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Research Article

School research in heritage education: Science teacher's specialised knowledge in a field trip

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The purpose of the research was to detect elements of specialised knowledge of an experimental sciences teacher in the design and implementation of a field trip in Secondary Education in order to draw pedagogical implications in initial teacher training. We developed a case study of a science teacher who carried out an educational intervention about heritage through a field trip. An interview and the field book design were used as instruments for data collection. Data were analysed using content analysis guided by a theoretical and methodological model of the specialized knowledge of teachers who teach experimental sciences, mathematics and social sciences. The results showed that the teacher has in-depth Content Knowledge, which allows him to characterise the river, an ecosystem and research in a heritage environment, as well as Pedagogical Content Knowledge using specific resources, methodological strategies and activities to teach science in Secondary Education. From these results, a series of implications have been drawn, such as the importance of an in-depth content knowledge related to topics to be taught and an interdisciplinary teacher training.

Keywords: Case study; Field trip; Heritage; Science; Teacher knowledge

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1. Introduction

One of the general aims of Compulsory Secondary Education, as set out in the Spanish regulations governing educational processes at this stage, is to ensure that students consider scientific knowledge as an integrated knowledge, being able to apply methods to identify and solve problems from the different knowledge areas and fields of experience (Education Ministry, 2022). To this end, it is essential to design and implement interdisciplinary projects that are meaningful and relevant to the lives of students at this educational stage. For teachers to contribute to effective science education that is meaningful and useful for citizens, responding to the needs of society (Landolfi, 2023).

In this sense, territory and heritage are resources of great educational value for analysing and understanding current societies and their history, and for citizenship education (Santisteban et al., 2020). In this way, heritage education becomes an ideal setting for promoting knowledge of the

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cultural and natural reality from a symbolic-identitarian and critical perspective (Cuenca et al., 2021) and for addressing the socio-environmental problems of the immediate context, while contributing to the achievement of learning in different knowledge areas and key competences (Van Doorsselaere, 2021).

In this line, research field trips are the main activity organised to bring students closer to the landscape and heritage (Stolare et al., 2021; Trabajo & Cuenca, 2020). Specifically, they could be considered in order to establish relations with subsequent studies, gather data that provide new perspectives in relation to the object of study, expand and verify knowledge already worked on previously and solve problems by integrating new skills and abilities that encourage students to identify themselves as scientists (Mills & Katzman, 2015; Pujol, 2003). Field trips encourage students to interact with the environment, observe and explore their surroundings, experience school learning alongside the object of study and reflect on the problems and controversies associated with it in a cooperative way (Braund & Reiss, 2006). However, the educational potential of field trips depends, as Aguilera (2018) argues, on the planning, commitment, training and knowledge of teachers. Along these lines, Behrendt and Franklin (2014) in their review note the importance of teacher training in field trips. These authors argue that good preparation before the field trip helps students make connections between what they are experiencing during the field trip and their previous knowledge and that, after the field trip, activities to reflect on what they have experienced should be promoted, so that students can structure their new ideas and make new connections. Teacher training will help teachers to avoid the tendency to repeat routines, which can cause students to miss out on learning opportunities, and to actively participate in the field trip, rather than being a mere chaperone (Tal & Steiner, 2006).

However, there is little research that study teacher knowledge required to extract the potential value of a field trip, despite the proven impact of the teacher knowledge on student learning in a number of subject areas and levels (Akosah et al., 2024; Aydın-Turhan & Mıhladız, 2023). The scientific literature addressing field trips in experimental sciences teaching revolves around teacher motivation (Julien & Chalmeau, 2022; Kisiel, 2005), methodology (Rahmawati et al., 2020; Subramaniam et al., 2018) and barriers and challenges (Behrendt & Franklin, 2014; Rebar, 2012; Rudmann, 1994), but hardly to teacher knowledge (Rebar, 2012).

Nevertheless, teaching science requires teachers to have in-depth knowledge of the content to be taught and of how it is taught and learned. So much so, that Nathan and Petrosino (2003) concluded that with good content knowledge alone, teachers are not able to anticipate their students' responses. Based on this premise, numerous studies have been carried out, the pioneer being Shulman (1987), who contributed the notion of *Pedagogical Content Knowledge* [PCK]. This is understood as the knowledge about teaching and learning intimately linked to the discipline per se. Building on this, other research has focused on science teacher knowledge (Nixon et al., 2019; Perona et al., 2017) and its influence on student achievement (Usak et al., 2022).

Taking Shulman's categorisation as a reference, different theoretical models have attempted to reflect what specific knowledge teachers require in relation to teaching a subject. In particular, this has been a specially fruitful field of study in the case of science teachers and mathematics teachers. Thus, based primarily on the Shulman's components of subject matter knowledge, pedagogical content knowledge and curricular knowledge, different categorisations of science teacher knowledge, such as that of Magnusson et al. (1999), or Park and Oliver (2008) and mathematics teacher knowledge, such as those of Ball et al. (2008), or Carrillo et al. (2018) have been developed. In our case, we rely primarily on the categorisations of Park and Oliver (2008) for science teachers and Carrillo et al. (2018) for mathematics teachers. We consider these two categorisations because they detail the three Shulman's domains mentioned above, because they take into account beliefs or orientations towards teaching the subject, and because they are compatible with each other as a basis for reflecting on the knowledge of mathematics and science teachers.

Park and Oliver's (2008) model, on the one hand, distinguish five components of science teachers' PCK, and on the other, the Mathematics Teacher's Specialised Knowledge (hereinafter

MTSK) of Carrillo et al. (2018), provides categories to analyse in a specialised way both mathematics teachers' content knowledge and PCK. In this research, we focus on the specialised knowledge, in relation to experimental sciences teaching, that a teacher deploys when designing and implementing a field trip in the context of an interdisciplinary heritage education project in secondary education. We refer to specialised knowledge in the sense that it refers specifically to science and its teaching and learning (as opposed to general knowledge about teaching any subject). For this study, we will make use of a categorisation of teachers' knowledge, constructed within the framework of a broader investigation, which considers the knowledge of teachers who teach experimental sciences, mathematics and social sciences (García-Viso et al., 2023; García-Viso, De las Heras, et al., 2024). Its construction is primarily based on Park and Oliver's (2008) categorisation of PCK for science teachers and the MTSK of Carrillo et al. (2018), for mathematics teachers (García-Viso, Climent, et al., 2024). Furthermore, we consider the adaptation of the MTSK to the case of Luís' (2021) biology teacher, specially in terms of science teacher's content knowledge, which is not covered in Park and Oliver's (2008) work. In this way, we consider it appropriate to use this model which contemplates knowledge of the content of each discipline, pedagogical content knowledge and orientations for teaching the discipline, because it would give us a more complete picture of the knowledge displayed by the teacher. Although we are only going to focus on specialised knowledge related to experimental sciences, it makes sense to consider this model that contemplates two other areas, since the data we are going to deal with consist of an interdisciplinary field trip design, in which experimental and social sciences subjects, among others, converge.

Thus, the specialised knowledge model that we will consider in this study includes categories to analyse and describe *Content Knowledge*, *Pedagogical Content Knowledge* and *Orientations for teaching Science* (García-Viso et al., 2023).

