whether the seeds germinate the same with distilled water as when the water is from the tap, whether the number of seeds influences the speed of germination, whether the seeds can germinate only with water or also with other liquids such as coca cola, etc.).

Table 1 summarizes the tasks, actions, and resources used in the ExA. The design is configured in different phases and actions based on the promotion of the learning-to-learn competence (Figure 1) or of metacognitive training as proposed by Osses and Jaramillo (2008). Each phase comprises a series of tasks in which the students worked in groups, while the instructor (first author) guided and supervised the degree of achievement of each task.

Table 1. Development phases of the flexible ExA

Phases	Purposes and moments	Description: Tasks and Resources
PHASE I: Motivating context	Creation of a situation that provokes interest in the subject. And exploration of prior ideas (plants: development and growth)	• Initial question posed by the instructor at the beginning of the session: *What did you all eat today?* • The instructor responds to the question: *Today I have eaten a plate of embryos with broth.* • Next question posed by the instructor: *Do you like embryos? I have a few uncooked ones in my pocket.* • Some legume seeds are shown, and the ExA to be carried out is presented under the general problem: *What does a seed need to germinate?*
PHASE II: Development of the ExA and learning processes	Sub-phase II.1: Introduction and prior preparation for the ExA	• Presentation of the activity: objectives, tasks, resources, and work method. • Providing basic information about seeds and their germination process.
	Sub-phase II.2 (pre-ExA): Reflection prior to the development of the ExA, and planning the phases of the ExA by the groups	• Presentation of the script of questions for reflection on the ExA before starting and planning it. • Each group defines the different stages that make up the ExA, and the instructor checks them over to look for potential difficulties and provide guidance on how to overcome them. • Whole class sharing session: Each group presents their selected problem for investigation and the specific design of the inquiry to resolve it. • Review of the initial designs: After the sharing session, the groups revise their initial designs to improve them.

	Sub-phase II.3 (during-ExA): Implementation of the designs, observation of the phenomenon, data acquisition, and whole class sharing of the first results	• Experimentation: The groups carry out their experiment autonomously, while the instructor keeps a check on how they do so (whether or not they write down the steps they follow, whether they use measuring instruments, whether the decisions they make are arbitrary, spontaneous, or the result of consensus). • Presentation of an example of a data acquisition and observation instrument based on the demands and/or difficulties manifested by the groups. This instrument helps to systematize the observation process, and to better control the variables studied. • Making weekly observations of the evolution of the seeds and their germination: The instructor checks on each group as to what they observe, how they do so, and what type of annotations or data they record in their notebook. • After three observations (three weeks of growth), the first results are discussed and shared in a whole-class session.
PHASE III: Learning and possible transfer	Post-ExA: Reflection on the learning derived from the ExA	• Each group records their reflections about the ExA in their notebook: (i) the ExA process (phases I and II), (ii) what they have learnt about the phenomenon studied (awareness and evolution of their prior ideas), (iii) what doubts or new questions the experience has raised (what they do not understand well, what they would like to know, etc.), and (iv) what they have learnt regarding their performance as future science teachers.

It should be noted that, in phase III, the prospective teachers were explicitly requested to give their reflections on questions (i)-(iii) in their notebooks. They were not, however, given any direct instruction about how to reflect upon the possible transfer of their learning (question iv). Also, phase III is of especial relevance in this study since, as will be detailed in the following section, it corresponds to the moment in which the prospective teachers record the ExA in their notebooks, which will serve as a source of information to analyse the grade of development of their learning-to-learn competence.

