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PESQUISA EMPÍRICA

Scientific experiments in early childhood education: activities planned by pre-service teachers

Experimentos científicos na educação infantil: atividades planejadas por futuros professores

Julio César Tovar-Gálvez

Faculty of Education, Universidad Internacional de La Rioja, Logroño, Spain

Abstract. There is evidence that teachers rarely implement scientific experiments in the early childhood education (ECE) classroom. Part of the problem lies in initial teacher education. This paper proposes alternatives to improve pre-service ECE teachers' knowledge of science teaching, based on their difficulties in planning scientific experiments. Methodologically, this is a qualitative study that inductively analyses the planning of an experiment presented by a sample of 97 pre-service ECE teachers. The results describe the activities before, during and after the planned experiment. The discussion addresses popular experiments that can lead to conceptual distortions, more adequate experiments, and considerations that can improve ECE teacher education.

Keywords: Early Childhood Education, Experiment, Planning, Science Education, Teacher Education.

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Resumo. Há evidências de que os professores raramente implementam experimentos científicos na educação infantil (EI). Parte do problema está relacionada à formação inicial dos professores. Este artigo visa propor alternativas para aprimorar o conhecimento de ensino de ciências de futuros professores de EI, com base em suas dificuldades no planejamento de um experimento científico. Metodologicamente, trata-se de um estudo qualitativo que analisa indutivamente o planejamento de um experimento apresentado por uma amostra de 97 futuros professores de EI. Os resultados descrevem as atividades antes, durante e depois do experimento planejado. A discussão aborda como alguns experimentos populares levam a distorções conceituais, quais experimentos seriam mais adequados e considerações para uma melhor formação de professores de EI.

Palavras-chave: Educação Infantil, Experimentação, Planejamento, Educação Científica, Formação de Professores.

Introduction

Planning scientific experiments contributes to the pre-service ECE teachers' education in science teaching. As background, some studies indicate that teachers rarely conduct scientific experiments in the ECE classroom, or do so simplistically or incorrectly (Garces et al., 2020; Mazas et al., 2018; Torres-Porras, 2021). This shortcoming is often due to ECE teachers' limited science training (Gerde et al., 2013; Mosquera et al., 2018; Oon et al., 2019). In contrast, other studies demonstrate the positive influence of teaching teachers how to plan science content in ECE. For example, Dejonckheere et al. (2016) demonstrated a better performance of ECE students in controlling variables when they participated in intentionally planned experimental activities. Moreover, Nayfeld et al. (2011) revealed that planned instruction significantly affects children's interest in science learning-corner materials compared to free exploration. Likewise, Paños et al. (2022) demonstrated that planned explicit teaching helps children better understand scientific experiments. Therefore, researching how pre-service ECE teachers learn to plan scientific experiments offers information for an evidence-based teacher education.

Contatos: joule_tg@yahoo.com

Consequently, the present study asks: What are the possible difficulties in the pre-service ECE teachers' planning of a scientific experiment and what recommendations for improvement might emerge? Thus, the results describe and illustrate the types and frequencies of pre-experimental, experimental, and post-experimental activities that the pre-service ECE teachers propose. Subsequently, the discussion will address the main difficulties identified in the plans and propose possible alternatives to improve pre-service ECE teachers' planning learning. With this information, teacher educators count on evidence to improve ECE teacher education in science teaching. Additionally, this information helps pre- and in-service ECE teachers identify effective practices in science education, specifically in science experimentation in ECE.

Literature Review

Limitations to including scientific experiments in ECE

The limitations to introducing scientific experimentation in ECE stem from specific problems teachers face. Thus, in addition to the problem of scientific education for ECE teachers already mentioned, there are other issues related to beliefs. For example, a sector of teachers still considers that ECE students cannot learn science because of its complexity (Rodríguez et al., 2021). This idea leads to excluding science teaching in ECE or implementing it superficially or only to fulfil the curricular requirement (Garces et al., 2020; Ortiz & Cervantes, 2016). Another sector of ECE teachers considers teaching science challenging due to the large amount of content. Thus, teachers forget to present students with contextualised science (Pérez et al., 2022) and with a reflective, analytical, and critical basis (Medina, 2017; Torres-Porras, 2021). Likewise, other teachers focus science teaching on students' freedom in empirical activities, so there is little planning for learning (Inan & Inan, 2015; Mazas et al., 2018; van der Graaf et al., 2015).