On the one hand, we describe the subdomains of *Content Knowledge* [CK] that we consider, here referring to the knowledge of the teacher who teaches science:

The first sub-domain, *Knowledge of Topics*, refers to teacher's knowledge of the science ideas to be taught, at a deeper level. It includes: teacher knowledge of science procedures [e.g. teacher knows that it is important to maintain the conditions of the experiments until the end for the results to be reliable] (*Observation and experimentation procedures and techniques*); knowledge of what characterises and defines a concept, law, principle or theory, as well as examples of them [e.g. teacher knows the main function of the kidneys] (*Concepts, laws, principles, theories and examples*) (Luís, 2021); knowledge of representations of the subject, including the language of science [e.g. teacher knows a scheme of a flower] (*Representations and models*); knowledge of phenomena with which a topic, contexts or situations are associated and scientific facts [e.g. teacher knows that left lung is smaller than the right one] (*Facts and phenomena*).

Secondly, the *Knowledge of the Structure of Science*, concerns to knowledge of big ideas or structuring ideas (Charles & Carmel, 2005), as ideas that interrelate contents, phenomena and facts of the discipline [e.g. teacher knows the idea of change as a big idea that interrelates different science contents].

Thirdly, the *Knowledge of Practices in Science*, is referred to syntactic knowledge (Schwab, 1978) as a set of ways in which to determine what is legitimate to say in science and what "breaks" the rules, or “the principles and means by which scientific knowledge develops and becomes accepted” (Anderson & Clark, 2011, p. 315) [e.g. teacher knows that scientists must measure and record data accurately and in an organized manner]. In this sense, the teacher's knowledge of the rules governing scientific practice will help students to develop the critical thinking that they will need to apply in their daily lives, not only in scientific fields (Ponce de Leon, 2025).

On the other hand, the three subdomains of PCK that we have examined in this model are presented (referred to the knowledge of science teachers).

With respect to the sub-domain *Knowledge of Science Teaching*, relating to specific knowledge about how to teach science topics. We consider four categories referred to: teacher knowledge of personal or institutional theories for science education *(Teaching theories category)*; knowledge of the potential of specific science resources [e.g. teacher knows the environmental agent as a resource] (*Resources*); *Strategies and activities* (content-specific and science-specific) [e.g. teacher knows a strategy for eliciting students' preconceptions about the position of the heart], and knowledge of various ways of representing scientific content [e.g. teacher knows the representation of the human heart size using the fist] (*Representations for teaching*).

With regard to *Knowledge of Features of Learning Science*, relating to knowledge about how science content is learned. We include: knowledge of personal and institutional theories of student cognitive development in relation to science learning (*Theories of learning*); knowledge of *Strengths and difficulties* in science learning (*strengths, misconceptions, difficulties and needs*) [e.g. teacher knows the difficulties in understanding the digestive process in relation to cellular respiration in nutrition]; knowledge of students motivation and interests [e.g. teacher knows the feeling of belonging of students to the ecosystem they are studying] (*Emotional aspects*); and, finally, knowledge of the strategies with which learners usually deal with specific science content (*Ways of interacting with a content*).

Concerning the subdomain *Knowledge of Science Learning Standards*, or teachers' knowledge of what should be taught at any given time, taking into account institutional curriculum guidelines or suggestions from teachers' associations or other experts. We distinguish the following categories: *Expected learning outcomes* or teacher knowledge of what must be taught at a specific level [e.g. teacher knows what ecosystems students need to learn at 5th grade, following the local curriculum]; *Expected level of conceptual and procedural development* or teacher knowledge of the depth that a given content can reach [e.g. teacher knows the level of depth that can reach the ecosystems as content in a concrete scholar level], and *Sequencing with previous and subsequent subjects* or teacher knowledge of the sequencing of content, horizontally (at the same level), vertically (at previous and subsequent levels) (Park & Oliver, 2008) [e.g. teacher knows that students have learnt biotic and abiotic factors to understand an ecosystem].

Finally, we consider the science teacher orientations or teachers' beliefs about the purposes and goals of teaching science at a particular grade level (Magnusson et al., 1999). We distinguish orientations about science and about the purposes of teaching and learning science (Reynolds & Park, 2021).

1.1. Research Questions and Aims

The importance of this research is based on the need to extract elements of knowledge that are mobilised in the preparation and implementation of a field trip to improve the training of science teachers in Secondary Education.

Thus, taking as a research context a heritage education project carried out in Secondary Education, specifically in the development of a field trip to the Tinto River and its surroundings, the main objective of this research is to detect elements of specialised knowledge of an experimental sciences teacher in the design and implementation of a field trip in Secondary Education in order to extract pedagogical implications in initial teacher training.

This main objective seeks to answer the following research question: What specialised knowledge of experimental sciences does a teacher bring into play when designing and implementing a field trip in Secondary Education?

In order to give a detailed answer to the research question, the specific objectives of the study are 1) to identify what content knowledge of experimental sciences a teacher mobilises in the design and implementation of a field trip in a heritage context, 2) to delimit the pedagogical content knowledge that a teacher brings into play when designing and implementing science activities in Secondary Education, and 3) to identify teacher's orientations for teaching experimental sciences that holds his design and implementation of a field trip in a heritage context.

2. Method

2.1. Research Design

The research carried out is based on the interpretative/qualitative paradigm (Thanh & Thanh, 2015; Willis, 2007) since, under this approach, educational reality is considered a social construct that is generated from the subjective interpretations and meanings that are granted by the participants, without seeking to establish inferences or generalisations. This approach is in line with the research projects in which it is framed. These projects work on the interdisciplinary teaching of heritage and the specialised knowledge of teachers. Specifically in this work, taking into account this context and the research objectives, a case study was chosen, as it is a technique that allows the gathering of in-depth and contextualised information (Yin, 2018), through various instruments including the interview (Brenner, 2012).

2.2. Context and Participants

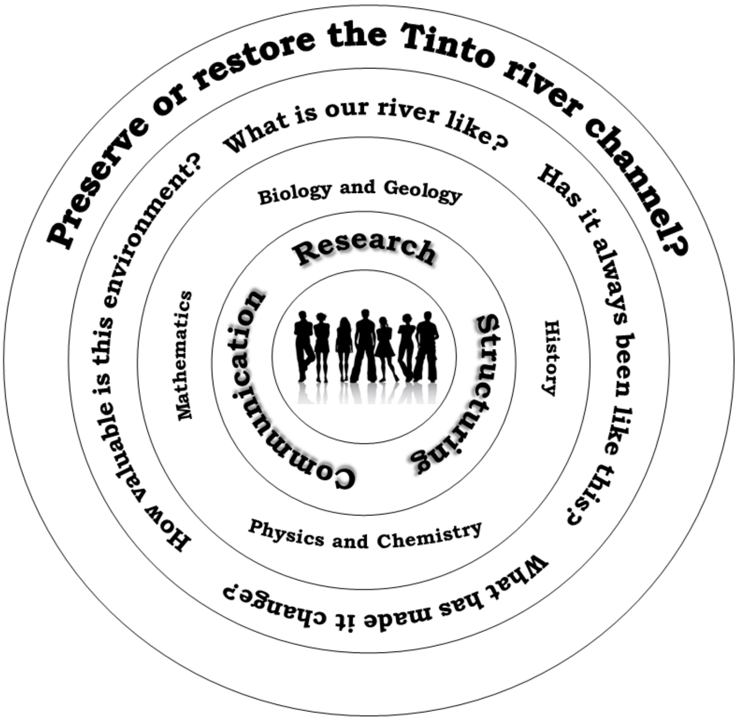
Alberto (pseudonym) has a degree in Geology, a master's degree in Secondary Teacher Education and a master's degree in Research in Science Teaching and Learning. He is a university lecturer in the area of didactics of experimental sciences, acting as educator of primary and secondary preservice teachers, with 3 years of experience in this position. The fact that he is a teacher with initial training in science and didactics of experimental sciences makes the chosen case particularly enriching. It is therefore interesting as an intrinsic case, since Alberto's broad and deep specialisation in both science and didactics makes him a particular case that is interesting in itself (Stake, 1995).