Instruments and analysis procedure

As noted above, each group recorded the development of the ExA in their notebook (Ruiz-Primo et al., 2004). The notebook is an instrument that invites students to naturally record their learning experiences. In it, they can describe the problems they are trying to solve, the procedure to use, the observations they make, as well as their more intimate reflections (Angulo, 1998; Campanario, 2000; Ruiz-Primo et al., 2004). Its use is therefore ideal in inquiry-type learning processes, with attention centred on the development of metacognitive strategies (White et al., 2009) in which the students are explicitly invited to become aware of those strategies' effectiveness (Osses & Jaramillo, 2008). Thus, the group notebook was the data source, and its content was analysed from a descriptive-interpretative perspective. In the notebooks, the groups recorded their reflections about the ExA in seven sections: (a) research problem, (b) hypothesis formulation, (c) variables to study, (d) design of the experiment, (e) data acquisition (the regular monitoring observations), (f) interpretation and conclusions of the results, and (g) overall final reflection. In line with what is described in Table 1, in these sections the groups were required to try to reflect in as much detail as possible on everything they did and learnt about the phenomenon of germination (basic scientific knowledge and skills) corresponding to phases I and II, and on the progress of their learning with the ExA, corresponding to phase III. For the analysis of all this information, a categories-descriptors relationship was established that allowed the degree of development of the learning-to-learn competence to be assessed.

Categories-descriptors of the learning-to-learn competence

In accordance with the described theoretical framework, the Categories-Descriptors derived from the groups' science notebooks as listed in Table 2 were used for the analysis of the learning-to-learn competence. It should be clarified that, although the European Commission uses four dimensions to evaluate this competence (*1. Why I learn*, *2. What I learn*, *3. How I learn*, and *4. I reflect on my progress*), in this case only the second (what I have learnt) and fourth (reflection on my learning progress) dimensions were used, since these were the ones that were mainly reflected in the groups' science notebooks. Likewise, both of these dimensions had been specified in a series of categories referring to the desirable teaching competences for science teaching (Guerra & Jiménez-Aleixandre, 2011). Thus, the dimension "*What have I learnt (and not)?*" corresponds to the Scientific Knowledge (SK) that was being dealt with and the Scientific Skills (SS) that had been developed (observation, formulation of hypotheses, interpretation, etc.). It also accommodates knowledge that still needs to be learnt or that arouses interest. The dimension "*Reflect on my learning progress*" is related to two categories: the metacognitive knowledge (MK) that the students put into play during the ExA, and the didactic knowledge and the transfer of learning to other areas, disciplines, or problems (DK).

Table 2. Table of Categories-Descriptors by dimension.

Dimensions	Categories	Descriptors
Dimension 1. *What have I learnt (and not)?*	Scientific Knowledge (SK)	Knowledge related to the content being studied gained (or not) by the students after the practical experiment, in this case, knowledge about seed germination and plant growth.
	Scientific Skills (SS)	Scientific skills (observation, setting out hypotheses, data interpretation, etc.) that students explicitly state they have developed (or not) during the experiment.
Dimension 4. *Reflection on my learning progress*	Metacognitive Knowledge (MK)	The students' awareness of what and how they have learnt, in terms of strengths, weaknesses, and proposals for improvement.
	Didactic Knowledge (DK)	Didactic Knowledge that the students have achieved as a result of reflecting on the ExA, and which will help them in their future teaching practice (didactic transfer of learning).

Since the groups' notebooks offered wide-ranging and varied information about the prospective teachers' opinions, evaluations, and reflections, their content was analysed and categorized in a progressive way through a process of inter-observer analysis (Padilla, 2002), following the usual standards in qualitative content analysis (Mayring, 2000). To this end, the first author extracted the data from the notebooks for its organization and systematic analysis. Once this information had been compiled, this same author subjected it to a preliminary analysis in accordance with the categories and descriptors of Table 2. This first categorization was reviewed by the second author, finding a high degree of agreement in about 90% of the information units analysed. The cases of discrepancy were reviewed again and discussed by the two authors until a consensus was reached on their definitive categorization.

Following Shenton (2004), in order to meet the *confirmability* criterion in this qualitative study, the data were analysed according to a clearly established categorisation system (Table 2) based on the theoretical framework described. In this way, possible biases of the researchers in classifying and interpreting the data are minimised. In addition, to reinforce the *credibility* of the analysis, the use of *low inference descriptors* is used in the presentation of the results (Latorre, 2003). In particular, as will be seen below, included together with the categories of analysis are textual fragments of the information recorded by the groups in their notebooks. This is done in order to provide evidence in support of the decisions the authors made regarding the categorization of the information.

Regarding the *transferability* of the study, it can only be partially contributed because, certainly, the results and conclusions cannot be generalised to the entire population of future primary school teachers, not even in the Spanish context. However, they can be considered as a source of reflection and reference for other research carried out in similar educational contexts (Elliot, 2000).

