What do prospective teachers know about the sort of activities that are helpful in learning science? A progression of learning during a science methods course

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The activities designed by 91 teams of primary teacher education students as part of their teaching proposals in a course on science teaching are analysed together with the subsequent reformulations of those activities. The objective of the study was to gain insight into the students' professional practical knowledge and the underlying focus of their approach to teaching. Qualitative methods based on content analysis were applied. The instruments used were a reflection script and the students' teaching proposals about the different versions of a specific theme of science content. The results indicate that these prospective teachers' knowledge about the types of activities that are appropriate for teaching science changed during the course from a teacher- and teaching-centred approach centred to one focused on the pupil and learning. The implications for science teacher education are discussed.

Keywords: teaching strategies; learning progression; methodology of teaching; pædagogical content knowledge; initial teacher training.

Introduction

Inquiry-based teaching is an approach that has to be addressed in teacher training as it is the most widely accepted in international reports (Rocard et al., 2007), curricular regulations (NRC, 2012), and education research (Pedaste et al., 2015). It emphasizes the development of skills associated with critical thinking, problem solving and complex projects, the ability to obtain, analyse, synthesize, and evaluate information, the development and reworking of the learner's own models, the application of knowledge to novel situations, interpersonal skills for people to work together, and finding the resources or tools needed and communicating effectively (Darling-Hammond, Flook, Cook-Harvey, Barron and Osher, 2019).

Understanding how in their initial training prospective teachers learn to teach science with this approach constitutes a line of research that is fundamental for the creation of new undergraduate teaching programs specifically oriented towards promoting students' appropriate learning. Research on contemporary learning proposes that this occurs along conceptual trajectories or learning progressions (Duschl, Maeng and Sezen, 2011; Liu and Jackson, 2019). Various studies have analysed the progressions of teaching knowledge in relation to both science content and pædagogical content. Their results support the relevance of this approach to analyses of the results of teacher training. There remains, however, a broad range of work to be done since, as Duschl (2019) stresses, the progression from implementing teacher-centred activities to others that are pupil-centred, based on fostering more sophisticated ways of knowing and thinking by means of inquiry into problems or projects, is an as yet unresolved issue of research, especially in the case of Primary Education teachers.

The purpose of this work is to go more deeply into this line, and contribute detailed information on how prospective primary teachers' knowledge about the types of activities appropriate for teaching science progresses throughout a course on science methods at our University. The ultimate purpose is to have relevant information with which to adapt the training given to these future teachers.

Teacher Knowledge and Learning

Contemporary approaches to improving the quality of teaching are always accompanied by consideration of the appropriateness of pædagogical content knowledge (PCK) (Fisher, Borowski, Andreas and Tepner, 2012). The definition of PCK has evolved from the basis of the ideas of Shulman (1987). It is understood as genuine knowledge associated with the profession that results from the integration and transformation of different types of components as teaching is planned and carried out (Magnusson, Krajcik and Borko, 1999).

The interest in understanding pædagogical content knowledge gave rise to a variety of models. One of the most influential for science education was that of Magnusson et al. This differentiated five components in PCK: (1) orientations towards teaching science, (2) knowledge of the science curriculum, (3) knowledge of pupils' understanding of science, (4) knowledge of evaluation, and (5) knowledge of instructional strategies. According to those authors, the last four components are related to the first, with the orientations influencing decisions on the design of activities, the content of pupil tasks, the evaluation of pupil learning, and the use of curricular materials.

At the BSCS summit held in 2012 in the United States (BSCS, 2012), PCK was re-examined. This gave rise to the Consensus Model of Teacher Professional Knowledge and Skill (TPK and S) (Berry, Friedrichsen and Loughran, 2015; Gess-Newsome, 2015 – Figure 1) which sets out a framework to define the relationships between the different types of teacher knowledge. The model takes into account Teacher Professional Knowledge Bases (TPKB), regarded as the teaching profession's general and public knowledge integrating five types of knowledge – about evaluation, pædagogy, content, pupils, and the curriculum. The TPKB interacts with a second component denoted Topic-Specific Professional Knowledge (TSPK). This is the knowledge that is characteristic of the science teaching profession itself, and includes science teaching strategies, content representations, pupils' understanding and intellectual skills, and science practices. The TSPK is put into practice in the classroom in specific contexts, and determines the PCK which is considered to be personal for each teacher. The relationship between the first two types of knowledge and personal PCK is influenced by amplifiers and filters (beliefs, affect, the teacher's and pupils' values, the teacher's orientation, and the context) which moderate the transfer of professional knowledge to actual classroom practice. The pupils' outcomes constitute another element of great influence on the teacher's personal PCK, an influence that is also mediated by amplifiers and filters (beliefs about the pupils, their knowledge, and behaviour). This model thus comprises two types of PCK – one personal and the other in action. The former is associated with reflection on planning the teaching – "about action" – and the latter on the teaching itself – "in action" (Park and Oliver, 2008).

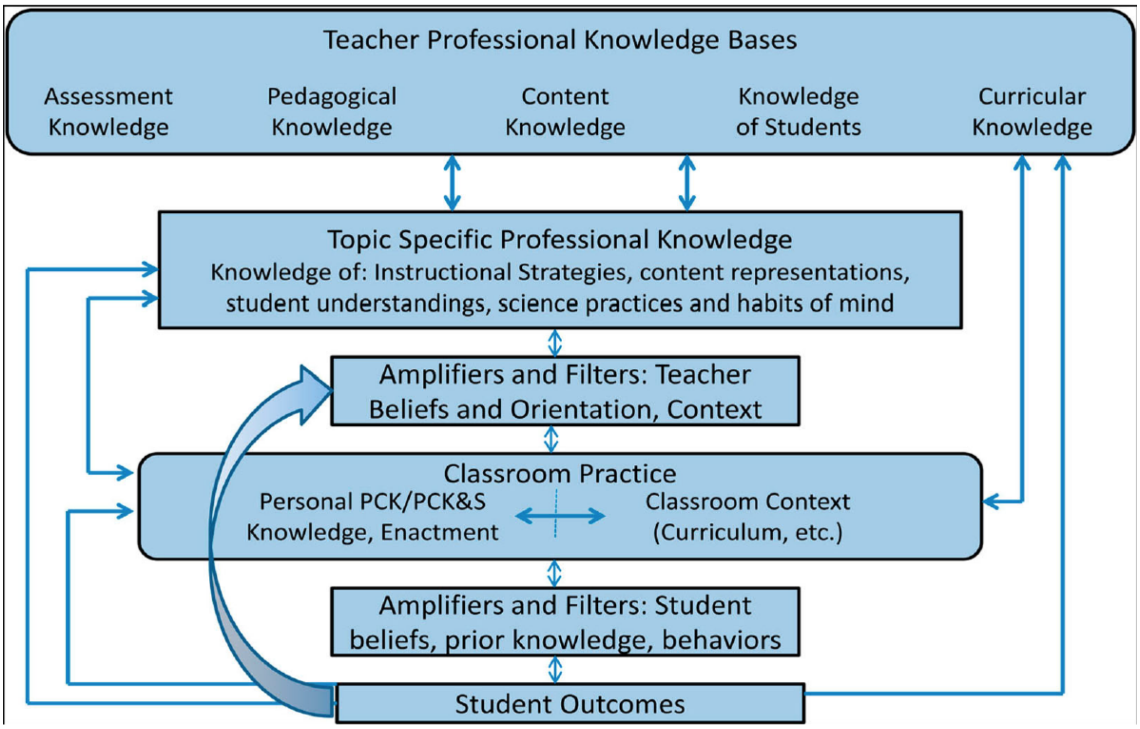


Figure 1. Model of teacher professional knowledge and skills including PCK (Gess-Newsome, 2015).