Science production as a context of the experiment and its teaching in ECE

A review reveals understanding of experimentation as part of the science production process. Moreover, this literature outlines trends in what to teach in the ECE classroom. The review included the keywords "experiment", "early childhood education", and "preschool" in Spanish and English in Google Scholar. The selection criteria were – a) from 2013 to 2023, b) experimental reports, and c) open access (including green access or authors' version).

a) Teaching a set of skills close to scientific production process: The authors aim to develop scientific reasoning through stimulating, motivating or promoting skills or abilities such as observing, identifying phenomena, asking questions, predicting, formulating hypotheses, investigating, experimenting, variables manipulation, evidence searching, inferring, comparing, critical thinking, concluding and communicating results (Mazas, et al., 2018; Ortiz & Cervantes, 2016; van der Graaf et al., 2015). Some of the skills listed here are part of the scientific research stages, steps, practices, or processes.

b) Teaching the scientific method or inquiry process: The authors need to clarify the difference between the scientific method and inquiry. However, they all aim to involve infants in a coherent set of problem-solving procedures, which includes, to a greater or lesser extent, observing, questioning, problematising, formulating hypotheses and predicting, searching for sources of information, planning, considering ethical aspects, experimenting, data collection, analysing and discussing findings, evaluating hypotheses, explaining, concluding, communicating and identifying new questions (Gerde et al., 2013; Inan & Inan, 2015; Medina, 2017; Pérez et al., 2022; Torres-Porras, 2021; van der Graaf et al., 2018).

c) Teaching skills through the scientific method or inquiry process: The proposals aim at the development of scientific thinking or reasoning abilities or skills through the scientific method or inquiry, as well as its variations (Aranda-Cuerva & Pérez-Martín, 2021; Balderas et al., 2020; Garces et al., 2020).

d) Teaching scientific practices: The authors assume that scientists produce knowledge through practices that do not necessarily follow a linear method or an order. For instance, to develop the practice of explanation, Monteira and Jiménez (2019) involve ECE students in experiments to collect evidence about the phenomenon they will explain. Similarly, Monteira and Jiménez (2019) and Mosquera et al. (2018) focus on the practice of inquiry, including observing, formulating questions, problematising, issuing hypotheses, designing experiments, experimenting and manipulating, investigating, exploring, interpreting information, data collection, results analysis, decision-making, and concluding.

e) Teaching precursor science models: According to Kambouri-Danos et al. (2019), children build mental representations of natural phenomena and some scientific concepts through their daily lives. However, those mental representations may not be compatible with the scientific models. The authors propose precursor scientific models as a means to bridge the gap between children's representations and scientific models. Those models allow students to describe physical phenomena better, pose explanations, and make predictions. Moreover, teachers need to identify students' representations and the appropriate elements to build the precursor scientific model (Georgantopoulou, 2022). From these sources, teachers plan and implement teaching strategies to guide students beyond their spontaneous, intuitive and alternative representations of phenomena (Charalampopoulou, 2023).

f) Motivating a sensory experience: Puig et al. (2020) define early learning as not conceptual and focused on the sensory. From this perspective, science teaching guides infants in exploring the environment through their senses. This learning emphasises experience and spontaneity, through which infants discover their surroundings.

Theoretical Framework

Philosophy of science proposes models to understand science and scientific experimentation. For Wei (2020), philosophers pay much more attention to theories than to experiments. Thus, this author identifies two main trends: a) experiments precede theories, because, as the logical empiricists proposed, researchers collect data about nature and then generalise what they have observed; and b) theories precede experiments, with the experiment being crucial

for Popper's view and less relevant for the view of Kuhn, Lakatos, and Feyerabend. Moreover, Wei (2020) identifies a moderate vision in the new experimentalism, since Hacking argues that scientists already have ideas about nature and their devices before experimenting. Additionally, Wei lists seven kinds of relationship between theory and experiment, according to Hacking. However, science education for ECE needs more than what philosophy tells researchers and teachers about science, since the central point is not to explain science but how to teach it in ECE. Even philosophy of science offers too little to ECE currently (Hansson et al., 2021). Therefore, given that kids are the most important factor, this framework requires elements from the philosophy of science, children's learning theories, and the didactics of science.

Consequently, discovery-based learning plays a prominent role in ECE science education. The basis of this approach is Bruner's (1966) theory, which explains infants' learning through three modes of representation. The modes serve as a guide for ECE curriculum design since they represent a progression of learning – a) enactive representation: it is an action-based learning phase that occurs from birth to around one year, and children learn primarily through physical interaction with their surroundings, b) iconic representation: this image-based learning phase happens from around one year to six years of age, and kids learn though their perception and store images or icons in their minds, and c) symbolic representation: during the language-based learning phase, kids from seven years of age onwards start learning abstract ideas through language and have the capacity of problem-solving. However, the philosophy of science also identifies discovery-based visions of science as empiricist-positivist. This vision of science assumes that objective scientists observe nature to discover and accumulate scientific knowledge. Thus, a scientific experiment in ECE is an exploratory and sensory process for gathering information about the subject itself and its surroundings.

However, inquiry-based learning is another view of science education in ECE. The background of this approach is the work of the philosopher and psychologist Dewey (1910), who proposed that science learning is an active process in real-life contexts. Thus, Dewey proposes the inquiry-based learning in which students follow some processes as a) identify indeterminate and puzzling situations, b) define a problem, c) formulate a hypothesis, d) test the hypothesis, e) evaluate the hypothesis, and f) find a solution to the situation and new questions. Later, Kilpatrick (1918) worked on the "project method" to bring Dewey's proposal into the classroom, considering intellectual, physical, and affective purposes and kinds of projects. Moreover, Ausubel's contribution to science learning, as the planning of mental structures beyond spontaneous discovery (Ausubel, 1968), also influences this approach. Additionally, as the previous review demonstrates, many works on science education in ECE align with the idea of experimentation as part of the science production process.