Results

Before going on to analyse in detail each of the dimensions and categories of the learning to learn competence, table 3 shows an overall synthesis of the attention they received by the groups during the ExA. As can be seen, the two categories of dimension 1 (What have I learnt (and not)?) were the most attended to by the groups; in particular, the category 'Scientific Knowledge (SK)' was addressed by all groups in their notebook, and 'Scientific Skill (SS)' by almost all. In contrast, reflection on their own learning (dimension 4) seemed to be less interesting or easy to address during the ExA. Both 'Metacognitive Knowledge (MK)' and 'Didactic Knowledge (DK)' categories were only addressed by about a third of the groups (4/11). However, given the exploratory-descriptive nature of this study, no information was obtained on the reasons why these were not addressed by the remaining groups in their notebooks. Below, it is delved into how the different categories were addressed by the groups that addressed them.

Table 3. Number of groups that explicitly referred to the different categories of learning-to-learn competence analysed in their notebooks during the ExA

Dimensions	Categories	No. of groups
Dimension 1. *What have I learnt (and not)?*	Scientific Knowledge (SK)	11/11
	Scientific Skills (SS)	9/11
Dimension 4. *Reflection on my learning progress*	Metacognitive Knowledge (MK)	4/11
	Didactic Knowledge (DK)	4/11

Dimension 1: What have I learnt (and not)?

Category – Scientific Knowledge (SK)

In their notebooks, the 11 groups indicated something relating to their SK learning after the ExA. Tables 4-6 present extracts from the notebooks in which the evolution can be observed of their prior ideas that conformed their initial hypotheses. Also indicated is the section of the notebook from which the fragments were taken and/or the moment of the ExA being referred to (inquiry problem, formulation of hypotheses, variables to study, experiment design, data acquisition, the monitoring observations, or the interpretation and conclusions of the results).

Table 4 gives examples of what the groups learnt (what they know). These reflections appear mainly in the ExA while observing the seeds and in the last phase of interpretation of the data and conclusions. All the groups contrasted their hypotheses as prior ideas, and become aware of those ideas. In the selected examples (notebooks of groups 1 and 7) it can be observed how, in addition to testing the hypotheses, the students expressed their surprise at the new findings with such expressions as "to our surprise" and "contrary to everything, we can deduce". Likewise, the difficulties that the groups detected during the development of the ExA and the common mistakes that they made in their learning are pointed to, as when group 7 notes "failure" and "redo the experiment".

Table 4. What they know: Dismantling their prior ideas or initial hypotheses.

Groups	Notebook section / ExA moment	Excerpts from notebooks
Group 1	Data acquisition: monitoring of observations	In our case, we were able to observe that our seed which had been placed in the dark, to our surprise, had germinated much more than our seed which had been placed in the light, as three stems had grown. Whereas, the seed that had been placed in the light had not grown at all, thus undoing the entire hypothesis that we had elaborated in the previous practical (…) we came to the conclusion that contrary to everything we had thought, our lentil seed which had been placed in the dark germinated better than the other lentil seed which had been placed in the light (…).
	Interpretation of the data and Conclusions	With this that our seeds have experienced, we can come to the conclusion that seeds germinate better without light, but that, on the other hand, they grow better with light, and that in addition, they need to be 'free' (that, to be able to grow well, they must not be compressed).
Group 7	Data acquisition: monitoring of observations	We decided to carry out the experiment again [the seeds did not germinate during the first week], but also changed the design. This time we planted seeds in three different vessels to make sure that, if there was a possible failure, it was not due to the poor condition of the seeds. (…). In this second design, we planted seven seeds in one vessel while in the other two we planted one seed each (…). After the observations made, we must add that our hypothesis was not true since the plant with the seven seeds grew earlier than those with one.
	Interpretation of the data and Conclusions	After the observations made, (…) we can deduce that the number of seeds affects whether a plant grows faster or slower than another, even though they were both planted and exposed to the same conditions (…) there are many factors that intervene in the embryonic development of a plant. If we find that one of these factors is not adequate, we will not get good results.