According to this model, PCK is an attribute of in-service teachers as it is generated and manifested in the classroom and should be distinguished from the more canonical topic-specific professional knowledge (TSPK). Also noteworthy in this model is the recognition of the student's results and classroom practicum as key elements in the configuration of PCK, thus resulting in dynamic rather than static knowledge. Nonetheless, there is little detail about PCK provided in the model itself, which makes it hard for researchers to locate specific knowledge analysed in their studies.

These limitations led to a second summit being held in 2017, the results of which subsequently led to the presentation of the Refined Consensus Model (RCM) of PCK in science education (Carlson and Daehler, 2019) (see Figure 2).

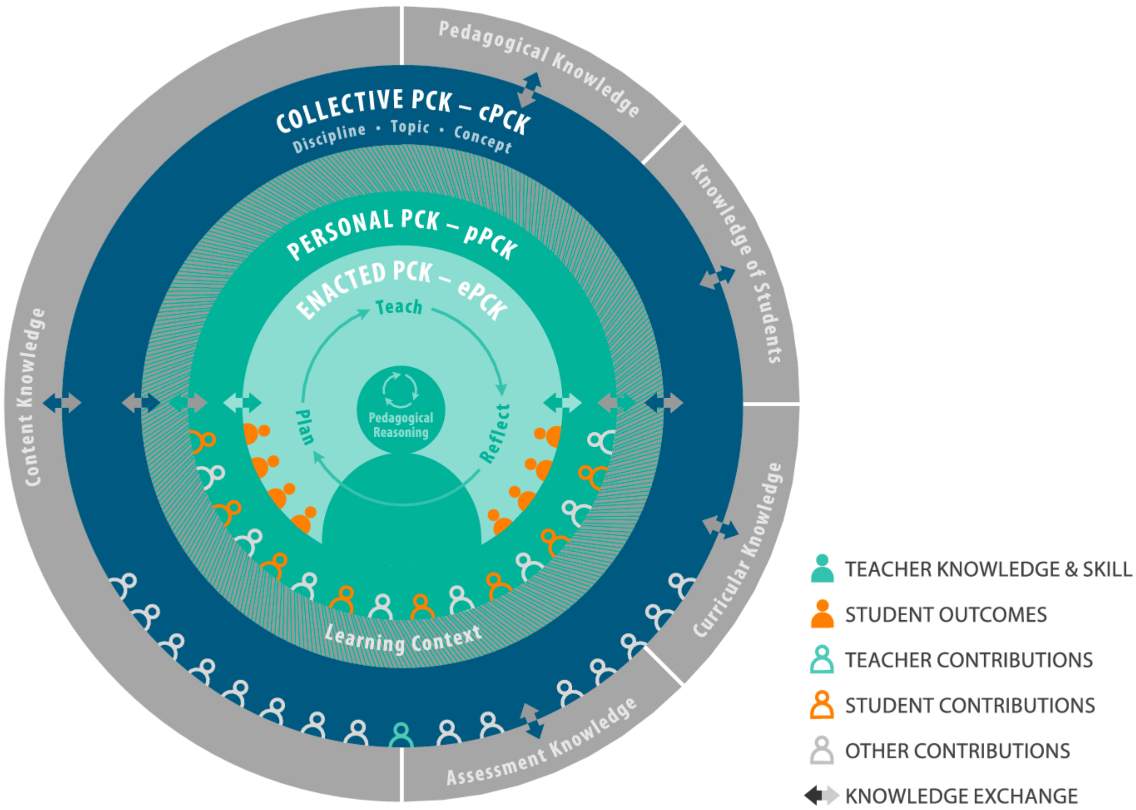


Figure 2. Representation of the Refined Consensus Model (RCM) of PCK (Carlson, 2019).

One of the results of that summit was the identification of three distinct realms of PCK: collective PCK, personal PCK, and enacted PCK. Enacted PCK is what teachers use in their classroom practice, whether planning, carrying out, or reflecting on that practice and the results obtained with their pupils. It constitutes the heart of professional knowledge. Personal PCK is the teachers' knowledge and science teaching skills in specific contexts. It is the result of their training and experience, and is broader than the enacted type since it contains more elements than those the teacher actually uses in any particular class. Collective PCK is an amalgam of knowledge built from the contributions of science educators (including those of the teacher themself), the combined base knowledge, and the teaching experiences more or less formally collected together. It is public knowledge that can be articulated and shared, and that includes the canonical PCK (which is produced in research), but is also developed in school contexts and by professional learning communities.

This precise distinction between levels does not imply a teaching knowledge model made up of watertight compartments, but rather that another distinctive feature of this RCM is establishing that the various domains of PCK maintain important two-way interchanges among themselves, as well as with the base knowledge and the practical context. One thus thinks of a continuum with mutual influences. This last idea is what leads one to emphasize that, from their initial training, prospective teachers could, and should, be encouraged to develop knowledge that can already act as a precursor of their PCK, and thus help to bridge the gap between theory and practice (Kenny, 2009).

In the context in which the research presented in this paper was carried out, science education courses are detached from the teaching practicum, so that it is complicated to favour the relationships between the University and schools because of schedules, work rhythms, opportunities, etc. But if the wish is to promote in prospective teachers the type of pædagogical reasoning that, in turn, promotes the development of PCK, it is essential to involve them in activities related (in as far as possible and with the necessary adaptations) to the design, carrying out, and reflection on practice. This can either be by developing teaching plans, by achieving specific collaborations with schools to develop specific collaborative activities, or by experimenting with micro-teaching proposals in partnership their peers (Nilsson, 2008). Of these possibilities, the present study focused on curriculum design. As expressly stated by Carlson et al. (2019): "When a team of teachers develops a shared teaching sequence this tacit knowledge (…) represents collective PCK and may be one of the main drivers for professional learning" (p. 90).

As we noted in the Introduction, teacher learning is understood as a process that occurs progressively. Learning progressions have their antecedents in studies such as those of Driver (1989), Black and Simon (1992), and Niedderer, Goldberg and Duit (1992). These studies highlighted the need to organize the changes that were detected in learners' ideas into increasingly sophisticated, ordered transition sequences. It also constitutes a relevant framework within which to analyse teachers' knowledge and its development over time (Schneider and Plasman, 2011).

To foster science teachers' learning, teacher education strategies have to take into account the way in which that learning occurs and be expressly adapted to it (Kang, Thompson and Windschitl, 2014). In this sense, and from the reviews of initial teacher training programs presented in various works (Crawford and Capps, 2016; Korthagen, Loughran and Russel, 2006), we can indicate the following points as being necessary for a proposal to be successful: a specific focus on the students' initial knowledge, beliefs, and interests; stress put on curriculum design and development; involving the students in continual conflictive demands; a vision of the knowledge needed to teach as being material to create rather than as something already created; encouraging the future teachers to investigate into their own designs and practices; promoting peer-to-peer cooperation and exchange; teaching these future teachers in a way that is coherent with how we propose that they should teach their own primary school pupils; and, finally, having enough time left available for the changes to actually occur.

In this work, these characteristics were taken into account to design (with the adaptations required by the context) a training proposal to instruct prospective teachers on how to take an inquiry-based approach to teaching science to primary school pupils (6-12 years old).

Activities for teaching science

Although the orientation of teaching has clear repercussions in terms of content, methods, and evaluation at the curricular level, it is probably in the methods where these relationships are most evident. Among the methodological aspects, activities constitute the central element since they describe what actually happens in class (Clemente, 2010).