Experiment as part of the science production process

An experiment is a set of procedures through which people carry out controlled experiences, collect information, corroborate events or assumptions, and construct new ideas. Furthermore, a scientific experiment aims to achieve previously proposed objectives within the framework of the scientific theories and the scientific knowledge production process.

Thus, the design and execution of a scientific experiment may seek to collect information on variables related by a hypothesis, put a theory into practice or corroborate it, or test a prototype. Scientists obtain information through direct observation or specialised instruments, and process it within parameters established by the scientific community.

On the other hand, experimentation is an innate human skill (Balderas-Mireles et al., 2020) through which subjects put experiments into practice; that is, humans execute procedures to gain experiences and obtain information, among other things. However, scientific experimentation follows parameters as a scientific skill or practice. Thus, the norms or rules defined by the scientific community condition experimentation. One standard is that experiments be reproducible, meaning that others besides the original designers can repeat them and obtain the same results. This mechanism regulates the execution of the skill. Additionally, this skill requires connections to other scientific skills, such as formulating questions, developing hypotheses, and collecting and analysing information.

In teaching and learning, students exercise the natural skill of experimentation, which teachers guide toward approximating scientific experimentation. This guide implies that teachers transform the expansion-and-exploration-based learning into selection-and-refinement-based learning (Lövdén, 2020) through planning. Thus, the planned learning favours the selection of the best ways to solve a problem or develop a task, and refines the use of those successful skills and strategies (Lövdén, 2020). For this purpose, teachers prepare the teaching or set of intentions, methods, and materials necessary to guide students towards school-based scientific experimentation. Likewise, teachers prepare the assessment or set of criteria, instruments and modalities to recognise the student's scientific experimentation process and product.

Considering that the experiment is part of the scientific production and that experimentation requires connections to other scientific skills, it is advisable to plan what precedes and continues after the experimentation. Therefore, it is helpful for teachers to plan to take into account the following moments:

a) Before the experiment: definition of the context, motivation or situation that justifies doing the experiment, evaluation of students' previous ideas, execution of the exploration, observation, collection of information, formulation of questions, formulation of hypotheses, design of the experiment, definition of information collection methods, design of information collection instruments, formation of work teams, and definition of safety, ethics and behaviour standards, among other aspects.

b) During the experiment: manipulation of the variables involved, observation, collection of information, repetition of the procedure, use and proper disposal of materials, waste and instruments, and regulating learning, as the main activities.

c) After the experiment: analysis of the information, evaluation of the hypotheses, construction of conclusions, identifying possible applications or explanations of other cases, thinking and discussing potential ethical implications, identifying new questions and communicating the results, principally.

Method

This study uses a qualitative methodology to describe the experimental activities planned by pre-service ECE teachers.

Population, source of information and data

The population consists of 165 students in an ECE program at an online Spanish university who participate in the subject of natural environment teaching and environmental education. However, only 102 presented the experiment planning. Within that number of participants, five planned learning objectives and content, but did not propose activities, so they are not part of the sample. Finally, the sample is 97 students. Moreover, the subject provides normative, theoretical and practical elements for teaching science and the natural environment in ECE. Likewise, the subject emphasises the transition from discovery-based to inquiry-based science learning. Therefore, the participants must plan pre-experimental, experimental and post-experimental activities, understanding the experiment as part of an inquiry. Additionally, the participants have other subjects that delve into learning planning.

Despite this research did not collect specific information from the participants, a view of the Spanish science education curriculum is useful to understand the context. According to the current education law in Spain (2020), the first three years of the compulsory secondary education curriculum include compulsory science learning. However, students must choose between the subject “biology and geology” or the subject “physics and chemistry”. This same law establishes that in the fourth year of secondary school, science is optional for students. On the other hand, according to the same law, the 2-year high school has different modalities: a) general, b) arts, c) science and technology, and d) humanities and social sciences. However, all modalities share compulsory subjects, and science is optional. As for higher education, the 4-year preschool program that served as the sample for this study does not include science subjects; instead, it focuses on its teaching. In this way, someone could choose to study the compulsory sciences until the third year of secondary school, not take them in the following 3 years before going to university, and not take them in the 4 years of the preschool education career.

Relevant background information is that most of these participants have completed a higher-level training cycle as technicians in ECE, so they already have experience working with infants and planning lessons. However, this research did not collect information on age, gender, culture, origin, work experience, and other identity categories to ensure identity protection and avoid discrimination against participants.