Table 5 presents two examples of the only two groups (groups 6 and 7) who, in addition to considering what they have learnt, reflect upon what they do not know. They do this in the form of new questions or issues that they would like to research into further. The expressions that denote it are "let's ask questions" and "new curiosities."

Table 5. What they don't know: New questions.

Groups	Notebook section / ExA moment	Excerpts from notebooks
Group 6	Data acquisition: monitoring of observations	These are the two samples that we kept in the refrigerator, we gave one more water than the other (…) after two weeks, in one nothing has grown at all and in another very little, this makes us ask ourselves such questions as: Does excess water cause the plant to suffocate and prevent its growth? Does the fact that they are in the refrigerator also slow down their growth? At first we think that yes, that the excess water and the temperature of the refrigerator do not favour growth, but we will confirm or disprove it next week, since this week we have decided to leave them out to resolve our doubts.
Group 7	Interpretation of the data and Conclusions	To us as a group, new curiosities arose about the growth of the legume embryo. Would the development of an embryo be possible if instead of water we used another liquid such as juice or coca cola? How does the absence of sunlight affect plant growth? Do these things affect all types of plants equally?

Finally, Table 6 shows at which point in the ExA the students reconsider their prior ideas, or this reconsideration serves as a learning experience. Five of the 11 groups made it explicit in their notebook (section: data acquisition and interpretation and conclusions) that one of the most relevant moments of their learning was after a session of joint reflection with the other groups, as appeared in the examples of groups 2, 5, and 8. In addition, group 5 highlighted that after this joint class session and the reflection that arose, they decided to look for more information on the Internet to be able to continue with the ExA: "As a result of this we decided to search the Internet for the characteristics of the plant."

Table 6. Key moments in group learning: whole class session.

Groups	Notebook section / ExA moment	Excerpts from notebooks
Group 2	Data acquisition: monitoring of observations	Lastly, after all our companions had recounted their experiences with their seeds, we came to realize that seeds need darkness and humidity to germinate, which is why the seeds that were buried and in a place where no light entered germinated better, as well as using cotton wool as it maintains moisture for a long time.
Group 8	Interpretation of the data and Conclusions	The results are different from those we expected (…) At first we believed that the seeds exposed to light would germinate the fastest, but this was not the case, so our initial hypotheses turned out to be wrong (…). In addition, we drew conclusions from other trials of our colleagues. The conditions for fungi to grow are high humidity and mild temperature (one group poured excess water). (…) In conclusion, fungi only appear in conditions of humidity and temperature.
Group 5	Final reflections	(…) In summary, the information in the table showed us that our plant did not evolve properly, and if we compared our evolution with that of other colleagues who carried out the same activity but with different seeds, ours was inadequate. This was the first difficulty we faced, the germination process did not advance. Because of this, we decided to search the Internet for the characteristics of the plant to find out what environment it grows in, and what its necessities are to grow.

Category – Scientific Skills (SS)

With respect to the SS developed, 9 of the 11 groups described in their notebook what skills and abilities they believed they had learnt (Table 7). Most agreed that the ExA had helped them identify the different phases or processes of a scientific research investigation (e.g., group 11), such as its planning (e.g., group 10) and the importance of observation (e.g., group 2). In addition, group 10 recognized the difficulties involved in performing ExA of this type.

Table 7. Recognition of methods and phases of a school science inquiry.

Groups	Notebook section / ExA moment	Excerpts from notebooks
Group 2	Interpretation of the data and Conclusions	In carrying out all this process, we realized that we were conducting a process of scientific method, since we set out a hypothesis "the substrate influences the germination of the plant" that we then carried out to test it and see if it was true or false. When we realized by observation that a step in the process was wrong, we had to correct our object of study (we had vessels with different conditions and different substrate) and carry out the hypotheses again, now using the object of study correctly (vessels with the same conditions and different substrate).
Group 10	Interpretation of the data and Conclusions	We have learnt the planning phases involved in conducting an inquiry, as well as the difficulties in conducting it.
Group 11	Final reflections	We have been able to reflect and learn the steps to carry out a research inquiry. (…) Also, another learning that we have acquired is the ability to point to the progress of our inquiry since we had to collect observational data and analyse them to draw conclusions.