Activities can be very diverse and can be analysed from different perspectives. For example, they have been analysed in accordance with the characteristics of the information they put into play, with the cognitive demands they make, with the degree of cooperation of their protagonists, with the pædagogical intention, etc. (García Barros and Martínez Losada, 2001; Kang, Windschitl and Thompson, 2016). While all of these aspects are relevant in characterizing activities, the pædagogical intention is probably the most revealing for their selection and organization. Thus, in transmissive teaching, there predominates the teacher's presentation of the topic in order to transmit already elaborated information and then use some of the modalities of the pupils' individual work for them to apply and verify the said information (Martínez Losada and García Barros, 2001). In inquiry-based teaching however, it is important to diversify activities to foster the pupils' role and the evolution of their mental models. In a large-scale review of works related to inquiry-based teaching, Pedaste et al. (2015) detected the following activities that are characteristic of this approach: activities designed to involve the pupils in the process; proposing problems or projects; expressing hypothetical models; planning and gathering information; organizing, analysing, interpreting, and/or evaluating that information; producing one's own well-founded arguments; reflective discussion with others; drawing conclusions, comparing them with the initial models, and making judgements based on them; and evaluating one's own learning.

Various studies have analysed the progression of teaching knowledge regarding methodological issues. For example, the work of Barnett and Friedrichsen (2015) describes the innovative strategies used by a secondary education biology mentor to develop a prospective teacher's knowledge about instructional strategies. It was carried out in the context of planning and reflection on the teaching of DNA/protein synthesis and evolution. According to their results, the mentor helped the teacher move towards a more pupil-centred orientation to science instruction. The team to which we belong has also carried out various studies on prospective primary education teachers' orientation regarding teaching science (Authors, 2011; Authors, 2017) in which a progression from a teacher-centred approach to a more pupil-centred one was detected. The present study addresses an aspect – the types of activity – that has as yet received little attention, and it involved a large number of participants.

Methods

Research context and participants

In this study we set ourselves the following four objectives. (1) Analyse prospective teachers' PCK regarding the types of activities in science teaching. (2) Compare this knowledge before, during, and after their teacher training program. (3) Describe and analyse their progression. (4) Propose a possible hypothetical itinerary of progression in the prospective teachers' PCK related to the types of activities. These objectives led us to the following general research question: How does prospective teachers' knowledge about science teaching activities change when they participate in a particular teacher training course?

In our university, the science methods course is of 90 hours duration. It takes an inquiry approach to the problems of professional practice (such as what science is and how this knowledge is developed, what science to teach, with which methods,…), encouraging the prospective teachers to contrast their ideas and experiences with innovative teaching practices and more general theoretical reflections.

At the beginning of the course, the students organize themselves into thenceforth stable teams by their own choice, and have to work on designing a plan to teach content of the Nature Sciences area that interests them (Design 1 – DS1). This is an open document, without any defined or pre-established guidelines, which they prepare without restrictions, taking into account their initial knowledge and experiences. Next, the course contents are addressed, organized around treating the following curricular problems: what content to teach; how to do so; how to take the pupils' ideas into account; and how to evaluate learning. The instructor provides guides to this process that are based on various resources of interest: educational legislation, innovative curricular materials, and contributions from education research. This is aimed at encouraging an in-depth reflection on the part of the prospective teachers. They are then asked to fill in a Reflection Script, which, unlike the designs, is a structured document consisting of a set of questions that must be answered by the teams through processes of negotiation and discussion. Its purpose is to get the students to express in synthesis their new knowledge about what and how to teach in science and what and how to evaluate. Also, they are asked to reflect on and justify whether they want to make changes to their first teaching plan, and, if so, what kind of changes. Once this process is complete, they design the changes they have decided on, preparing their second version of the plan (DS2). After this, a new contrast is proposed, this time with videos recorded in innovative classrooms that reflect science teaching based on pupil inquiry. The prospective teachers analyse the practices they have observed, and, guided by a Practice Script, reflect again on science teaching, again explaining whether they want to make changes to their second plan and, if so, of what kind. After that, they prepare their third version of the teaching plan (DS3).

Specifically, 5 of the 9 classes in which the Experimental Sciences Teaching course is taught participated in the research, each one led by a different instructor who followed the teacher training program described above. We shall identify these classes as A, C, E, F, and J. In total, 91 work groups were involved (consisting of 3 or 4 students each). Of the 311 participating students, 98.7% were taking the course for the first time, there were about twice as many women (65.9% – 205) than men (34.1% - 106), a common characteristic in initial teacher training bachelor's degree courses in Spain. Their mean age was 20 years (SD = 2.79).

Data collection and analysis

In this study, we used the three versions of the teaching plans (designs 1 – DS1, 2 – DS2, and 3 – DS3). These were collected at different points during the course – initial moment -M1-, once the content related to the nature of the subject has been approached, and before beginning the training more focused on what and how to teach science and evaluate the process; intermediate moment -M2-, after having dealt with the questions of what content to teach, how to do so, how to take the pupils' ideas into account, and how to evaluate their learning; and final moment -M3-, after having worked with the videos. In them, we analysed the participants' professional knowledge of the types of activities and the change in that knowledge. The documents were subjected to a process of content analysis (Cohen, Manion and Morrison, 2007) and some methods typical of grounded theory (Charmaz, 2014) for a descriptive-interpretive analysis. This was done in three phases.

In the first phase, the activities included in the prospective teachers' designs were identified. The said identification was carried out according to the activity's format and pædagogical purpose, so that each activity was marked with two codes. Examples of the former are: theoretical exposition by the teacher, reading documents, outings into the environment, etc. Examples of the latter are: to present information, to explore the pupils' ideas, to obtain information, etc. The coding was based on the constant comparison method, with continuous revisions being made as more data were analysed. This process was carried out in detail, differentiating, for example, theoretical exposition by the teacher (only words are used) from exposition supported by pictures and other resources (using photographs, diagrams, or real samples, various fruits for instance). As another example, synthesis carried out by the teacher (when the teacher is the one who summarizes, reviews, or synthesizes the content that has been worked on) was differentiated from synthesis carried out by the pupils (when they are the protagonists). As a result, we identified 16 types of activities (depending on their pædagogical purpose) and 132 subtypes (depending on their specific format) (Authors, 2016).

In the second phase, we drew up an information unit of a descriptive nature reflecting the types and activity subtypes that are proposed in each team's designs at each of the three data collection moments. For example, the following information unit reflects the types of activities included in the initial design (DS1) of team 1 of class A (Table 1).

Table 1. Information unit of team 1 of class A at time M1 (source DS1)

Type of activity	Subtype	P88:A1.M1.DS1
Explore initial ideas	Brainstorming	We shall start with a series of questions on the subject. In this way we will be able to know from which level the pupils start and the possible doubts.
Present information	Theoretical explanation on the part of the teacher	Second day: Parts of the plant (root, stem, leaf, flower, fruit). Third day: Types of plants (herb, shrub, tree). Fourth day: Leaf types (deciduous, evergreen). Sixth day: Respiration and nutrition of plants (photosynthesis, xylem sap, phloem sap, synthesis of their food, nutrient absorption). Seventh day: Respiration and nutrition of plants (photosynthesis, xylem sap, phloem sap, synthesis of their food, nutrient absorption). The teacher will explain each part of the topic.
Apply and/or check and/or reinforce information	Exercises	Pupils will do activities from the book. We will do them together and out loud.
	Interactive activities	The pupils will carry out different activities with the computer on the different contents they are given. These activities may be filling in the words, matching, etc.
	Murals	They will make a mural with the leaf samples collected in the field after they have been dried, classifying them according to the groups explained.
Not known	Outings	Field trip: collecting leaves, games, . . .