The context of the research corresponds to an educational experiment carried out in a secondary school in Valverde, in the province of Huelva, Spain. Eighteen girls and eleven boys in the fourth year of Secondary Education (16 years old) participated during the 2022-2023 school year. This intervention proposal consists of an inquiry-based sequence (Strat et al., 2023) that follows the indications of Cañal et al. (2005) and national educational regulations (Education Ministry, 2022), with an interdisciplinary approach and with the Tinto River and its surroundings as the focus of interest, which is a heritage element used as a resource to teach about ecosystems (Illescas-Navarro et al., 2025). The Tinto is a river from the participating students' close context, whose reddish and highly acidic waters serve as an ideal context for reflecting on the interaction between the natural environment and human activities and for the study of a nearby and unusual ecosystem, used in NASA research due to its similarity to the planet Mars (Amils & Fernández-Remolar, 2014; Kyle et al., 2008). The mining exploitation of the area since ancient times and its fundamental role in the industrial revolution with the arrival of the British Rio Tinto Company (Kapelus, 2002) make this area a controversial heritage site with great educational potential.

Specifically, the project aims to provide a response to a major problem to be investigated –"Preserve or restore the Tinto River channel?" – which is worked upon by solving four sub-problems linked to it (see Figure 1). These sub-problems address, broadly speaking, the ecosystems, the scientific controversy over the contamination of the Tinto River, the physicochemical characteristics of the river, the effects of the English settlement and the mining that took place in the town of Minas de Riotinto, as well as the heritage controversy generated in the whole province of Huelva as a consequence of the arrival of the English settlement and the mining that took place there.

The four sub-problems were addressed, in a general way, through a wide range of activities and educational resources (e.g., using different measuring tools and models). Firstly, students focused on searching for information through different sources. Subsequently, activities were carried out in which the information from the previous activities was structured, synthesised and represented, with the aim of constructing knowledge. Next, activities were carried out to communicate the results obtained previously. Finally, a debate on the main question that initiated the research was held, focusing on the scientific controversy and the controversial heritage generated in the area. All this involved a total of 24 one-hour sessions at the school and two field trips, one to the University of Huelva and the other to the Tinto River and its surroundings, lasting one morning each.

Figure 1
Outline of the intervention proposal



Note. Translated from Illescas-Navarro et al. (2024).

One of the relevant activities in the didactic sequence was the visit to the Tinto River and its surroundings. In this field trip, the students had to accomplish a series of missions, through which they collected data and evidence in a field notebook. The missions encourage students to work on the flora of the area, its geology, physicochemical parameters of the river and social and historical aspects, as well as Andalusian and British heritage.

Due to the interdisciplinary approach underlying the research questions of the teaching proposal, it was necessary to involve in the design a team made up of teachers from the area of social sciences didactics, experimental sciences didactics and secondary education teachers from the participating school.

2.3. Instrument and Data Collection

To achieve the proposed objectives, two instruments were designed to gather information through two sources: a personal source, the experimental sciences teacher, and a material source, the field notebook designed for the students to record the information from the field trip.

On the one hand, the first instrument consisted of a semi-structured interview with a total of 28 questions, which was designed by a multidisciplinary team of experts in experimental and social science didactics, heritage education, specialised teacher knowledge and initial teacher training. The interview questions revolved around the teacher's training, experience and the learning situation implemented, specially the field trip. The topics covered in the interview were selected so that the teacher could provide information about his knowledge from the different subdomains, particularly in relation to:

- Choice of the heritage context as an object of study.
- The aim of the different actions carried out in the field trip.
- The needs of a teacher to carry out the field trip.
- Difficulties detected during the development of the field trip and solutions.

- Selection criteria for the contents, as well as their inclusion in regulations.
- Learning difficulties expected in the students.
- Organisation and structuring of the sequence around challenges, as well as pedagogical strategies carried out.
- Strategies for motivation of the students.

On the other hand, the second instrument of analysis was a field notebook used by the students to record the data gathered on the pH, temperature, turbidity and flow of the river, the native species of the ecosystem and the distinctions between local and British society and heritage during the field trip. In the specific case of this study, the focus is not on the students' responses, but on the questions, tasks, challenges and indicators that the teacher included in the field notebook, in order to triangulate the information gathered through the interview with the didactic design and the assessment techniques used.

The data collection was carried out following the requirements of ethical research, duly informing the participants about the nature and objectives of the work and ensuring that their privacy was not invaded and that they were not exposed to any harm. Thus, the teacher interviewed, the rest of the teachers at the school, the students participating in the educational project and their families gave their informed consent for the development of this research.

2.4. Data Analysis

The data gathering is carried out through an audio-recorded interview with Alberto. To analyse the content, first a literal and linear transcription of the interview is made. It is then divided into units of information, i.e. fragments with semantic unity. Grammatical and syntactic omissions and errors are corrected and, once these corrections have been made, the data are analysed using descriptive methods and content analysis (Gläser-Zikuda et al., 2020).

To analyse the information, the model of knowledge of science teachers (experimental, social and mathematics) (García-Viso et al., 2023), described in depth in the previous section, is used. This model (see Table 1) serves as a theoretical and methodological reference and constitutes the basis for the design of the data collection instruments and for the analysis and informed interpretation of the data. Specifically, associations are established between the units of information and the subdomains and categories of the model, so that the knowledge mobilised by the teacher when designing a field trip can be observed, as well as when preparing the field diary linked to it. For this research, only the notions related to the contents of experimental sciences and their teaching and learning are taken into account, as Alberto is a specialist in this area of knowledge.

To analyse and interpret the information, Alberto's responses to the various interview questions were categorized based on the conceptualization of each category within the model of knowledge of science teachers (experimental, social, and mathematics). From each excerpt, sentences or words that denoted specialized knowledge were labelled.

As an example of the analysis procedure, consider the interview question: “Do you think your experience as a teacher in the field of science education has contributed anything to your secondary school teaching practice?” Alberto's full response was as follows:

> Alberto: Yes, yes, because one thing is my knowledge of geology, but then there's the fact of applying methodological strategies such as inquiry, modelling, computational thinking... I didn't get that from my degree [on Geology]. These are things I've learned here [at the Faculty of Education, where the interview is developed], and they seem to be intrinsic to scientific practice itself. […] These are things I've acquired not only during my teacher training but also through my own teaching practice, where I've had to learn that there are different methodologies related to science education, beyond the application of the scientific method to processes of enquiry, modelling and project-based learning. By using resources and digital tools that I didn't know about. In that sense, yes. If I hadn't had that training, I doubt I would have been able to design and implement that teaching sequence, because I wouldn't have had the necessary background.

Table 1

Subdomains and categories to analyse science teachers' specialised knowledge

Domains and sub-domains	*Categories*
Content Knowledge	
Knowledge of Topics	Observation and experimentation procedures and techniques Concepts, laws, principles, theories and examples Representations and models Facts and phenomena
Knowledge of the structure of science	Big ideas or structuring ideas
Knowledge of practices in science	Syntactic knowledge
Pedagogical Content Knowledge	
Knowledge of science teaching	Teaching theories Didactic resources Strategies and activities (content-specific and discipline-specific) Representations for teaching (content-specific and discipline-specific)
Knowledge of features of learning science	Theories of learning Strengths and difficulties (strengths, misconceptions, difficulties and needs) Ways of interacting with a content Emotional aspects
Knowledge of science learning standards	Expected learning outcomes Expected level of conceptual and procedural development Sequencing with previous and subsequent subjects (vertical and horizontal curriculum)
Orientations for teaching science	

Note. Adapted from García-Viso et al. (2023).