Dimension 4: Reflection on my learning progress

Category – Metacognitive Knowledge (MK)

In their notebooks, 4 of the 11 groups noted down aspects related to the MK developed during the ExA (Table 8). Unlike the previous results (Tables 4-6), which section of the notebook or moment these notes were made has not been included since they only appear in the conclusions and final reflections part of the ExA. The selection of the extracts corresponds to the most outstanding characteristics of the cognitive or metacognitive strategies developed by the groups.

In their reflection as future science teachers, groups 2 and 5 show an attempt at didactic transfer of what they had experienced to a class of primary school children (isomorphism). Moreover, group 2 offers more details of this transfer by outlining an educational proposal: "For example, if a child (…)". For its part, although it considers that its ExA had not been successful, group 5 recommends its use with primary school children "… it is a good activity (…)". Group 8 becomes aware of the importance of "… making classes and activities more flexible, and adapting them" in the future when they are teachers. Likewise, group 11 states that what is interesting about this type of ExA is the motivation and interest it can arouse in primary school students.

Table 8. Reflection on my learning progress: Category MK

Category	Groups	Excerpts from notebooks
MK	Group 2	For example, if a child is interested in growing a plant, they will first observe one that they already have planted, second they will look for information about that plant (when to plant it, if it needs a lot or little water, if it needs humidity, or how much sun, what kind of compost is better for it, etc.), third they will formulate the hypothesis by planting different seeds in different conditions and they will experiment these hypotheses to see which ones work, finally they will draw conclusions (…).
	Group 5	Although our experiment was not successful, this is a good activity to carry out with primary education children as they discover the factors and needs that influence the growth of a plant.
	Group 8	Here we realized the need to make classes and activities more flexible, and adapt them if necessary.
	Group 11	It made us feel like good scientists, and if we transfer this to the mind of a child, the motivation with which this task is carried out is very interesting, since we felt autonomous from the beginning to the end of the activity. Each group will draw their own conclusions and reflections and it is important to promote a critical sense in our future students.

Category – Didactic Knowledge (DK)

In the same way as in the MK category, the examples collected of the DK of the groups (Table 9) appear only in the conclusions and final reflections section of the notebook. Mentions of the DK that had developed after the ExA were only found in the notebooks of 4 of the 11 groups. Group 7 identifies the way they learnt, using such expressions as "experimental", "self-taught", and "trial and error". In addition, this group identifies their alternative ideas and the lack of knowledge about the subject as obstacles to the development of their learning. The case of Group 11 is similar. Groups 8 and 9 identify their learning process with the theoretical knowledge worked on in the subject: "We have learnt in a unitary way" as indicated by group 8, and "Starting from everyday knowledge to school knowledge" as indicated by group 9. Group 8 adds that the learning process they experienced must be the same as that which they will construct with their future students: "Both in the subject and for our future students, we must use a differential constructivist model". Finally, worthy of note is the positive emotion that the students have when they become aware of their progress, as observed in the rhetorical question "It’s a good start, isn’t it?" put by group 8.

Table 9. Reflection on my learning progress: Category DK

Category	Groups	Excerpts from notebooks
DK	Group 7	After having carried out the experiment with legumes, we are going to see the different ways that we have to learn knowledge, the way we learnt during the practice of legumes was experimental, self-taught, and with trial and error, because we did not have enough knowledge to know which were the best methods and materials to make the plant germinate and then make it grow.
	Group 9	We can relate this task to what we have worked on in a practical way in the laboratory, about planting the seed since without being aware of it we have been learning, starting from everyday contents until reaching school knowledge.
	Group 8	We think that we have learnt in a unitary way and now, both for the subject and for our future students, we must use a differential constructivist model since in this way our knowledge will be lasting, and not ephemeral (which it would be for the unitary way) (…) This that we have experienced in class, it has been meaningful learning, since from an experiment we have observed and analysed what was happening. Understanding differences and establishing similarities. It’s a good start, isn’t it?

Group 11	We have learnt that to carry out an activity like this we started out from our prior knowledge to give rise to the steps that we must follow for our research.