In the third phase, each information unit produced was organized and classified into different categories depending on the degree of sophistication. We started with two categories that had been defined previously based on the literature: Initial Category, consistent with a transmissive approach to teaching, and Reference Category, consistent with science education based on pupil inquiry. But the results also led to the formulation of intermediate categories (Table 2) since the constant comparison applied to the information units revealed characteristics that differentiated among them.

Table 2. Categories of types of activities

Initial category(C1)	Intermediate category 1(C2)	Intermediate category 2(C3)	Intermediate category 3(C4)	Reference category (C5)
The basic activities in teaching science are the presentation of information (mainly the teacher's theoretical explanation) and its application (mainly pencil and paper exercises)	The basic activities in teaching science are the presentation of information (various activity subtypes) and its application (various subtypes), which can sometimes be combined with other activities to motivate and/or involve the pupils	The activities suitable for promoting science learning are of various types and subtypes, for example, exploration of initial ideas (brainstorming, questionnaires, . . .), obtaining information (bibliographic, personal, . . .), synthesis of information (reports, expositions, murals, board, . . .)	The activities suitable for promoting science learning are of various types and subtypes, close to inquiry-based teaching (for example, setting out problems and approaching their solution, expressing and dealing with pupils' ideas, organising and/or exchanging information, . . .)	The activities suitable for promoting science learning are those of inquiry-based teaching (involve the pupils, put forward problems to investigate, express and deal with pupils' ideas, plan and collect information, organise and evaluate it, develop arguments, discuss with others, re-work initial ideas and make judgements, evaluate the learning itself)

For the data analysis, reiterated revision of all this information was necessary, always with the aim of discriminating, corroborating, and strengthening the segments that help to pursue our goal. To facilitate this treatment, we used the support of the ATLAS.ti v8 software. Furthermore, triangulation among the researchers was applied so as to enhance the reliability of the observations and eliminate the bias that may arise from the vision of a single person, as recommended by Cohen, Manion and Morrison (2007). A first triangulation process was carried out when 45 information units had been analysed. The evaluations obtained before the discussion were: 69% coincidences (31 evaluations), 27% non-coincidences (12 evaluations), and 4.4% doubts (2 evaluations). After the discussion, these numbers were: 91.12% coincidences (42 evaluations), 6.67% non-coincidences (2 evaluations), and 2.23% doubts (1 evaluation). After the categorization and coding of all the data, a new selection (50%) was made of the overall set of data that had been obtained, and it was subjected to independent categorization and coding again by the two researchers. In this case, the coincidences accounted for more than 90%.

Findings

Initial moment (M1)

At the initial moment, we detected 21 teams (23.33%) who mainly formulated information presentation activities (fundamentally through the teacher's theoretical explanation, accompanied or not by illustrations, slides, or other elements) and application and/or verification of that information (fundamentally by means of exercises from worksheets, the textbook, or proposed by the teacher) (Figure 2). Although exploration of the pupils' initial ideas is included in some cases, this is done without any pædagogical utility. Sometimes activities of revision or summary are proposed, mainly with the teacher as protagonist. This conception is associated with the initial category C1: The basic activities in teaching science are the presentation of information (mainly the teacher's theoretical explanation) and its application (mainly pencil and paper exercises). We present an example in Table 3.

Table 3. Level C1 information unit of team 4 of class E at time M1 (source DS1).

LEVEL N1		P5: E4.M1.DS1
Type of activity	Subtype	
Present information	Theoretical explanation on the part of the teacher	We shall explain the systems that intervene in the nutrition process: Digestive System, Respiratory System, Circulatory System, and Excretory System. We shall develop each of the systems, explaining its functions and its parts.
	Slides, images, other elements . . .	Next, we shall make a brief definition of what nutrition is, its function, and name the organs related to this function. For this, we shall use as an aid in class an educational doll to be able to observe and differentiate these organs so that the pupil visualises them at the same time as they are being explained.
Apply and/or check and/or reinforce information	Exercises	Using the textbooks with their respective activities as an aid, together with worksheets that we provide the pupils with to reinforce their knowledge

Many teams, 62 of the total (68.89%), propose combining the teacher's theoretical explanation with other subtypes of activities presenting information (videos, outings,…). The same is the case with the exercises, since they add other subtypes of application activities (murals, oral questions, experiments,…). Occasionally, other activities are also used with the aim of involving and/or motivating the pupils (searches for information, exploration of initial ideas,…). Finally, other activities of closure are used, mainly those carried out by the teacher (review,…), although also, but to a lesser extent, by the pupils (summaries, review, expositions, exercises,…). It is necessary to emphasize that these teams show greater diversity than the previous ones, but this diversity affects the activity subtypes more than the types themselves since the presentation and application of the content continue to predominate. We grouped these plans into category C2: The basic activities in teaching science are the presentation of information (various activity subtypes) and its application (various subtypes), which can sometimes be combined with other activities to motivate and/or involve the pupils. An example of this level is the unit of team 1 of class A that we presented in the Methods section (Table 1).

We also identified 4 teams (4.44%) positioned at a level different from those of the previous cases since they include different types of activities without just the presentation and application of information being the main pair of types. We defined this category of knowledge as C3: The activities suitable for promoting science learning are of various types and subtypes, for example, exploration of initial ideas (brainstorming, questionnaires,…), obtaining information (bibliographic, personal,…), synthesis of information (reports, expositions, murals, board,…). Table 4 presents an example of an information unit at this level.

Table 4. Level C3 information unit of team 6 of class F at time M1 (source DS1).

LEVEL N2		P269: F6.M1.DS1
Type of activity	Subtype	
Explore initial ideas	Brainstorming	First we shall brainstorm on the topic among the pupils to know what their previous ideas are
Synthesis of initial ideas	Closed board	During the brainstorming, we shall write down the correct ideas on the board and correct the wrong ones
Obtaining information	Varied bibliographic search	Pupils will research the topic through different resources (Internet, books, encyclopaedias, asking other people, . . .)
Partial synthesis (or closure) of pupil information	Mural	They will make a mural illustrating the topic which they have investigated
	Exposition	Make a short presentation in front of their classmates
Present information	Outings	A visit will be made to the nearest zoo during school hours. This visit will allow the animals' characteristics to be presented to the pupils while they observe them closely
Apply and/or check and/or reinforce information	Murals	Each pupil will be asked to make a drawing and a description of an animal. For this task, the teacher will distribute sheets of white card, and each pupil will choose two of the zoo animals that they liked
	Games	Pupils will come to the board and say the characteristics they had included regarding the animal, and the others will have to guess which animal it is, and complete the characteristics that the pupil had not included
Synthesis (or closure) of pupil information:	Report	A book will be made that will include the activities carried out during the classes (animal worksheets, murals, drawings, . . .)
	Review	A review will be done in common with the whole class, introducing everything that has been done and, in general, all the new material that the pupil wants to create and add. This exercise is so that they do not forget the material they have been given
	Exposition	Make a short presentation in front of their classmates

Finally, we detected 3 teams (3.33%) who formulated no type of activity (C0).