In this particular case, special attention was paid to Alberto's mention of various methodological strategies specific to science teaching. The relevant elements of his response for this study were aligned with the *Teaching theories* category of the model. This selection led to the creation of the unit of information 16, which is described in the results section:

> Alberto: There are different methodologies related to science, beyond the application of the scientific method to processes of enquiry, modelling and project-based learning. (U16)

This analysis is first carried out individually by the authors and then discussed until a degree of consensus of over 90% is reached.

Likewise, in order to analyse the content of the field notebook designed by the teacher, a systematic review sheet was used, the sections of which correspond to each of the categories of the subdomains of the specialised knowledge model of science teachers (experimental, social and mathematics) (see Table 1).

3. Results

The results are presented below, taking into account the objectives set out in the research, i.e. ordered according to the knowledge manifested by the teacher when designing a field trip –to obtain information about the Tinto River and its surroundings– within an interdisciplinary project in experimental sciences. Specifically, the results related to the *Content Knowledge domain* are addressed first, before going on to carry out the same process with the *Pedagogical Content Knowledge* domain and, finally, with *Orientations for teaching Science*.

3.1. Content Knowledge

3.1.1. Knowledge of topics

Throughout the interview transcript and in the field notebook, there is ample evidence of how knowledge of the "river ecosystem" theme underpins the field trip design and implementation. Regarding the category *Concepts, laws, principles, theories and examples,* there are several units of information (hereinafter U) in which Alberto shows his knowledge of scientific concepts such as pH (U1). pH is a core concept of the project about the Tinto River and its surroundings, specially in the field trip, where it is approached theoretically and practically through its measurement with sensors built by the students.

> Alberto: [...] So that they could understand with the tools they had built and with the samples they had already taken in situ, they could make a model of the source of the river, mix the water, measure it and understand by adding more or less from one place to another how the pH level was changing and realising that this was not a linear scale, but a logarithmic scale. (U1)

In the same category, Alberto shows knowledge about the concept of pollution (U2), distinguishing the natural pollution from the anthropic one and the ways in which both impact the environment. In the educational project, this knowledge made it possible to reflect on the origin of the red waters of the Tinto River and to discuss their management.

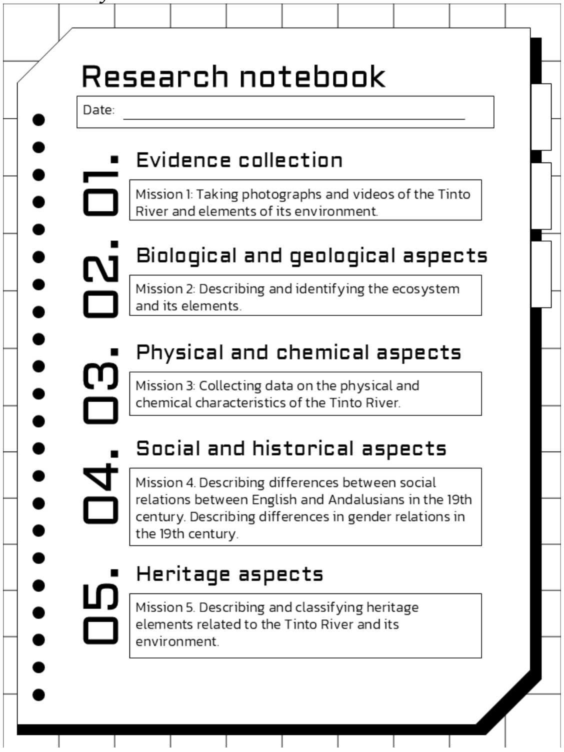
> Alberto: [...] I couldn't remember all the concepts [previously held by the students, which he had been asked about] that there were, but they were detected beforehand and taken into account […] then to characterise what pollution is, that it is natural, that there is anthropic pollution, as in that sense they were taken into account. (U2)

Similarly, there is evidence of the teacher knowledge of the concept of ecosystem (U3 in Figure 2), which enables him to structure the didactic proposal, urging students to learn about both aspects of the biocenosis and the biotope that make it up.

All this knowledge lets him propose a model of the river to the students that enables them to study it (U1), to put forward alternative scientific ideas to the students' previous conceptions (U2) and to structure the didactic proposal for school research on the river (U3 in Figure 2).

Figure 2

General field notebook index



Research notebook

Date: ______________________

01. Evidence collection

Mission 1: Taking photographs and videos of the Tinto River and elements of its environment.

02. Biological and geological aspects

Mission 2: Describing and identifying the ecosystem and its elements.

03. Physical and chemical aspects

Mission 3: Collecting data on the physical and chemical characteristics of the Tinto River.

04. Social and historical aspects

Mission 4. Describing differences between social relations between English and Andalusians in the 19th century. Describing differences in gender relations in the 19th century.

05. Heritage aspects

Mission 5. Describing and classifying heritage elements related to the Tinto River and its environment.

Note. Extract from the instrument (U3)

For Alberto, the study of the Tinto River is a particular case to study the physicochemical parameters of any river (U4). In this sense, he is showing knowledge of the topic related to the category *Representations and models.* This means that this specific didactic situation has a purpose for him that transcends the phenomenon of study itself.

> Alberto: [...] when distinctions were even drawn between the River Tinto, the River Odiel or articles were created in which the practices of any river were studied, there is a series of values that [...] are usually applied to characterise any river. (U4)

Moreover, both in the interview (U5) and in the field notebook (U3, Figure 2), it can be observed that students investigate both the biocenosis and the biotope of the selected ecosystem. Both aspects are the constituent elements of any ecosystem, as mentioned above, so that together with the overview of the proposal described in methodology, it can be considered as an indication of a model for the study of ecosystems in a general manner.

> Alberto: [...] let's try to characterise an ecosystem to study ecosystems. We are going to try to characterise the physicochemical characteristics in order to know how to characterise any river in the world. (U5)

In relation to the category *Facts and phenomena*, Alberto demonstrates knowledge of the factors that have characterised the Tinto River and its environment. Firstly, he mentions the geological characteristics of the area as well as natural factors influencing the characteristics of the river, such as ancient volcanic activity and associated hydrothermal processes (U6 and U7).

> Alberto: So, I know everything about the province, the lithology and geological history of the area inside out, [...] which, of course, has helped me to study a lot of geological aspects, to be able to contextualise geologically what it was like in the past. (U6)

> Alberto: [...] there used to be volcanoes and these volcanoes, in the end, are associated with hydrothermal processes. (U7)

Secondly, Alberto shows knowledge of the anthropic factors that affect the Tinto River and its environment. In this sense, he recognises the mining activity in the area as a key factor in the composition and characteristics of the river (U8).

> Alberto: [...] mining in the area, which has influenced the river. (U8)

Remaining in the category *Facts and phenomena*, there is evidence of Alberto's knowledge about the effect of pH on skin (U9). These notions allow him, as can be inferred from his discourse, to start from the students' alternative conceptions and from those questions that generate curiosity or interest in them in order to construct scientific learning.