Discussion

This study has investigated to what extent an ExA can contribute to the development of prospective teachers' learning-to-learn competence. Although there are previous studies that have explored this issue (e.g. Huang & Chang, 2013; Chang et al., 2020; Nunaki et al., 2019), they did so without delving into the dimensions that make up the learning-to-learn competence or at specific moments, or situations that promote this learning. The present study has identified (1) the dimensions of the learning-to-learn competence (Dimension 1. What have I learned (and not)? and Dimension 4. Reflection on my learning progress) that improve in the context of an ExA, and (2) the moments and/or specific tasks of this in which such learning occurs. The identification of the tasks or situations that provoke learning and to what extent they do so (explored dimensions) are relevant aspects in the effective design of educational proposals and in the identification of possible strengths and obstacles to be resolved for the design of ExA. Likewise, it is key so that the teacher her/himself can guide the teaching-learning process during the ExA. In addition, to exemplify it, a "classic" activity in primary classrooms (plant germination) has been used as an ExA from an inquiring perspective in order to show how traditional school activities can be worked from an inquiring approach to develop metacognitive skills. For this, the main question was broken down into two research questions for its analysis: (1) What moments and/or tasks of an ExA favour strategies for the development of the learning-to-learn competence?; (2) What strategies do prospective teachers use as part of their learning-to-learn competence during the ExA? Even so, as noted above, the two problems are clearly intertwined because it is hard to address metacognitive issues without addressing cognitive issues (Osses & Jaramillo, 2008), in this case, aimed at resolving a specific objective: to get seeds to germinate and grow.

As noted by Cornford (2002), not all cognitive and metacognitive strategies are made explicit or can be made explicit in educational processes. Starting from this premise, here we shall discuss those that the groups expressed in their notebooks.

After the conclusion of the ExA in its different phases and moments, it was found that not all the actions carried out had the same implication in the degree of progress of the learning-to-learn competence. Three major actions and moments stand out in particular: (1) data acquisition and follow-up with weekly observations, (2) interpretation of data and conclusions, and (3) final reflections. In addition, in each of these a different category took on especial relevance. While in the development of the ExA the prospective teachers questioned their prior ideas (SK) and showed their Scientific Skills (SS), it was not until the last phase of reflection, once the ExA had been finished, that they became aware of their learning strategies (MK) and the didactic transfer of the said knowledge (DK) as future teachers. Thus, it was confirmed that the use of flexible ExA oriented towards metacognitive training leads the students to check their own inquiry and learning strategies that they used, as well as to become aware of the effectiveness of those strategies (Osses & Jaramillo, 2008). Likewise, key in this process is the final reflection recorded in the notebooks on how to attain these achievements. It is therefore unsurprising that activities which allow ideas to be challenged, debated, and reflected on, such as the different moments when the groups shared their inquiry findings, were those that the prospective teachers valued most highly in pursuit of their learning progress. Similar results have been found in other studies with secondary education students (García-Carmona, 2012). This underscores the importance of promoting socio-constructivist strategies in science teaching, since learning is developed through a social process based on an ongoing interactive dialogue among equals (student-student interaction), as well as with a higher cognitive agent (the teacher).

Another positive result, which had a great influence on the prospective teachers' learning with the ExA, was the awareness and management they made of mistakes, errors, or apparent failure in their inquiry. Far from negatively evaluating these failures in their experiments, the prospective teachers stressed how assimilating them catapulted their learning. It allowed them to recognize and review their conceptions about germination, and to propose alternative solutions based on the reformulation of their learning strategies. The prospective teachers saw the failure itself to be a challenge or obstacle to overcome in attaining their objectives within their capacities (Ministerio de Educación, 2014). In this sense, a key factor was their constant motivation with the ExA, with the aim of getting their seeds to germinate and testing their initial hypotheses. As highlighted by Osses and Jaramillo (2008), learning-to-learn is a result of the interactive confrontation of cognition, metacognition, and motivation, which together constitute an essential triad for self-regulated learning. Another positive emotion that created interest and motivation during the ExA was surprise, generated when the prospective teachers saw how, in a relatively short period of time (one week), their seeds and seedlings developed. This helped them directly check and collate the validity of their designs and their initial premises or hypotheses (Angulo, 1998; Campanario, 2000). The fact of obtaining quick and visual results, in this case getting the seed to germinate, is a key factor for learners' involvement in the proposed task, and therefore in their learning progress (Cornford, 2002). Also, being able to verify for themselves the relationship of their theoretical knowledge from the science teaching subject with the practical activity they experienced had a very positive effect on these prospective teachers. This was reflected in one group's statement, in the form of a rhetorical question, that "This is just the beginning of something new". One can say that at that moment the prospective teachers begin to make sense of the subject when they see theoretical knowledge integrated with the practical activity, and express what they had learnt meaningfully. Likewise, studies such as Huang and Chang (2013) and García-Carmona (2019) point out the importance of teamwork and collaborative practices as key aspects to achieve metacognition.