Intermediate moment (M2)

In this subsection, we shall present the results obtained from the second version of the teaching plan (DS2). At this point in the course, no teams were identified in the starting category (C1), there was a notable decrease in the teams positioned at C2 (30%), and category C3 took centre stage with 60% of the teams being identified at that level (Table 2 and Figure 2). Various activities are proposed at this level. The following types predominate: initial exploration of ideas (questionnaires, debates, games, drawings, etc.); presentation of information (teacher's explanation accompanied by audiovisual materials, experiments, etc.), the pupils' getting information (although mostly bibliographic and audiovisual search, other subtypes also appear, such as observation of the environment, interviews with relevant people, etc.); activities of closure or partial synthesis (at different times throughout the sequence of activities) and final synthesis (proposals at the end of the complete sequence), with either the teacher or the pupils as protagonist (reports, expositions, murals, boards,…); application of information (murals, games, drawings, theatre, song, etc.). At this level, the teams design plans that differ from each other, since the type or types of activities that appear may vary from one team to another. Table 5 presents an example.

Table 5. Level C3 information unit of team 10 of class A al time M2 (source DS2)

LEVEL N2		P105:A10.M2.DS2
Type of activity	Subtype	Information Unit (UI)
Explore initial ideas	Brainstorming or questions	This activity will be done by groups. It will consist of collecting on the board the previous ideas that the pupils have about the Solar System. The children will be saying what they think as the teacher writes it down on the board. From here, the teacher will develop the topic
Present information	Slides, pictures, other elements . . .	Present to pupils various images about the universe, mainly of the bodies that make up the Solar System
Apply and/or check and/or reinforce information	Pooling	Pooling with the whole class, where the information they have seen in the previous activity is collected together. For this, the teacher will provide them with a script with a series of questions. The class will be divided into groups of five. They will then write their conclusions on the board. The pupils' participation will be encouraged so that they correct their own mistakes among themselves and arrive at the correct answer
Obtaining information	Bibliographic and/or audiovisual search	Pupils are divided into groups of four. Then they will be asked to search for information through the Internet about the effects that the Sun has on our planet.
Apply and/or check and/or reinforce information	Exercises	We shall carry out an activity to check what knowledge the pupils know (. . .). A worksheet will be presented to the pupils in which there will appear characteristics that are or are not related to the Sun. The pupils will have to put a circle around the characteristics of this body
Obtaining information	Bibliographic and/or audiovisual search	We shall divide the pupils into 8 groups and each group will work on a certain planet chosen at random. They will seek information.
Partial synthesis (or closure) of pupil information	Murals Exposition	Making the mural with the information collected Exposition about the work done
Explore initial ideas	Brainstorming or questions	Ask some questions to find out what ideas they know about the movements of the planets. We shall do this activity together, with all the pupils in the class. We shall divide the board into two. In each part, we shall put a question: Why do days and nights occur? Why do seasons of the year happen?
Synthesis of initial ideas	Board	Every time they say an idea, the teacher will ask the rest of the class, do you agree? And if they do not, the teacher will ask them why do you not agree? What is the reason that you do not agree? At the end of this, the pupils will have a board with two questions and several answers for each of them. In the following activities, the pupils will learn if their ideas are wrong, close to the truth, or true
Present information	Vide	After learning the ideas of the pupils about the movements of the Earth, we shall put on a video
Apply and/or check and/or reinforce information	Experiences	This activity consists of simulating the movements of the Earth with the pupils' own bodies. For this, we shall assign one pupil the role of the Sun and another pupil the role of Earth. In this way, the person who plays the role of Earth must turn around on themself, and also go around the Sun. To do this pupils will come out to the board in pairs
Explore initial ideas	Brainstorming or Questions	The questions might be: What do you see at night in the sky? Can you see everything always or only sometimes? Do they have movements? Are they part of the Solar System?

LEVEL N2		P105:A10.M2.DS2
Type of activity	Subtype	Information Unit (UI)
Present information	Theoretical explanation of the teacher	The teacher's explanation about the other bodies, so that they get related to the content that was seen at the beginning of the session (previous activity) and that will be written down on the board
	Experiences Category	Do an experiment to teach what eclipses are and how they occur. First, we shall explain that the flexible desk lamp will act as if it were the Sun, the big ball will represent the Earth, and the small ball the Moon. Next, we shall leave the room completely dark, so that the lamp is the only light source. We shall continue by explaining that each ball will have a trajectory, and that if the one representing the Moon hides behind the shadow of the Earth, an eclipse of the Moon will occur. On the other hand, if the Moon gets in the way of the Sun's rays, an eclipse of the Sun occurs.
Synthesis (or closure) of pupil information	Diagram	The activity consists of making a concept map that summarises everything that the pupils have learnt in this unit. It will be done in groups of four. The teacher will provide a template with some terms so that it is easier for them to associate concepts
	Summaries	From the concept map they have made, the pupils must individually prepare a summary of the topic

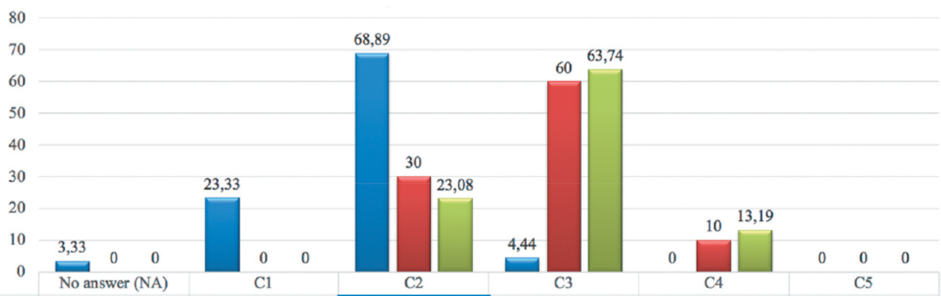
Finally, at this intermediate moment we detected 9 designs (10%) classified in Category 4. They present types of activities close to inquiry-based teaching, incorporating one or more of the types of activities characteristic of this approach: problem formulation (although not really investigated throughout the sequence of activities); activities where the exchange of information is encouraged (either an open exchange in which any information is admitted, or closed in which only the idea considered correct by the teacher is finally admitted, or even seeking a certain negotiation of meanings), or activities for reflection or creation of knowledge from the information obtained (talks, writing, etc.). We present an example in Table 6.

Table 6. Level C4 information unit of team 16 of class E at time M2 (source DS2)