> Alberto: [...] we are going to work on the pH, the fear of what might happen to us if we put our hand in… (U9)

Additionally, closely related to Alberto's knowledge of ecosystem, he also shows knowledge of how the biocenosis of the ecosystem is determined by the biotope (U10). All this knowledge allows him to design more contextualised teaching and establish relationships between different aspects of the ecosystem in a classroom outing.

> Alberto: [...] that they should know that there is a scale whereby the lower the values, the more acidic the pH is, and that this conditions the life of the ecosystem [...]. (U10)

Moreover, in the interview, Alberto shows knowledge about the procedure to measure the flow of a river (U11), which can be identified as an indication within the Observation and experimentation procedures and techniques category. This knowledge favours the inclusion of activities related to scientific practices in his teaching proposal linked to a classroom trip.

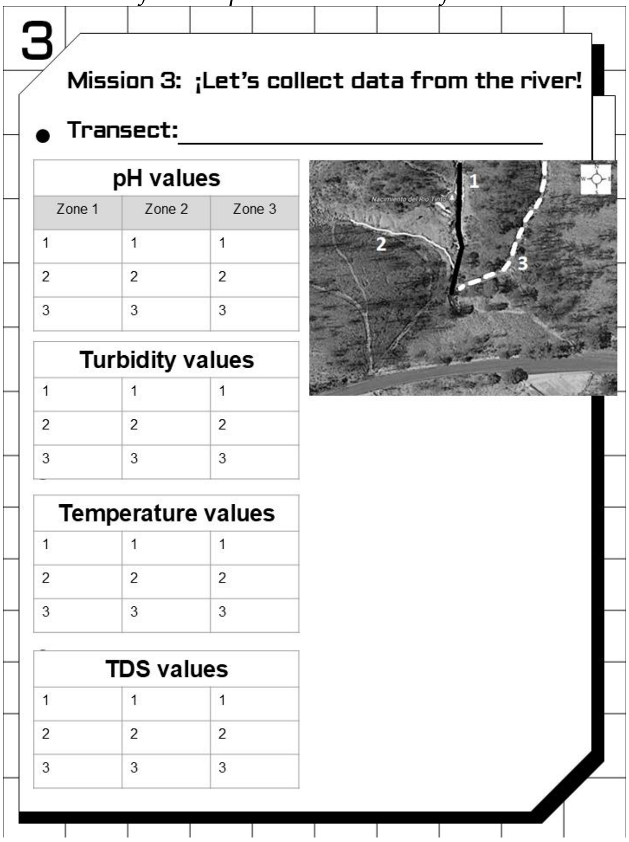
> Alberto: [...] for the subject of flow, I found it a very didactic way to work in a team, using instruments, gathering data, doing mathematical calculations, measuring areas, sections, etc. [...]. I know that there are different ways of measuring flow rates, and when I saw the float method, [...] I wanted them to take that [...]. If it has a ball, you have to time it. They have to take measurements in the river section. [...] I saw that at the end of a data collection, a graph or chart had to be made. I said "this is perfect to carry out the whole thing". [...] That's because the other methods were purely

> mathematical, for measuring speed in different sections, areas and with other apparatus that they didn't have. (U11)

The field notebook also evidences Alberto's knowledge of the procedure for data gathering in the natural environment on pH, turbidity, temperature and total and dissolved solids (TDS), as it encourages the students to sample data at three different points, both in the river and in two of its tributaries (U12 in Figure 3).

Figure 3

Mission 3 of the trip described in the field notebook



3

Mission 3: ¡Let's collect data from the river!

● **Transect:**____________________________

pH values

Zone 1	Zone 2	Zone 3
1	1	1
2	2	2
3	3	3

Turbidity values

1	1	1
2	2	2
3	3	3

Temperature values

1	1	1
2	2	2
3	3	3

TDS values

1	1	1
2	2	2
3	3	3

Note. Extract from the instrument (U12)

3.1.2. Knowledge of practices in science

Regarding *Knowledge of Practices in Science*, Alberto presents teaching methods that are directly linked to scientific practice (U13 and U14), which can be seen as an indication of his knowledge of how experimental sciences are constructed. In this sense, this knowledge will help Alberto to design classroom activities that take into account the set of rules that determine what is legitimate in the field of experimental sciences.

> Alberto: [...] methodological strategies of enquiry, modelling, computational thinking, I don't have that in my degree. These are things that I have learnt here, and they are things that [...] are intrinsic to the practice of science per se. (U13)
>
> Alberto: So, we are putting the first block of the scientific method into practice. We are carrying it out with all the aspects and about how data are sampled. (U14)

3.1.3. Knowledge of the structure of science

Finally, Alberto highlights the connections between different disciplines within the area of experimental sciences, such as Physics, Chemistry and Biology, among others. Thus, in their discourse, there is evidence of their knowledge of ecosystems as a structuring idea in experimental sciences. This structuring idea also makes it possible to address the interaction between human beings and the environment as an element that connects the experimental sciences with the social sciences, such as History, Geography and Economics, as evidenced by Alberto in his speech (U15). All this will enable him to implement teaching sequences with an interdisciplinary perspective, as well as to interrelate contents, phenomena and facts of the experimental sciences by means of structuring ideas.

> Alberto: In the end, it became clear that everything was interconnected [...]. The physicochemical aspects conditioned the ecosystem and the ecosystem conditioned the type of life and the type of fishing and the type of cultures that have been developing over all these thousands of years and that have characterised the province, its economy, and everything. (U15)

3.2. Pedagogical Content Knowledge

3.2.1. Knowledge of science teaching

Alberto shows knowledge of the theoretical foundations of experimental sciences teaching, such as the application of the scientific method to processes of enquiry, modelling and project-based learning. He also shows that this knowledge has been acquired both in his initial training and in his teaching practice (U16). This will allow him to design appropriate proposals considering what is currently proposed in the didactics of experimental sciences. This knowledge is included in the Teaching theories category.

> Alberto: There are different methodologies related to science, beyond the application of the scientific method to processes of enquiry, modelling and project-based learning. (U16)

Moreover, the teacher recognises that his specific training in experimental sciences, specifically in geology, has provided him with knowledge of specific resources for obtaining information in educational projects on socio-scientific issues (U17):

> Alberto: [...] I know which resource, where to look for it, where to find it, who to ask if I need anything. I mean, I know how to mobilise resources which, if I hadn't taken a geology degree, I might not know where to find [them]. For example, I know which books specifically have been written about the Tinto River, which people have worked at the University of Huelva and are the ones who have contributed the most about the river. [...] I already had many very powerful articles [...]. (U17)

Similarly, Alberto mobilises different resources and means of interpretation and representation of the information collected in the design and implementation of his teaching proposals (U18). This knowledge, according to this teacher, comes from his initial training and is used in his teaching designs to bring students closer to scientific work.

> Alberto: I knew where to find all the resources that I could then put into practice in maps, geological profile columns, all of that. (U18)

Moreover, Alberto shows knowledge of the didactic potential of the design and use of instruments for measuring the physicochemical parameters of the river that allow relevant data gathering for the understanding of complex scientific content (U19).

> Alberto: [...] these tools that they had designed, [...] so that the sensor could measure the temperature and so on, [...] this really works. So, they also went there and [...] they were using the programs, [...] the algorithms that they had designed and [...] they liked it, to see that it worked, that it was real, that it was providing data, and in that sense, they could see that it made sense. (U19)

Likewise, in his discourse, the teacher displays knowledge about resources to collect, represent and interpret information, as is the case of the field notebook (U20). This resource plays a fundamental role both in the field trip and in the rest of the educational project, as it fulfils a double function: an instrument for collecting information for the students and an evaluation instrument for the teacher.