The source of information is the electronic files in which the pre-service ECE teachers presented their experiment planning. This source was the second plan the participants submitted during their participation in the subject, so they already had feedback on general planning aspects. Each file had to contain information about a) title, b) context, c) learning objectives, d) contents, e) materials and resources, f) activities prior to the experiment (more than one), g) experimental activity, h) post-experiment activities (more than one), and i)

assessment criteria and instruments to implement previous, during and at the end of the experiment.

The data are the text fragments explicitly titled "activity" and that involve direct work with potential students. In this way, information such as the description of the educational centre, students' characteristics, learning objectives, content, required materials, security measures, and learning assessment criteria is not data for this study.

Analysis process

This analysis is qualitative and descriptive. The first step consists of grouping all the activities according to the moment: a) pre-experiment, b) experiment, and c) post-experiment. This analysis uses a priori categories from the framework (Cisterna, 2005) or a direct content analysis (Hsieh & Shannon, 2005). The second step consists of forming new groups of activities based on patterns or convergences among them. Each activity receives a label for this grouping according to its function, objective, type, or variety. Subsequently, similar labels will form emerging categories. This inductive analysis identifies emergent categories (Cisterna, 2005; Hsieh & Shannon, 2005).

RESULTS

Pre-experiment activities

Table 1 displays the frequency with which each type of pre-experiment activities appears in the 97 planning proposals.

Table 1. Types of pre-experiment activities.

TYPE OF ACTIVITY	FREQUENCY	%
HYPOTHESIS	48	20
MOTIVATION TO EXPERIMENT	42	18
EXPERIMENT PREPARATION	40	17
QUESTIONS	38	16
CONCEPTUALISATION	30	13
ARTISTIC EXPRESSIONS	17	7
ASSEMBLY	11	5
PREVIOUS IDEAS / PRIOR KNOWLEDGE	10	4
INCLUSIVE ACTIVITIES	02	1
TOTAL	238	100

Formulating hypotheses is the most common pre-experiment activity. For the most part, the students would propose hypotheses in response to the teacher's questions, for instance, *"What objects will break when dropped?" What objects will float?* On certain occasions, teachers consider variables, for example, the material (whether an object breaks or floats) and the shape, which do not influence the possibility of rupture or floating unless they modify the density or strength of the structure. Additionally, the pre-service teachers propose that students formulate hypotheses individually and collectively using supporting tools. Some

tools are a list with the drawing or photo of the object that kids would test or some boxes to mark "*yes/no*" or put "*happy face/sad face*" or "*green dove/red x*", depending on whether it, for example, breaks or sinks.

The next most frequent type of activity is motivation to experiment. This motivation may be that the teacher demonstrates the experiment that students will perform later. Other cases include students experimenting without prior instruction or observing a phenomenon around them. In all cases, motivating activities lead students to propose hypotheses.

Experiment-preparatory activities are the third most common type. The most frequent are: the teacher explains the experiment and reviews or prepares the necessary materials and instruments. On only two occasions, the plan included extra-class tasks for students to prepare the experiment. Only one participant proposed organising working groups.

The question is relevant because it ranks fourth in frequency. Most of the time, the questions arise from the motivation activities or are single-motivation questions.

The pre-service teachers also planned activities to conceptualise the experiment or related topics. The principal means for students to conceptualise are videos and teachers' verbal explanations.

Artistic resources appeared seventeen times as a way to motivate students or to conceptualise. Writing or reading stories, and singing, were the most common expressions.

The assembly is the only form of organisation explicitly named to motivate students and to allow teachers to ask questions.

Regarding the previous ideas (prior knowledge), only on ten occasions did pre-service teachers plan to assess them explicitly. Aking questions individually or by brainstorming is the assessment modality.

Finally, on only two occasions, the participants explicitly plan to include students with special learning needs. In particular, one activity aims to include students with cognitive diversity, and another aims to include students with functional diversity.

The following excerpt illustrates how a participant planned an activity to guide students in posing hypotheses:

> Formulation of hypotheses. Is it sinking or floating?
>
> As I have already mentioned, questions will be raised in the students' assembly about the flotation of each object (why do some objects float and others sink? Is it because one is bigger than another? Will the pencil float? Does one weigh more than the other? or why is its density higher? What is density?).
>
> The teacher will organise students into small groups and have them look for different objects in the classroom that can get wet, then record them in the worksheet. Thus, the worksheet will include drawings of some objects for the students to find, but they can add more if they want. Finally, each group will have to finish the worksheet and comment on the objects they will use for the experiment and the hypotheses they have made about them (which one will float? which one will sink?).

The participant who wrote the previous excerpt used questions to motivate students to guess which objects would sink or float in water. Then, the participant mentions a specific form designed for students to register their hypotheses regarding the object's behaviour when immersed in water.

Experimental activities

Table 2 details the types of experiments and their frequencies across the 97 plans.

Table 2. Types of experimental activities.