LEVEL N23		P24: E16.M2.DS2
Type of activity	Subtype	Information Unit (UI)
Motivation and/or involvement	Video	On the first day of class we are going to carry out a series of motivational activities with the aim of getting the pupils interested and starting to feel curious about the new topic. In the first activity, we are going to watch a series of videos to introduce the theme of life on other planets. While the videos are showing, we are going to share with the whole class what can be appreciated in each of them.
	Games	True and false game: to carry out this game we shall distribute green (true) and red (false) cards. As teachers, we shall make a series of affirmations and the pupils will have to raise the green or red cards depending on whether they believe that the statement is correct or not. With this we intend to obtain information about the knowledge, experiences, . . . that the pupils have, and from which we shall start in programming the content
Posing problems to investigate (PR)	Problem/ Project	We shall put forward a question to investigate: Is there life on other planets?
Explore initial ideas	Questionnaires	In order to know the previous ideas on the topic, we have prepared a survey questionnaire, which the pupils will answer individually
Information exchange	Closed	There will be a whole class pooling of responses to the questions in the questionnaire. The pupils start from a series of ideas that they correct, eliminating some and adding others according to the new information that the teacher presents to them.
Obtaining information (OBI)	Reading	We offer a series of links to Web pages or written documents such as encyclopaedias, dictionaries, etc. in which the necessary information appears, in order for the pupils to be able to answer a series of questions: The Solar System: 1. What is the Solar System? 2. What planets make up the Solar System? 3.How did the Solar System form? 4. What types of planets are there in our Solar System? And which are the ones that comprise them? (. . .). The Moon: 5. What is the Moon, and how did it form? 6. What are the phases of the Moon? 7. How long does the Moon take to go around the Earth? 8. What are the two types of eclipses? (. . .) The movements of the Earth: 9. What are the movements of the Earth, and what do they consist of? 10. What are their consequences? 11. What is the Midnight Sun? (. . .) 12. What are the stars? 13. How does a star evolve? 14. What parts is a star divided into?
Organise information	Schemes, maps, . . .	4 groups will be formed in the class, and each of them will be in charge of making a concept map on a point of the topic. The teacher will have to supervise and guide the pupils when they are making the concept map
Partial synthesis (or closure) of pupil information	Exposition	Each group will have to present their concept map and explain it to the class
Present information	Outings	This day we shall dedicate to a visit to the planetarium of Granada's City of the Sciences. With this visit, we aim to make the content more practical for the pupils.
Obtaining information	Bibliographic search	On this day, the teacher will divide the pupils into groups of 3 or 4. Each group will be assigned a different planet, so that the eight planets would be covered. Each group has to fill in a table looking for information about the planet that they have been assigned. This information will be corrected by the teacher
Synthesis (or closure) of pupil information:	Apparatus	Making a Planetarium. Each group will have to make a model of their planet to put it in our planetarium into which we shall convert our class.
Posing problems to investigate	Problem/ Project	Taking into account the problem proposed at the beginning of the unit about whether there is life on other planets, and the planet that each group was assigned, we put to our pupils a scientific project: Design a house on the planet that they had to investigate. The pupils will have to consider the following data to design their home: average temperature of the planet, duration of days and nights, how many satellites it has, if it has water, if the land is fertile?

Final moment (M3)

At this point in the course, the teams positioned at C2 fell in number to 21 (23.08%), the C3 level remained the protagonist, with a majority of 58 teams (63.74%), and 12 teams were at the C4 level (13.19%). Figures 3 and 4 show the teams' distribution in the categories described at the three moments during the course.



	No answer (NA)	C1	C2	C3	C4	C5
Percentage of groups (M1)	3,33	23,33	68,89	4,44	0	0
Percentage of groups (M2)	0	0	30	60	10	0
Percentage of groups (M3)	0	0	23,08	63,74	13,19	0

Figure 3. Distribution of the teams.

The teams' itineraries of change

In this subsection, we shall consider the changes that each team underwent. As can be seen in Table 7, 11 itineraries of upward changes are identified in more than half of the sample (in 70 teams – 76.92%), 2 itineraries showing no change in 17 teams (18.68%), and 4 itineraries of unknown type of change in 4 teams (4.40%). The pro-dominance of the progressions and the diversity of specific itineraries detected stand out. Thus, within the itineraries with upward changes, the following can be distinguished: 6 itineraries we have termed of the progression-plateau type, present in more than half of the sample (61 teams – 67.03%), 2 of a continuous progression type (4 teams – 4.40%), 2 of a plateau-progression type (4 teams . 4.40%), and 1 of a regression-progression type (1 team – 1.10%). With respect to the itineraries without changes, we labeled 2 to be of a plateau type (17 teams – 18.68%). In the following paragraphs, we shall characterize each type.

Table 7. The teams' itineraries of change

11 Itineraries of upward changes (70 teams (76,92%))		FREQUENCY							TEAM
		%	E	A	C	F	J	T	
Progression-plateau type (67,03%)	C1-C2-C2	4,40	2	0	0	1	1	4	E15, E18, F5, J23
	C0-C3-C3	3,30	2	1	0	0	0	3	E1, E10, A4
	C1-C2-C2	15,38	3	2	0	7	2	14	E2, E8, E16, A5, A12, F2, F3, F7, F10, F11, F18, F19, J10, J17
	C2-C3-C3	34,07	4	9	2	5	11	31	E6, E9, E17, E19, A1, A3, A6, A7, A9, A10, A13, A14, A16, C7, C14, F4, F8, F9, F13, F15, J4, J6, J7, J9, J11, J13, J14,J15, J16, J20, J22
	C1-C4-C4	1,10	0	0	0	1	0	1	F1
	C2-C4-C4	8,79	0	3	3	0	2	8	A2, A11, A15, C10, C13, C15, J5, J18
Continuous progression type (4,40%)	NC-C2-C3	2,20	1	0	1	0	0	2	E4, C16
	C2-C3-C4	2,20	0	0	2	0	0	2	C8, C9
Plateau-progression type (4,40%)	C2-C2-C3	3,30	1	0	1	1	0	3	E12, C2, F20
	C2-C2-C4	1,10	0	0	0	1	0	1	F12
Regression-progression type (1,10%)	C3-C2-C3	1,10	0	0	0	1	0	1	F14
2 itineraries showing no change (17 teams)									
Plateau type (18,68%)	C2-C2-C2	14,29	2	1	3	2	5	13	E3, E13, A8, C3, C4, C6, F16, F17, J1, J3, J12, J19, J21
	C3-C3-C3	4,40	1	0	0	1	2	4	E7, F6, J2, J8
4 itineraries of unknown type of change (4 teams)									
4,40%	C2-C3-X	1,10	1	0	0	0	0	1	E5
	X-C3-C3	1,10	1	0	0	0	0	1	E14
	C2-X-C3	1,10	0	0	1	0	0	1	C5
	C2-X-C2	1,10	0	0	1	0	0	1	C12

Itineraries of a progression-plateau type

Most teams (67.03%) change from an unsophisticated vision at the beginning of the course to a more elaborate one at the intermediate moment, with this becoming stabilized once the course has finished (see Table 7). Specifically, 45 teams (49.45%) are detected that basically use activities of presentation and application of information that are more or less diverse (C1 and C2), and progress by including in their planning other types of activities apart from the Presentation-Application pair (such as exploration of pupils' ideas, posing problems, information searches, activities of synthesis,…) (C3 and C4), then remaining that way for the rest of the course.

The most frequent itinerary in this group is that which starts at level C2, where the presentation and application activities are much more varied than at level C1, and ends at level C3, in which the activities are significantly diversified, but still with scarce presence of those that are essential for an inquiry-based teaching approach (31 teams). To try to understand the scope of this change, it is necessary to take into consideration the statements of the prospective teachers when explaining or justifying their second version of the design. In these we find signs of the importance they give at this moment of the course to the pupils being active protagonists in the teaching and learning process, which they intend to achieve by diversifying the types of activities. For example:

> The activities are used for the pupils to capture new information, understand it, put knowledge into practice, relate different content, and internalize this new information. Together, they have one ultimate goal in common, the pupils' learning.

> The role of activities in science teaching and learning is that, through them, pupils learn the content of the subject, i.e., they learn in a practical way, they themselves being the true protagonists of their learning.

Arguments of this type suggest a shift in the orientation of teaching from one centred on the teacher or teaching to one centred on the pupil or learning. This change gives meaning to proposing activities other than those of the Presentation-Application pair, such as activities to explore the pupils' ideas, activities in which pupils are asked to synthesize what they have learnt, etc. Nonetheless, there are no arguments related to how they understand the learning process. They seem to be confident that if pupils are given prominence then they will learn automatically. There is no allusion to learning difficulties, to the need to reflect on the information or data obtained, or to negotiate the ideas that the pupils are developing.

We located 14 teams (20%) which take a small step at the initial level (C1) in DS1, towards the intermediate level (C2) in their following designs. Their progression can be characterized as “quantity” (they know and use more subtypes of activities), but not “quality” (they do not use types of activities that really involve a change in their teaching approach). In their designs, statements can be found about the role of activities as facilitators of teaching (not of learning, as was the case for the teams of the previous itinerary):

> Activities play a fundamental role in this process, since they energize the class and help the pupils to attain the objectives proposed by the teacher.