A striking aspect with regard to the transfer of DK is that, despite not providing the students with explicit guidelines about this category for them to reflect on in their notebooks, a large proportion of the groups did make such references. Nonetheless, they did not all experience the ExA in the same way, and neither did it have the same implication for their learning. There were moments of stagnation for some groups in the development of their ExA, mainly caused by the novelty of the activity since they had not experienced it before (Angulo, 1998). Indeed, the autonomous decision-making and the uneasiness caused by the approach of open-learning situations, in which the students must make decisions, setting out the scheduling, the phases, and even deciding on the data acquisition instruments, was a situation that some of the groups found hard to manage, so that they ended the ExA with limited results. Specifically, three groups did not reflect on their learning (dimension 4), despite the instructor's indication in this regard. We believe that a possible explanation why these prospective teachers did not register these moments of stagnation, limiting themselves almost exclusively to showing the final result or product, addresses aesthetic rather than educational issues. Perhaps this is due to the fact that they unconsciously associated the notebook with such social tools as Facebook, Twitter, or some other, in which personal successes or idyllic moments prevail. This then leads to them highlighting those more superficial and banal aspects rather than the deeper ones such as recording the process followed and the obstacles encountered (what went "wrong", why, and what was learnt from it). We infer this observation from noting that these two groups decided to make their notebooks using these social or communication networks.

Limitations and perspectives

Determining from the reflections in their notebooks the level of acquisition of the learning-to-learn competence, or the cognitive and metacognitive strategies that the prospective teachers develop about an ExA was a task of great complexity. Fundamentally, this was due to the variety of forms of recording information and to the prospective teachers' own capacity for expression. Added to this was the difficulty that, unlike other better studied educational competences, this competence entails given its psychological and didactic conceptualization (White et al., 2009). Likewise, it must be said that the results presented are limited in that they emanate from the particular circumstances and context in which the study was carried out, with a small sample chosen for convenience. However, the profuse description of the context, the activity, and the profile of the participants may favour some type of transferability to other similar teacher training contexts, always with the precaution needed concerning qualitative studies such as the present. This suggests the need to undertake new inquiries in both the same context in order to deepen the findings presented here, and other contexts to make comparative analyses. In this regard, it would be especially interesting to explore the other two remaining dimensions – why I learn (dimension 1) and how I learn (dimension 3) – which also conform the learning-to-learn competence (European Commission, 2012).

With regard to the research instruments used, it would be desirable to combine the notebook with other data acquisition instruments such as video recordings, which would help to obtain a greater quantity and diversity of information or even do a pre-interview to explore participants views on learning motivation and metacognition. Additionally, a mixed-method approach might have been appropriate to address the research questions of the study and use a control group and data at the individual level. This was not done in the present case because, being a preliminary study about such a complex issue, it was not even known how the notebook was going to work. But it has proven without a doubt to be an immensely rich source of information to record, and therefore analyse, metacognitive and self-regulatory learning processes.

Finally, and in view of all the above, it can be said that this study has made an interesting and suggestive contribution to a subject that is rarely dealt with in science teaching in general, and particularly in initial primary teacher training – in this case, the development of cognitive and metacognitive strategies to learn how to learn science, as an essential step in learning to teach science. It was also done by taking advantage of an activity – the germination of seeds – which is classic but, in the form in which it was implemented, i.e., with an inquiry-based focus within a flexible ExA, has been profiled as ideal for the development of competences as complex as that of learning-to-learn in the initial training of prospective teachers.

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Ethical Statement

This study met the ethics requirements for research that involves human subjects at the time the data was collected.

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