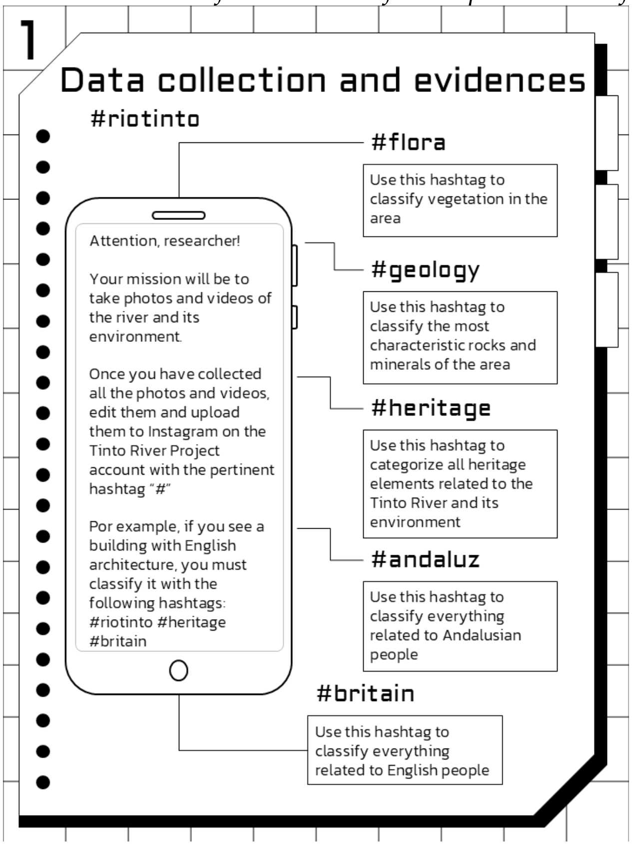
> Alberto: So, we also have to do a lot of planning about which areas and what we are going to find. And perhaps we should also, when developing the field notebook, take into consideration [...] what things they are going to find [and] what maybe they can't find, because there were also certain aspects that they couldn't see or photograph. (U20)

The teacher also shows knowledge of the potential of the use of digital tools, specially websites and social networks, as every day and motivating educational resources for students and as a means of communicating the results of scientific projects (U21 and U22 in Figure 4). These indications about the Resources category allow us to glimpse that he will be able to design classroom outings with a variety of resources with a high didactic potential, from the standpoint of experimental sciences.

> Alberto: [...] what we did is we created an Instagram site where everything that they work on is only posted there. [...] the idea was to motivate them to say, "I'm using a tool that I use outside of class, something that I like to use and I'm using it for something related to what I'm working on". [...] that site was a repository of information that they themselves had collected with the idea that they could then implement it on their websites. (U21)

Figure 4

Indications in the field notebook for the publication of data sampling results



1

Data collection and evidences

#riotinto

Attention, researcher!

Your mission will be to take photos and videos of the river and its environment.

Once you have collected all the photos and videos, edit them and upload them to Instagram on the Tinto River Project account with the pertinent hashtag "#"

Por example, if you see a building with English architecture, you must classify it with the following hashtags: #riotinto #heritage #britain

#flora

Use this hashtag to classify vegetation in the area

#geology

Use this hashtag to classify the most characteristic rocks and minerals of the area

#heritage

Use this hashtag to categorize all heritage elements related to the Tinto River and its environment

#andaluz

Use this hashtag to classify everything related to Andalusian people

#britain

Use this hashtag to classify everything related to English people

Note. Extract from the instrument (U12)

Finally, his knowledge on the design of a field trip to a natural environment where environmental conditions normally change is demonstrated. For Alberto, this requires planning and delimitation of the area to be explored and what can be encountered with more and less difficulty (U20 above). There is also evidence of the teacher's knowledge of heritage as a focus of interdisciplinary interest for educational projects that include field trips (U23). Therefore, this knowledge could be included in the *Strategies and activities* category.

> Alberto: We wanted not only to characterise the River Tinto [...], but also to use it as a site to carry out a project in an interdisciplinary way [...], which, through the Tinto River and its environment, we can work on different areas, different disciplines [...], working on aspects of history, aspects of Biology, Geology, Physics, Chemistry and Mathematics. (U23)

3.2.2. Knowledge of features of learning science

The teacher shows an awareness of the students' prior conceptions and the difficulties they have with scientific content. Specifically, he refers to the students' unexpected knowledge about pollution of the river (U24) and the expected lack of knowledge on the geological origin of the river environment (U25). This knowledge, linked to the *Strengths and difficulties* category (*strengths, misconceptions, difficulties and needs*), will be useful to design classroom outings adapted to the diversity and needs of his students.

> Alberto: But when after the initial tests, [...] before launching the project, I realised that they already knew a lot; they were aware of concepts about pollution, they even talked about a polluted river. (U24)
>
> Alberto: There are geological aspects, for example, that not everyone knows about [...] about the province of Huelva, about what it was like X years ago and [...] not everybody knows that this was a volcanic mountain range, that there were very, very high volcanoes. (U25)

On the other hand, Alberto presents scientific content related to the river and its environment that he uses to arouse his students' interest, like details and anecdotes that, not being obvious or widely known, have repercussions on the river's appearance (U26). Likewise, the students' lack of knowledge on the geological origins of the environment, like the hydrothermal processes associated to the volcanic activity, is leveraged by the teacher as a way of motivating them, since this information causes a surprise feeling in students (U27). This evidence, related to the *Emotional aspects* category, will allow him to take into account the students' expectations and interests in order to improve the design of a classroom trip.

> Alberto: I think that it does highlight a lot of characteristics that can attract [the attention] of the students [...], because many aspects of features that are either relevant or striking …. It's no longer just a red river, [it's] that there are many things behind it. (U26)
>
> Alberto: I drew the students' attention [...] knowing that there used to be volcanoes and that these volcanoes [...] are associated with hydrothermal processes, they were close to the sea, and they were surprised not to know that there were volcanoes in Huelva. (U27)

In addition, Alberto makes it explicit that students need to visualise the contents in reality in order to learn experimental sciences (*Ways of interaction* category) (U28). This knowledge favours a design that considers the learners' strategies when dealing with content.

> Alberto: In other words, they need to have a context so that they can then go there and say look, yes, it is true, so they look at things that they wouldn't look at if they didn't have that prior knowledge. (U28)

3.2.3. Knowledge of science learning standards

There is evidence that the teacher knows that ecosystems (U29) and the scientific method, including scientific procedures like research designing, data gathering and its organisation and interpretation, (U30) are curricular content in the 4th year of Secondary Education in Spain. This knowledge, included in the *Expected learning outcomes* category, will thus help him design classroom outings adapted to current curricular regulations.

> Alberto: The ecosystem was one of the things that had to be taught in Biology and Geology. (U29)
>
> Alberto: It's not just that they define what the flow rate is, or what the pH is, or what the temperature is [...] it's that we wanted them to design [...] their own research [...] knowing how to gather data, then knowing how to do calculations, knowing how to make conversion factors if there are significant figures. If they knew how to express information in graph or chart format, how to interpret the graph, how to interpret data. That is scientific knowledge that is in Block 1 [on scientific method] of all levels of Secondary Education, Physics and Chemistry in everything that is in the curriculum. (U30)

Alberto shows a knowledge linked to the level of depth that should be reached in content considering the academic level of the students (U31). This evidences his knowledge regarding *Expected level of conceptual and procedural development*, which will enable him to adapt his design to his students' abilities.