Whatever the specific itinerary in this Progression-Plateau group, the change is experienced between moments 1 and 2 of the course, with no further changes being distinguished between moments 2 and 3. Despite this, it cannot be said that changes do not occur in this phase of the course. It can only be stated that any such change is incapable of being recorded with the instruments that we used. Thus, during the classes, there were abundant comments by the prospective teachers about their greater security regarding the "goodness" of their own designs to promote science learning in Primary Education pupils (6 to 12 years old), as well as about their greater predisposition towards innovation, or the acceptance that it is possible to develop innovative teaching in real practice, even though they had not experienced it themselves throughout their own time at school.

Itineraries of a continuous progression type

In this case, 4 teams (4.40%) evolve gradually and continuously throughout the course, although they follow different itineraries, perhaps influenced by their different starting points. The teams of this group follow the itinerary C2-C3-C4. They explicitly include information in their latest versions of the design (DS3), which positively evaluates the inquiry-based teaching that was exemplified in the videos analysed, as a strategy to promote their pupils' learning. For example:

> We start from the fact that the child is the main one interested in learning and in developing themself. For this, inquiry motivates the pupils and makes them feel like working and learning by discovering, hence we consider that it is the best method for the child to learn something and not having forgot it the next day.

We emphasize that an itinerary of the type C1 or C2-C3-C4 or C5 may seem logical theoretically, but in our study only 4 of the 90 participating teams experienced this type. This is indicative that learning is an uneven process subject to numerous and varied influences.

Itineraries of a plateau-progression type

We identified an itinerary in which the exact opposite to the majority itinerary occurs, since there is stability from the initial to the intermediate moment (C2-C2), and progression from the intermediate to the final moment (C2-C3 and C2-C4). The trajectory resulting in C2-C2-C3 is presented by 3 teams (3.30%) and C2-C2-C4 only by 1 team (1.10%).

It seems that in these cases the teacher training activities carried out between moments 1 and 2 reinforce rather than question their initial knowledge. Only at the end of the course do they express coherent ideas with an approach centred on the pupils and learning in their designs. For example, we find this in the DS2 and DS3 of one of the teams:

> DS2: In our proposal, theory always precedes practice, as in our first design. But practical activities in science teaching-learning are very important, since science implies practice and verification of knowledge, thus achieving unequivocal and accurate learning.
>
> DS3: We get the children to participate in their own learning. Being listened to, giving their opinion, and expressing their own ideas make them feel that their role is also valued and is essential for them to learn.

Itineraries of a regression-progression type

Finally, we identify one team that follows a different trajectory from the previous ones in the sense that at the initial moment it starts at the C3 level, takes a step backwards at the intermediate moment (C2), and finally rises back to the level where it was to start with (C3).

In the first design, the team uses different types of activities, for example: obtaining information through the Internet; motivating or involving the pupils by giving them the opportunity to express opinions about some aspect of the theme; the presentation of and debate about the work carried out; and the synthesis of the information with summaries and diagrams (level C3). At the intermediate moment, we identify a certain regression in the DS2, since the planned activities are mainly (a) the teacher's theoretical explanation, sometimes accompanied by images and videos to present information, and (b) exercises, murals, apparatus, drawings, and outings to apply that information. They also include, with much less weight in the overall design, activities to introduce the topic in a motivating way (video and debate) and synthesis of the information transmitted (murals) (C2). Finally, at the end of the course, we find in the DS3 a greater diversity of activities: initial exploration of the pupils' ideas (brainstorming and questionnaires); expression and specific treatment of those ideas (blackboard, etc.); posing a problem, searching for information, synthesis activities (mural, pooling in whole class sessions, etc.).

Although the design changes level throughout the course, if we fix on this team's arguments and justifications, we find that its approach to teaching does not change in essence (it is always a teacher-and-teaching-centred approach), although some elements of it do (concern with capturing the pupils' interest, for example):

> DS2. We think that activities are necessary in the teaching-learning process, since they help to strengthen theoretical knowledge.
>
> DS3. The design is done in a dynamic way to attract the pupils' attention. The activities should be strengthened further if the pupils do not understand the content one is trying to teach them.

It seems that the changes experienced by this team are not sufficiently important, stable, and/or secure, which gives rise to this itinerary of steps backwards and then forwards.

Itineraries of a plateau type

We located 17 teams (18.68%) who showed no changes throughout the course, regardless of whether they started with more or less complex visions – C2 and C3 – (see Table 7).

We have no information that would allow us to explain or conjecture why they remained at the same level throughout the course. But we do want to draw attention to the fact that no team of the 19 that were at a C1 level at the beginning of the teacher training activity is included in this group of plateau itineraries, and that only 12 teams reached level 4. Therefore, these results may be indicative that the jump to level C3 is difficult (at least more difficult than the jump from level C1 to level C2), and it is even more difficult to advance towards level C5 which is considered desirable in education research.

Discussion and Conclusions

At the initial moment of the course, there stands out the relevance of the presentation and application of information as the activities most used by these prospective teachers when designing their teaching plans (C1 and C2), as other studies have also detected (Brown, Friedrichsen and Abell 2013; Pilitsis and Duncan 2012; Vilchez and Bravo 2015). Similar results are found too with in-service teachers. For example, in the study by Furman, Luzuriaga, Taylor, Anauati and Podestá (2018) in 19 schools in Buenos Aires, the most frequent activities are the exposition of content prepared by the teacher, and activities with the textbooks in which pupils must use lower-order thinking skills (recognizing, remembering, and reproducing information) to resolve them. The participants in our study design the activities in a way coherent with what would be done from a transmissive approach, although not in its most extreme version. They consider that presenting information and checking or reinforcing it (using a certain diversity of activity subtypes) is the basic way to carry out teaching, although they also take into account, much less frequently, other types of activities (such as exploring the pupils' initial ideas). Perhaps having previously and expressly analysed the nature of science and scientific research influenced this.

Between the initial and intermediate moments, we detected improvements in the participants' knowledge, since the pair "presentation of pre-prepared information / application of the said information" ceases to be the protagonist, and a greater and more balanced diversity of activities appears. The designs change from a teacher and teaching centred approach to one focused on the pupil and learning (with categories C3 and C4 predominating). This change reflects deep learning not only in relation to the different forms that an activity can take (from an explanation to a game), but also in its pædagogical purpose and the role it plays in teaching (facilitating the pupils' expression of their ideas, their organization and synthesis of the information,…). This is an important change since, as Odom and Settlage (1996) point out from their evaluation of prospective teachers' understanding of the activities present in the cycles of learning, understanding the purposes of the activities is difficult, complex, and quite abstract. However, despite different types of activities being designed, we detected no teaching plan whose proposal of activities is consistent with an inquiry-based approach (C5). In such an approach, authentic tasks are proposed in which the pupils engage in complex and personally meaningful work related to real-world situations, and in which they themselves produce knowledge from working on problems, discussing their findings, and sharing negotiation of meanings. But activities in which problems are formulated that make sense in the sequence of activities, which foster a certain negotiation of meanings, in which the findings are reflected on, or the pupils' own knowledge is constructed, are few and far between in the participants' designs.