TYPE OF ACTIVITY	FREQUENCY	%
MIXTURES OF SUBSTANCES	18	17
ORGANISM MONITORING	15	15
USE OF THE SENSES	13	13
FLOATING AND SINKING	11	11
VOLCANO MODEL	11	11
PHYSICAL AND CHEMICAL PROPERTIES	10	10
OBJECT CHARACTERISTICS	09	9
PROPERTIES OF WATER	08	8
THE LIGHT	05	5
UNCLEAR ACTIVITY	03	3
TOTAL	103	100

The experiments most frequently planned by the participants involve mixtures of substances. Specifically – a) water/oil and occasionally others such as alcohol, salt or sugar to see the solubility, b) water of different colours mixed through filter papers or directly to see the formation of secondary colours, c) water with other substances such as baking soda, for more recreational aspects such as the creation of "artificial snow", d) other types of materials for sensory purposes. Only on two occasions did the pre-service teachers explicitly plan to record the experiment. On four occasions, they included the formulation of hypotheses.

The next type of experimental activity in frequency is monitoring organisms or their parts. The most usual is to plant and observe seeds and, to a lesser extent, observe flowers and fruits. In most cases, participants plan the explicit manipulation of variables and regularly use explicit monitoring tools such as data tables, drawing tables, or photographs. On a few occasions, pre-service teachers plan to guide students in posing hypotheses.

Sensory activities occupy a relevant place in the frequency of planning by the participants. Some proposals are: sensory bottles (filled with liquids of different densities and colours), coloured materials, materials to manipulate, and photographs.

Experiments on objects' floatability and buoyancy force are recurrent, involving (and confusing) concepts such as density and weight. In less than half of the cases, there is explicit manipulation of variables and data collection. Occasionally, the pre-service teachers planned the formulation of hypotheses.

Participants frequently planned a model volcano to simulate an eruption. Students would produce the eruption by reacting baking soda with vinegar, then colouring it. A variation of the simulation is to use effervescent tablets in water with dye. This model fails because it uses

a chemical reaction to represent a physical-geological phenomenon with totally different variables.

Another type of experiment proposed by the participants is the physical and chemical properties of substances. Some focused on chemical reactions (oxidation of citrus juice or making soap), others on static electricity, and others on the polarity and solubility of substances.

Participants also considered activities on objects' properties – a) strength (breaks/does not break), b) weight, c) shape and other characteristics. Most of the time, pre-service teachers planned to register observation, mainly through video recording. In a third of cases, participants expect students to propose hypotheses. Only a plan proposed that students manipulate variables.

To a lesser extent, the pre-service teachers considered experiments on the properties of water: a) states, b) melting point, and c) pressure.

Participants rarely planned experiments related to light – a) shadows and b) modification of the light path. The pre-service teachers also included the issuance of hypotheses, analysis and conclusions as part of the experimental activities.

In very few cases, the participants present activities that are confusing regarding procedure and objective.

The following excerpt illustrates how a participant planned an activity to guide students in experimenting:

> Experimentation. Let us throw the objects!
>
> They will collect the chosen objects, throw them into the water, and observe what happens. Then, they will collect a small amount of data on the information they consider relevant to resolve the doubts raised.
>
> Thus, they test each hypothesis to determine whether it is correct.

The excerpt describes what the students should do to experiment with the object's behaviour when immersed in water. The experimental activity includes manipulating objects, observing behaviours, and collecting data to test the initial hypothesis.

Post-experiment activities

The 97 pre-service teachers have planned a set of post-experiment activities of different types and frequencies, as shown in Table 3.

Table 3. Types of post-experiment activities.

TYPE OF ACTIVITY	FREQUENCY	%
ANALYSIS OF RESULTS	67	45
CONCLUSIONS	52	35
MIXED ACTIVITIES	29	19
OTHERS	02	1
TOTAL	150	100

Regarding analysis activities, the pre-service teachers in the sample proposed – a) a third of the proposals, using of artistic expressions such as drawing and murals to record, report, return to and summarise what they experienced, b) explicit assessment of the hypotheses almost another third of the time, c) process the information using tables and cards for classification and comparison, and d) on very few occasions there is no specification of the type of analysis.

Conclusion activities were less recurrent than other activities. Some proposals are – a) re-conceptualise at the end, mainly through the teacher's explanation and videos of the topic, b) very general or superficial descriptions of this activity, c) public presentation of results and conclusions, d) repetition of experiments, e) less frequently the collective construction of conclusions, and f) on infrequent occasions, the construction of conclusions regarding the initial hypothesis or question.

According to the participants' planning, a set of post-experimentation activities serves to analyse and conclude in a mixed way. Within this group, the assembly stands out. Assembly is a moment for students and teachers to meet and share what they have experienced, their emotions, opinions, learnings and conclusions. There are also final evaluation activities through questions and online games.

Finally, only twice did the pre-service teachers explicitly plan post-experiment activities to address cognitive and linguistic diversity.