> Alberto: In other words, it is something that is not really developed. Acidity is defined [...] at the 4th year Secondary Education level, but there is no mention of basic acids nor is there... But we felt it was important [...] to define the pH because there were a lot of doubts (U31).

3.3. Orientations for teaching Science

Moreover, as a complement to the specialist knowledge of experimental sciences that the teacher shows in his responses to the interview, in his discourse we can also detect educational guidelines for designing and implementing a field trip to a heritage context through which to address science contents.

The teacher explains the importance of selecting an environment in which different types of heritage can be approached in a systemic way in order to develop the students' scientific and heritage identity and sense of belonging to their community, while learning science concepts and procedures (U32).

> Alberto: [...] there is a lot of infrastructure and mining heritage in the town of Valverde. So, it was an ideal place to find out about the sense of identity that they might have with the river, with everything that happened at the outset of the industrial revolution in the area. (U32)

In the same way, carrying out a field trip to work on knowledge from different curricular areas within an interdisciplinary heritage education project requires, as Alberto shows, that the experimental sciences teacher handles some of the contents of other subjects involved in the knowledge of the sociocultural and natural fact to be studied (U33).

> Alberto: [...] is associated with mining and the beginnings of the industrial revolution and the industrial revolution that began in the country, as they could be associated with the history content that is taught in the same subject that is taught in the 4th year of Secondary Education. (U33)

4. Discussion

The aim of this study was to examine the specialised content knowledge and pedagogical content knowledge of an experimental sciences teacher in the design and implementation in Secondary Education of a field trip to study a heritage context consisting of a river and its natural and cultural environment.

First of all, the teacher presented knowledge about *Concepts, laws, principles, theories and examples*, with relevant concepts such as pH, pollution and ecosystems. In this sense, Van-Dijk and Kattmann (2007) and Park and Chen (2012) had already focused on the importance of teachers' in-depth knowledge of concepts in experimental sciences, not only because of the need for a good command of the content, but also to understand the limitations linked to their learning. This result is similar to that of the study by Poti et al. (2022) in which they state that the teacher analysed has "relatively good" content knowledge. In addition, Sofianidis and Kallery (2021), note that secondary school teachers have good knowledge of the content of their subjects.

On the other hand, there were several indications of the teacher's knowledge of *Representations and models* in experimental sciences, as they used the study of a river and a specific ecosystem as a starting point for their students to learn about rivers and ecosystems in general. This type of modelling could, according to Adúriz-Bravo and Izquierdo-Aymerich (2009), approach one of the different epistemological conceptualisations of the idea of model. Specifically, continuing with these authors, it would be a vision of a model in which an object is taken as an example in order to construct from it the theory that would represent it. Therefore, the use of modelling could help students learn about many phenomena from a specific way of looking at them, without falling into a teaching based on conceptual content items without any connection between them (Garrido & Couso, 2017).

Likewise, the teacher showed a knowledge of the various factors that have affected the river and its environment, both naturally and anthropogenically, emphasising the close relationship established between the biotope and the biocenosis of a specific ecosystem. In this way, considering that facts are data from observations that attribute meaning and validity (Valadares & Moreira, 2009) and the phenomena consist of the sequencing of these facts (Novak & Gowin, 2002), the teacher used knowledge classified within the *Facts and phenomena* category. Specifically, this knowledge is relevant in the design of an outing in the context of the proposal that was carried out, since according to Pujol (2003) an outing to nature to study an ecosystem helps students to observe the importance of other species for the maintenance of life, the relationship between the biotic and the abiotic and between the natural and the social, as well as the dynamic processes of change associated with all this, thus allowing them to understand the close relationship between human beings, other species and the non-living world.

Regarding the *Observation and experimentation procedures and techniques* category, the teacher demonstrated knowledge both of how to collect data on various parameters of a river at a given location, and of the sampling procedure itself. In this sense, the importance of this type of knowledge should be highlighted, since according to Pujol (2003) scientific technique is the set of all those more manipulative skills that are needed in scientific activity to achieve greater reliability in the observations, carry out certain actions and gather data in a more systematic way and, therefore, are sometimes necessary to approach knowledge of *Facts and phenomena* in experimental sciences. Also, continuing with this author, these techniques are "a necessary condition for cognitive development and, in general, learning to use them requires the development of cognitive and/or attitudinal aspects" (p. 141).

In relation to *Knowledge of the Structure of Science*, the teacher showed evidence of knowledge about structuring ideas from which to develop content from different disciplines of experimental sciences and to introduce elements from other knowledge areas, such as social sciences. In this framework, the notion of ecosystem acts as a structuring idea in whose characterisation elements of biology, physics and chemistry are interrelated, while at the same time it is connected with analysis of the interaction between human beings and the environment from the perspective of ecology (Llambí, 2012). Classroom work based on these structuring ideas, such as the ecosystem, fosters the construction of a conceptual scheme where the specific contents are more comprehensible and the relationships between them more significant, as these characteristics can act as bridges between the different disciplines both in the area and in relation to other knowledge areas, facilitating interdisciplinary work (Chaille & Davis, 2015; Garriga et al., 2012; Liguori & Noste, 2007).

With respect to *Knowledge of Practices in Science*, the teacher showed methods that could be linked to scientific practice, so it would be a knowledge linked to the construction of science itself. This contrasts with what was found in other research, where teachers were found to be lacking in knowledge about the nature of science, i.e. about scientific practices that allow us to trust the knowledge generated by them. This lack of knowledge limit teachers' teaching to facts, concepts and principles (García-Carmona et al., 2011).

Regarding *Knowledge of Science Teaching,* the teacher expressed an awareness of teaching theories, as he indicated methodologies such as project-based learning or the scientific method as part of the enquiry process. This contrasts with the results reported by Sofianidis and Kallery (2021), who state a low percentage of teachers who used enquiry as a teaching technique. Therefore, this knowledge placed it in an investigative methodological approach widely based on science teaching (Cañal et al., 2005; Couso, 2014; Domènech-Casal, 2018). However, this knowledge had presumably been acquired not only during his teacher training, but also through educational practice. In particular, the peculiar characteristics of the study of the Tinto River and its environment favoured his training in the design of interdisciplinary research projects. In this sense, Park (2005) already indicated that it was unlikely that teachers would first develop *Pedagogical Content Knowledge* and then apply it, pointing out that the development of this knowledge linked to change in educational practice occurs within the context of the action itself.

Moreover, his knowledge of *Strategies and activities in science* was revealed, as he pointed out relevant aspects linked to the design of a field trip in a changing natural environment (Álvarez-Piñeros et al., 2016; Braund & Reiss, 2006). At the same time, it was observed that his field notebook design is adapted to the characteristics of the field trip he intended to carry out and he selected appropriate instruments, the sensors, to sample data from the river during the field trip, although on this point he differs from the results of some studies that claim the scarce use of technological tools (Sofianidis & Kallery, 2021). Thus, the strategy chosen by the teacher influenced the resources, as already detected by Goes and Fernández (2023) in their study on *Pedagogical Content Knowledge* with chemistry teachers, thus enriching their knowledge about *Resources in Science*. In addition, with regard to resources, he also highlighted the importance of knowing a wide variety of resources to work on science content, which are also effective in supporting classroom content (Azam, 2020). In particular, he acknowledged that his training as a geologist had helped him in this regard, putting him in a more advantageous position compared to a teacher without such training. As for the teaching context or centre of interest, we agree with the study developed by Maseko and Khoza (2021), in which they highlight the knowledge that the teacher has about the application of the contents to be worked on in a context that the students feel as an everyday context. In the specific case of this study, the participating teacher uses a heritage element from the nearby or local environment —little explored in formal education (Gabardón, 2005)— for an interdisciplinary approach to the contents of Biology, Geology, Physics, Chemistry, Geography, History, technology and culture (De la Vega & Iranzo, 2021; Trabajo & Cuenca, 2020).