Between the intermediate and final moments of the course, improvements are also detected that confirm the trend presented above: the numbers of teams in C3 and C4 increase, but teaching plans at the C5 level are still undetected. These results coincide with Osborne (2014) who noted that teachers either do not accept or poorly understand the types of activities that are appropriate and necessary for inquiry. Our results support other studies that have found prospective primary teachers to focus more on carrying out activities and recording data than on explanations and reasoning about the phenomena being studied (Lee et al., 2020). They also coincide with those of Weinburgh, Smith and Clark (2008) who indicate that it is easier to include activities aimed at obtaining information than at the pupils themselves suggesting problems. Likewise, they are consistent with the results deriving from the review of professional knowledge carried out by Schneider and Plasman (2011) which highlighted the very low importance given to activities of interpretation of results and the development of knowledge from them. For some authors, this difficulty in comprehending such activities or taking them into consideration derives, in addition to their inherent complexity, from the few opportunities that prospective teachers have had to reflect on and develop an inquiry-based approach to teaching and learning science, since curricular innovation has not been implemented in classrooms, and actual practice continues to be trapped in classic models (Spector 2016).

According to Kang, Windschitl and Thompson (2016), for teachers to be able to design activities of quality, they must be provided with multiple situations related to the collection and analysis of information, and develop evidence-based explanations after exchanging, negotiating, and reconstructing ideas. The activities proposed in the course were consistent with this perspective: professional problems were posed, and the students were encouraged to analyse their own designs and contrast them with different sources of information (theoretical and practical), to reconstruct new knowledge and then re-work their designs, all in a collaborative way and guided by the instructor. Experiencing these principles seems to have helped the students to change their proposals of activities, moving away from those focused on transmission to focus instead on the pupils and their learning. But it was still not enough for them to actually transfer the experience of the course at its greatest level of depth to the designs they made for teaching science in Primary Education. It is likely that more opportunities for metacognitive reflection on learning itself will be needed. It is also likely that it will be necessary to fully develop the design-development-reflection cycle and analyse the learning results achieved with their designs (either by trying them out them with their classmates, also prospective teachers in initial training, or facilitating in a more determined way contacts with schools in which they can practise) in order for the changes in the prospective teachers to be more important.

We can conclude that the teams followed an important diversity of types of itineraries in their learning. This confirms the idea that people do not change radically but rather gradually, tentatively, and unevenly. We differentiated itineraries with upward changes, itineraries that do not show any changes, and itineraries in which the change is unknown. There predominate changes from the initial to the intermediate moment, while hardly any were detected from the intermediate to the final moment (see Table 7). This is perhaps because the instruments used in this research were not sufficient to record those that may have occurred. But it is also possible that it is necessary to promote other types of activities related to carrying out and reflecting on the teaching and on the learning created in schoolchildren in order to promote learning of a greater depth on the part of prospective teachers.

Finally, based on the results of this study, Figure 4 presents a general itinerary of progression in relation to the types of activities. In it, we include the counts of the teams positioned in the various categories throughout the course. This indicates that progress from the level represented in C1 to that of C2 is quite feasible, progress to C3 is achievable for most of the students during the course, but evolution up to C4 and C5 is very difficult.

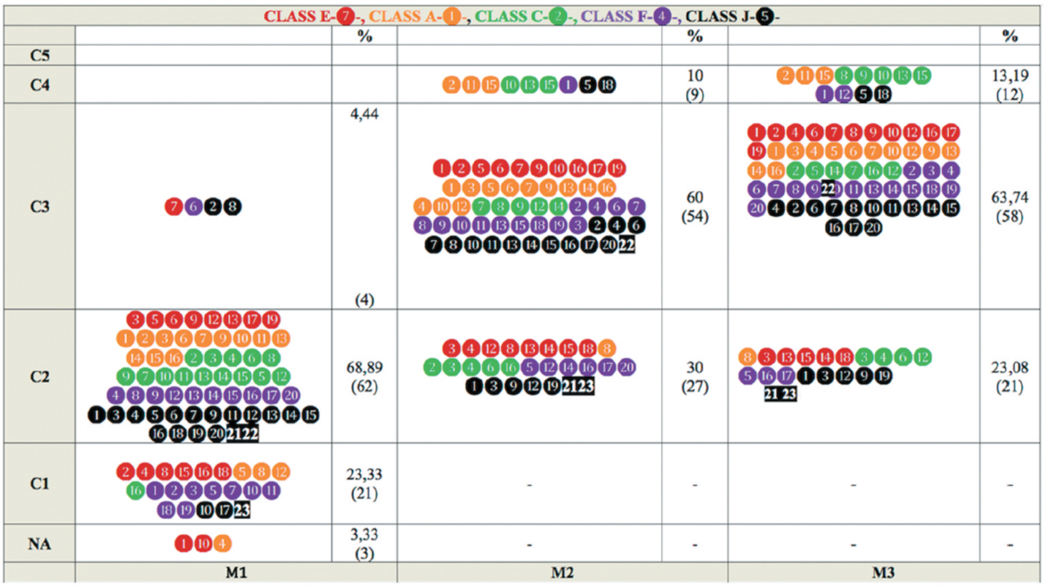


Figura 4. Distribution of all the teams throughout the course

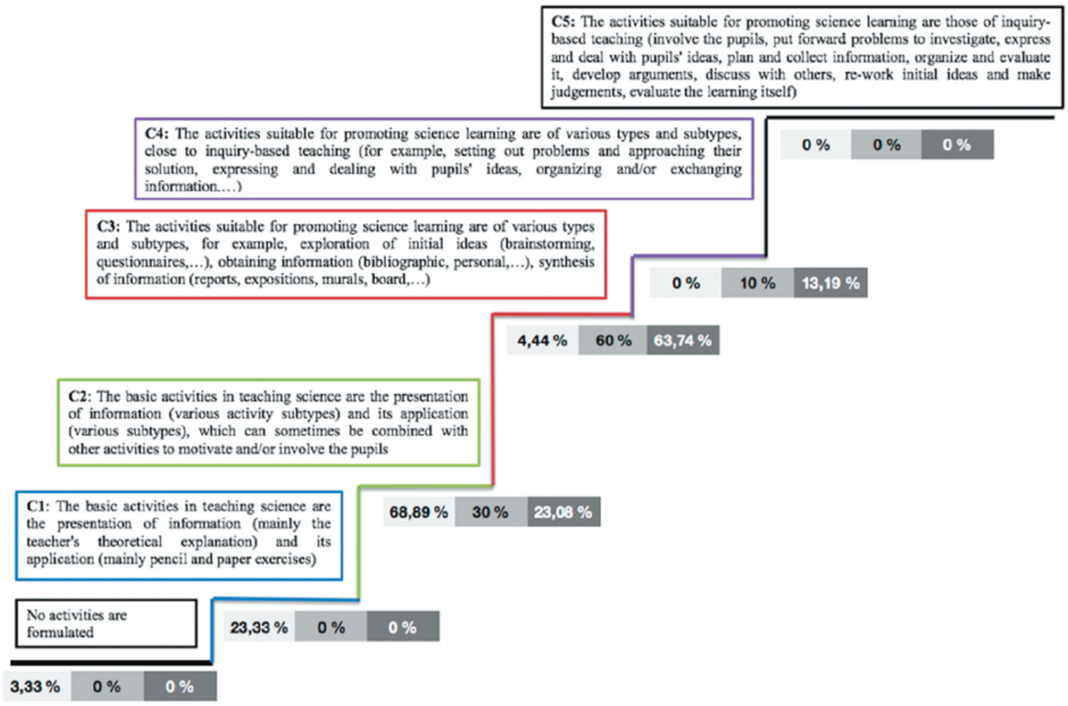


Figura 5. Hypothetical itinerary of progression

Disclosure statement

No potential conflict of interest was reported by the author(s).

Ethics statement

Ethics approval was granted by the Human Ethics Committees of the University in this study, and all participants gave informed consent.

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