The following excerpt illustrates how a participant planned an activity to guide students in analysing and concluding after the experiment:

> Formulation of conclusions and communication of results: What has happened to the hypotheses?
>
> This process occurs after experiencing it firsthand and observing the flotation of each object and the collection of data. Students will compare and classify objects according to their float. To do this, they will use a second worksheet with a chart to classify the objects. We will cut out the drawings of the chosen objects for the experiment and paste them into the corresponding section of the chart. Students will draw on the chart the objects that were not on the first worksheet to cut out. Students will then discuss what each object has in common to identify the materials or characteristics that make objects sink or float.
>
> To finish the activity, the students will have to communicate the results of their small research. To do this, they will go from group to group, exposing the cards and the information they have been filling in. First, they must explain what they initially thought (the hypotheses), what happened (the experiment) and the conclusion they have reached. Finally, the teacher will guide the class to reach a joint conclusion.

The pre-service teacher planned in the previous excerpt a worksheet-based activity to process data. Thus, during the experiment, students classify the registered information in an analysis chart. Moreover, the pre-service teacher planned the evaluation of the hypotheses, the proposal of the conclusion, and socialisation.

Discussion

To answer the initial question What are the possible difficulties in the pre-service ECE teachers' planning of a scientific experiment and what recommendations for improvement might emerge? the discussion addresses the main difficulties found, and it explores alternatives to improve pre-service ECE teachers' planning leaning. The main difficulties are – a) conceptual errors that make evident that pre-/and in-service ECE teachers need more profound knowledge in science (Gerde et al., 2013; Mosquera et al., 2018; Oon et al., 2019), and b) suitability of some experiments because of their potential incidence in students learning. Considering the difficulties, this section proposes alternatives as: a) dialogues between the results in this study and other studies, and b) a wider view of planning for teacher education and professionalisation.

Conceptual errors in teaching scientific experimentation

The analysis revealed some conceptual errors. Researchers have identified conceptual errors in science in pre-service teachers (Branca et al., 2021) and in-service teachers (Muñoz et al., 2021). In the present study, it is not clear whether these errors persist because the pre-service teachers hold such beliefs or whether they result from the reductionism they adopt when seeking a didactic transposition based on the students' age (Chevallard & Bosch, 2014).

Thus, explaining what happens when mixing water and oil leads to one of the most frequent errors among pre-service teachers: stating that oil floats on water because it is lighter. With this explanation, the participants ignore that carboxylic acids have a higher molecular weight than water, yet cooking oil floats on water. For example, that weight is not the reason for buoyancy; olive oil floats in water despite being a mixture of carboxylic acids with a higher molecular weight than water. This phenomenon occurs because olive oil has a density of 0.916 g/mL (at 20°C), which is lower than that of water (+/- 1 g/mL at 20°C). On the other hand, sulphuric acid has a molecular weight of 98 g/mol and a density of 1.84 g/mL (at 98% concentration and 20°C), which are higher than those of water (18 g/mol and 1 g/mL at 20°C). However, sulphuric acid does not sink; rather, it solubilises. The last example shows that it is not just about molecular weight and density. The phenomenon also depends on the type of chemical bond. Thus, oils have long carbon chains with nonpolar covalent bonds and the carboxyl group, making them poorly soluble in water. In contrast, sulphuric acid strongly dissociates the first hydrogen ion in water, making it soluble in water.

In addition, pre-service teachers must consider other associated errors. For example, it is a frequent error to reduce the concept of density to that of weight: "*Oil floats because it is less heavy than water", "the density of oil is less than that of water*", or "*We can say that Density is like weight*." To work on that, teachers and students might analyse the "material" variable of the objects to put in water. One case would be for the students to weigh 1 gram of plastic and 1 gram of metal to identify the volume displacement difference. Likewise, they could put 10 grams of plastic in water to see that it does not sink, even though it is ten times heavier than a piece of metal. To access detailed studies on floatability buoyancy force, teachers might, for example, see Paños et al. (2022). Considering the water/oil mixture again, teachers

might also remember the formation of emulsions (a case named by only one participant). Although teachers are not necessarily going to teach the behaviour of liquids from all these variables, they need this knowledge to avoid reductionism.

Experiments suitability

The experiments identified as unsuitable may lead to wrong ideas or conceptual confusion. Meanwhile, the experiments identified as more suitable employ concepts adequately, are connected to other scientific practices, processes or skills, and follow a progression to establish complexity levels.

Examples of unsuitable experiments

The volcano: This activity involves building a volcano model and simulating the eruption. This case is one of the most widely cited examples of experimentation. Although there are variations, the basic idea is to make a volcano model and put a bottle inside. The teacher sets a mixture of water, liquid soap, dye, and baking soda into the bottle. The eruption occurs when the teacher adds vinegar to the bottle containing the mixture described; at other times, it results from adding effervescent tablets to water. The contributions are – a) students work on their motor skills and imagination to make the model, b) the model contributes to learning about geography, geology and ecology, and c) simulating the eruption is striking and motivating. However, the activity is inappropriate because a) the simulation requires a chemical reaction, and a genuine volcano does not erupt due to a chemical reaction; b) the simulation reaction occurs when a hand from outside deposits something in the crater, while in a real volcano, main activity starts internally and c) the simulation foam is very far in properties from natural lava, leaving aside the learning volcanoes hazards (Todesco et al., 2022).