In relation to *Knowledge of Features of Learning*, evidence was obtained of three types of knowledge: knowledge linked to students' *Strengths and difficulties*, knowledge related to *Emotional aspects*, as well as *Ways of interacting with a content*. In other words, firstly, the teacher based his design on the students' knowledge of difficulties, to help them understand (Azam, 2020), for example, the concept of pollution or the geological origin of the river environment (Azam, 2020). This way, he was able to address these ideas and identify and deal with the erroneous content, as described by Buma et al. (2023) Secondly, he presented scientific arguments to arouse students' interest, which demonstrates knowledge that can be interesting or, on the contrary, boring (Marake et al., 2022) and, finally, it indicated the need to connect reality with the content being worked on. In this sense, Park (2005) states that learners' performances and their knowledge are a resource for the construction and reconstruction of *Pedagogical Content Knowledge.* Thus, continuing with this author, only when teachers know how students think and learn and understand their affective state regarding the learning of a content, can they carry out pedagogically appropriate procedures to promote learning, like the use of technology in inquiry-based learning strategies (Dereje, 2023).

Finally, with regard to *Knowledge of Science Learning Standards,* the teacher highlighted two types of knowledge. On the one hand, coinciding with the study of Marake et al. (2022), the teacher knew what content to teach at the 4th year of Secondary Education level with regard to experimental sciences subjects, i.e. Biology and Geology as well as Physics and Chemistry. On the other hand, he recognised the level of depth that can be achieved in a content. In particular, although acids and bases are not included in the curricular regulations at this level, he considered it important to define and work on pH. The two evidences pointed out above show an interesting balance in the design of a teaching proposal in experimental sciences: to place it within the current curriculum, relating it to what it prescribes (Shulman, 1986), and, at the same time, to provide opportunities for students to construct scientific knowledge with a certain depth and integration, even though working on elements not prescribed by the curriculum.

As for the *Orientations for teaching Science*, Alberto shows evidence of their influence on the design and implementation of the trip, in line with Maseko and Khoza's (2021) statement on the power they exert in *Pedagogical Content Knowledge*. In this line, the teacher acknowledges the need to introduce issues of culture and heritage close to the students as an element that generates processes of construction of personal and collective identity (Llull-Peñalba, 2010), as a resource that reflects the relationship between the territory and the community and as a vehicle to address emotions (Cuenca et al., 2021), as well as to integrate the contents of the experimental sciences. This category is closely related to the category of teaching context or centre of interest, since, as stated in the teacher interview, the implementation of projects based on heritage contexts to tackle content from different subject areas requires experimental sciences teachers to be aware of what is being worked on in other subjects in order to establish connections with their own subject area.

5. Conclusions and Implications

In this case study, linked to the knowledge of a teacher in the design and implementation of a field trip, the teacher's knowledge has shown to be situated in the two domains that make up the specialised knowledge model (experimental, social and mathematical) of science teachers: *Content Knowledge* and *Pedagogical Content Knowledge.*

With regard to the first specific objective of this study, concerning *Knowledge of Topics*, of the structure and practice of science, several pieces of evidence have been detected that show teacher knowledge in these three subdomains. The design and implementation of a field trip to a heritage context, as shown throughout this work, requires that teachers have an in-depth knowledge of the concepts and facts associated with the object of study. Thus, in his discourse, the teacher interviewed displays knowledge of scientific concepts, such as the definition and description of the notion of ecosystem and the parameters necessary to characterise it; concepts that are essential for the study of the physical and natural environment. Likewise, his knowledge of observation procedures and techniques in fieldwork, as well as of the scientific method as a practice of science, enable him to teach students the necessary steps to study this ecosystem.

Moreover, knowledge of the ideas that structure experimental sciences, as well as the interrelationships established between different disciplines in the study of an environment, is a key requirement for students to be able to understand the connections between nature, culture, society, heritage and territory and to analyse their reality as a whole that cannot be divided into knowledge areas.

With regard to the second objective of this research, related to *Pedagogical Content Knowledge*, it has been observed that teacher's design is based on his knowledge of *Teaching theories* linked to the didactics of experimental sciences, *Resources* for different purposes, *Strategies and Activities* for the teaching of scientific content, the use of interdisciplinary centres of interest, students' previous conceptions, students' strategies for dealing with science content and *Emotional aspects*, as well as knowledge of the curriculum and the level of depth to which they can aspire in scientific content. Thus, the modelling of the scientific method in science teaching is a methodological approach that guides the design and implementation of a field trip to a heritage context, in which students must collect data, interpret them, elaborate on the results obtained and transfer them to the public. To do this, the teacher uses resources such as the field notebook, pH sensors and social networks as a communication tool in the development of a research project.

In relation to the third objective of the work, referring to the ideas of experimental sciences that guide their teaching —*Orientations for teaching Science*— the teacher can be seen to use elements from other areas of knowledge, specially the social sciences, which allows the use of interdisciplinary centres of interest, such as the heritage of the immediate context, to ensure globalised and meaningful teaching for pupils.

The evidence observed seems to show an interrelation between the domains, subdomains and categories of the model, showing that content knowledge of experimental sciences determines pedagogical content knowledge and vice versa, and that orientations permeate both domains. Likewise, the knowledge that becomes evident as the outing takes place is not exclusively due to the initial training of the teacher, but is presumably enriched throughout his own practice, supported by adequate continuous training.

From the outcomes obtained, a series of implications or keys can be drawn which can guide the design of training tasks so that future Secondary Education teachers are able to design and implement field trips. First of all, starting from the content knowledge of experimental sciences that should be built up in initial training, it is considered relevant that future teachers should have an in-depth knowledge of scientific concepts and the theories that support them. Thus, in order to be able to study an ecosystem, teachers must have knowledge of the definition, description and characterisation of ecosystems and their constituent elements in general, and of the environment around which the specific educational project is being developed.

Similarly, the educational tasks designed and implemented for this purpose must make use of the natural, social and cultural environment of the future teachers. Science teachers must know how to apply scientific knowledge in order to respond to relevant socio-environmental problems in their immediate context.

Finally, the training tasks that revolve around field trips should be composed of interdisciplinary activities, promoting the construction of knowledge about the interconnections established between the environment, society and culture, for which heritage is an ideal resource. In this way, teachers in initial training would undergo learning experiences that can be replicated in Secondary Education classrooms, matching the initial training model with the didactic model, based on the principle of isomorphism (Estepa, 2019).

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Data availability: The data generated throughout this research will be stored in the scientific repository of the University of Huelva, Arias Montano (validated and deemed SUITABLE according to the RECOLECTA guidelines: https://guiasbuh.uhu.es/AriasMontano/rankings), and will be available for members of the scientific community who, upon receiving explicit permission, wish to verify the data or use the anonymised information in new studies adopting a different perspective from that of the present research.

Declaration of interest: Authors declare no competing interest.

Ethics declaration: This study was approved by the Ethics Committee for Experimentation at the University of Málaga (Approval Code 98-2023-H) on 30 January 2024. The participant teacher consented to be interviewed and audio-recorded and the study did not involve sensitive personal data.

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