The Milky Way: Only a participant proposed this experience, but its implications for learning are striking. The experiment consists of adding drops of dyes to milk to simulate the appearance of the Milky Way. The experience can contribute to a) aesthetic aspects and imagination, b) observing the diffusion of one liquid in another, c) addressing heterogeneous and homogeneous mixtures, and d) the experience is fun and attractive. However, the activity does not contribute to understanding cosmology, and its focus was not on understanding mixtures. This reductionism is one of the reasons students enter primary school with intuitive or incorrect ideas about the solar system and universe (Sharp & Kuerbis, 2006).

Paper worms: This one-time activity consists of moistening twisted strips of paper, which, when untwisted, simulate the movement of worms. Although this proposal is attractive, it could create the impression that worms come from paper (perhaps creationism) or that paper is alive because of its movement (children at a certain age identify a "living being" with movement – Sanz, 2015).

More suitable experiments

One of the most frequent experiments, and one with significant scientific potential, is seed germination. Based on the analysis, as well as the literature (see Rodríguez et al., 2021), it is possible to describe this experiment at different levels of complexity:

Level 1. Just observe: This is the simplest version of the experience. It consists of germinating a legume seed in a container with cotton and water. The experience is an experiment because it motivates students to observe systematically. Observation is both a practice of the scientific method and a scientific skill. Students might register the observations in different ways – a) observe and comment on what they have seen, b) drawings, c) photographs, d) student observation notebook, e) teacher observation notebook, and f) control sheets, among others.

Level 2. Observe and answer questions or evaluate hypotheses: In this experience version, the teacher motivates students to engage in a process beyond observation. Thus, the teacher draws the students' attention through a context, phenomenon, situation, demonstration, or event. Based on this motivation, the teacher asks questions or leads students to ask them. Questions are the starting point for formulating hypotheses, understood as possible answers to a question or the prediction of an event. The formulation of the hypotheses varies according to the results. For example, in some cases – a) the teacher asks, and the children respond; b) the teacher shows objects, and the children only have to say whether they believe that such objects would float or not or would break or not, and c) the Children have a chart with drawings of the objects on which they must predict the behaviour and put a happy/green face or a sad/red face or an X in "yes" or "no" to express their belief. After this, students develop a systematic observation to evaluate the hypotheses using the collected information.

Level 3. Observe, manipulate variables, and evaluate hypotheses: At this level of complexity, the teacher motivates students to propose hypotheses, taking variables into account. Thus, to evaluate the hypotheses, students must manipulate the different variables. This process offers students a greater opportunity to participate in the design of the experiment to evaluate the different relationships among variables. Then, variations could occur in – a) what to plant: a seed, nothing (evaluating the possible previous idea of spontaneous generation), inert material (evaluating whether they associate the plant with living matter) or a potato (to see reproduction by budding), b) light contribution: with sunlight, without sunlight, with artificial coloured lights or restricted light (waiting for the plant to grow looking for the light source), c) water contribution: with clean water, with dirty water or no water, and d) the substrate: humus, sand, clay, stones, water, or nothing. The experiment provides students with information to evaluate hypotheses or formulate new ones.

Regarding results from other research reports in the field

From a philosophical perspective, the participants proposed scientific experiments within a view of experimentation as part of the science production process. This frame includes scientific practices, skills or steps as stated in the framework – problem identification, hypothesis statement, experiment, data collecting and analysis, among others. Additionally, the participants planned the scientific practices, skills or steps in three moments: a) pre-

experiment activities, b) experimental activities, and c) post-experiment activities. This structure follows the framework in this paper and the instructions in the subject at the university. Nonetheless, the data demonstrate that the pre-service teachers plan much more pre-experiment activities (288) than post-experimental activities (150). The last category considers analysis and conclusion activities.

However, it is not easy to determine whether the participants' proposals align with one or another philosophical view of the relationship between theory and experiment. For instance, accordingly to Hacking (in Wei, 2020), subjects have pre-existing ideas, perceptions, or experiences about nature prior to experimentation. Thus, children participating in some experiments may already have ideas about colours, textures, sensations, the behaviour of particular objects and other things before the experiment. Nevertheless, if the experiment is entirely new to the children, the mechanism would resemble that proposed by rational empiricists (in Wei, 2020), whereby subjects acquire information about nature and thereby identify regularities and generalisations about it.

On the data side, Cantó et al. (2016) conducted a study on the perception that future ECE teachers have about science teaching. The mentioned study connects to the present in two aspects:

First, the authors identify a shortcoming in terms of methodologies for teaching science, including the development of experiments. The present study advances because participants receive training in planning an experiment within the scientific production process. This information indicates that future ECE teachers have theoretical and methodological elements that may motivate the inclusion of experiments in the classroom. In addition to this assumption, the majority of the plans make it clear in their contextualisation sections that the participants work or have worked in ECE centres. The documents also reveal that the proposed experiments have been or will be part of actual practice. However, it is necessary to enrich this experience as ECE assistants with the professionalisation, since many of the proposals for experiments with conceptual errors are activities, they have already carried out in their previous experience.

Second, the authors identify the abundance of technical activities and the scarcity of activities such as argumentation. The present study shows interest in planning experiments that include formulating motivating questions and hypotheses, which is an advance in leading children to construct arguments for why something happens. One aspect that hinders the implementation of practices such as argumentation is that the analysed plans show that data collection is rare during the experiment, hindering future analysis and conclusions about what the children observe. Another limitation is that only a few pre-service teachers explicitly planned to test the hypothesis or answer the initial question, which is crucial for making an argument.

Planning as a process for teacher education and professionalisation

A different view of planning could guide teacher education and professionalisation in addition to its didactic (teaching and learning) function. Thus, planning is a practice for

managing the processes of teaching, learning, and student assessment and, in addition, driving part of the teaching profession's development. From this perspective, planning would intersect with didactic theory, teacher education theory, and the regulations governing them. The following subsections describe some references that could enrich planning:

The critical administration of teaching, learning and assessment

Considering the results, teachers need to go beyond planning the expected learning, the most suitable teaching for this, and its assessment, in line with the regulations and what they have learned. The evidence confirms that teachers take up content, experiences, or activities they have learned through their own experience or found on the Internet, but in an uncritical manner. For this reason, enriching planning should include elements that help teachers evaluate information sources and use that content in planning (Tellez-Acosta et al., 2021). Additionally, teachers need better instruction on how to use learning assessment results formatively beyond the normative requirements (Cáceres et al., 2018; Guzmán, 2010).

The ecologisation of knowledge systems

Using different disciplines, knowledge forms or systems to interpret the world is a general educational objective. In this way, enriched planning would guide teachers to achieve multi-, inter-, and trans-disciplinary integration and collaborative relationships across culturally differentiated knowledge systems (interculturality). Although there are theories and policies regarding these relationships among knowledge systems, teachers need better instruction in planning and implementing them (Tovar-Gálvez, 2022; Tovar-Gálvez, 2023).

Metacognitive processes

Although teachers should plan the development of students' metacognitive processes, teachers also need to develop their own metacognition. Thus, in terms of Tovar-Gálvez (2012), teachers would – a) reflect on their knowledge and skills related to the didactic field (planning, learning, teaching and assessment) and the discipline they teach, b) manage those identified resources to develop strategies for their own learning and teaching goals, and c) they would assess the achievement of those strategies. In this same sense, planning, as part of the didactic process, is also a learning process for teachers (Puerto, 2022). From this perspective, enriched planning would lead teachers to question and act on their own learning. Furthermore, in some ways, metacognitive processes help regulate the influence of teachers' shortcomings on student learning (Rodríguez & Navarrete, 2020).

Classroom-research

Critical vision, knowledge systems' integration, and metacognitive processes help teachers research their didactic practice in context. In classroom and school research, teachers lead the identification of problems, situations to transform or processes to strengthen or consolidate the search for solutions or alternatives and the mobilisation of the community towards these transformations (Tovar-Gálvez, 2018). Therefore, adequate planning would

guide teachers to reflect on their knowledge of content and teaching, student learning, context, curriculum, and community; to consider how to systematically collect information about the processes; and to analyse, use, and communicate the research results.

Conclusion

The experiment is more than just a practical, funny or aesthetic experience. The results, literature and discussion suggest that a context, phenomenon, question or reason motivates students to participate in school scientific experiments. As scientists, the children would at least formulate and evaluate one hypothesis, or try to answer a question or solve a problem. Practical experience should provide information to evaluate, answer or solve. Thus, the experiment involves manipulating variables to consider various scenarios or possible outcomes of the experience and obtain information or data. The data can be photographs, videos, accumulated experience, or data tables with pictograms or symbols, which, when analysed, help to evaluate the hypotheses.

The activities that the pre-service teachers of the sample plan to develop a scientific experiment for ECE are mainly characterised by – a) being within the framework of the scientific knowledge production process, with activities before, during and after the experimentation, b) on some occasions, they explicitly report the formulation of hypotheses and on other occasions the formulation of motivating questions, c) the experiments are varied, although some include conceptual errors and wrong representations of phenomena, d) to a lesser extent, they propose the manipulation of variables, e) to a lesser extent, they propose that students record empirical information and f) the analysis and conclusion activities very rarely address the initial hypothesis or question.

The main difficulties identified in the sample's plans are: a) Conceptual errors, especially the confusion between weight and density when addressing floatability and buoyancy force, and b) experiment suitability because some proposals distort scientific concepts like the volcano model that represents eruptions as chemical reactions (mixing substances). Additionally, the discussion offers some recommendations to help pre-service teachers overcome the main difficulties and proposes a broader view of planning. On the other hand, although the information about the school and university curricula reveals a weak science education, the main limitation is that the current study does not inform the origins of the main difficulties. Consequently, future studies might contribute to a better understanding of the origins of the difficulties.

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