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Research Article

What knowledge do science teachers need to teach the ecosystem concept using a river? Didactic implications to promote good practices in secondary school

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ABSTRACT

Teacher knowledge is vital to provide meaningful learning opportunities. In this case study, a secondary education teacher's knowledge about how to teach the concept of ecosystems from a river is explored. A category system drawn from the literature about science teacher knowledge was used for the analysis. Science teaching requires teachers to have content and pedagogical content knowledge. The identification of these knowledge elements and their relationships has allowed to draw didactic implications so as to improve science teacher training.

Keywords: knowledge, teacher education, ecosystem, secondary education

INTRODUCTION

A teacher's knowledge is vital for them to be able to offer their pupils meaningful learning opportunities (Nixon et al., 2019). Knowing what knowledge underpins good teacher practices will also help guide the content of future training programs.

In telling us about his model of teacher, Shulman (1986, 1987) indicates that, in addition to having knowledge about the subject to be taught, they must have what he calls pedagogical content knowledge (PCK) which he refers to as being the knowledge that allows teachers to make the subject knowledge understandable for their pupils.

PCK has been the object of numerous research studies about science teachers (Duran et al, 2021; Nixon et al., 2019; Park et al., 2018; Perona et al., 2017; Pontes et al., 2013; Sæleset & Friedrichsen, 2021). There stands out among the different models that have been proposed that of Park and Oliver (2008). It is based on previous PCK models for science teachers such as that of Magnusson et al. (1999).

Park and Oliver (2008) differentiate five components in science teachers' PCK:

(1) knowledge of the pupils' understanding of science, in which the pupils' knowledge of alternative conceptions plays an important role (Fernández & Sanjosé, 2007),

(2) knowledge of instructional strategies for teaching science, which includes knowledge of strategies, activities and representations in relation to teaching some particular content, as well as general strategies for teaching science,

(3) *knowledge of the science curriculum*,

(4) knowledge of the assessment of science learning, and

(5) orientations towards teaching science, linked to the purposes and objectives established by the teacher in a specific grade (Kutluca & Mercan, 2022; Maseko & Khoza, 2021; Reynolds & Park, 2021).

This study focuses on four of the five components of the Park and Oliver (2008) model: knowledge of the pupils' understanding, knowledge of instructional strategies, knowledge of the curriculum and orientations towards teaching, all referred to the teaching of science as it does not focus on specific issues regarding assessment.

However, the science teacher's content knowledge, despite being considered the basis of that teacher's specific knowledge (Ayala-Villamil & Fúquene, 2022; Mavhunga & Ndlovu, 2023), has been the subject of less attention in studies about science teachers' knowledge (Rollnick & Mavhunga, 2016). In order to detail the components, the dimensions differentiated by Luís (2021) in relation to the teacher teaching topics of biology were taken as a basis. Thus, we shall consider knowledge about scientific topics (including knowledge about procedures and techniques of observation and experimentation; *concepts, laws, principles, theories and examples*; *models*; and *facts and phenomena*, all related to science). We shall also consider the teachers' knowledge about big ideas in science (Chaves Mejia, 2024; Eff-Darwich et al., 2023) or ideas that link different classes of knowledge, often crossing different cores of content (Charles, 2005), and finally their syntactic knowledge (Schwab, 1978) related to how to do science.

The practice analyzed has as center of interest the River Tinto, as a model of an ecosystem. The teaching about the natural environment, due to its variety and complexity, poses a challenge to teachers to define models that allow the pupils to connect and organize the knowledge they are learning (Garriga et al., 2012), and even poses the challenge of having pupils build these models themselves (Cañal, 2004; Solé et al., 2024). In the same way that in science several key ideas are proposed which facilitate the understanding of other knowledge (Galfrascoli, 2017), the study of the environment as a system allows understanding the relationships and interactions that take place within it, thus serving as a structural idea for the understanding of other natural systems (Hecht & Crowley, 2019; Wamba & Jiménez, 2003). In the present case, the study of the river and its environment serves as a model for studying other rivers and conceptualizing the ecosystem content. At the same time, the use of models in the teaching facilitates the pupils' understanding of how science works since it shares characteristics with scientific research (Windschitl et al., 2008).

Complex natural systems, such as rivers, should be studied in compulsory education science classrooms (Martínez Peña & Gil Quílez, 2014), thus allowing the pupils to understand, explain and predict the complexity of interactions within this environment and the socio-scientific issue in which is involved, and to position themselves in terms of its conservation (Ke et al., 2021).

In this study, teachers' knowledge regarding the teaching of rivers is explored: What knowledge does a secondary education science teacher need to teach about the ecosystem concept based on the study of a river? Thus, to define this question, the objective of this study is to determine the knowledge that a secondary education science teacher mobilizes when they want to teach the ecosystem concept based on the study of a river, to serve as a basis to promote good practices in the training of secondary education science teachers.

METHOD

Participants and Context

A case study was carried out. David (pseudonym), the selected teacher, is a graduate in geology, with a master's degree in secondary education teacher training, a university professor and has a PhD in experimental science teaching. He has 3 years of experience as a university professor. He was considered to be of especial

Figure 1. Educational intervention scheme (Source: Authors)

interest due to his disciplinary and didactic training, as well as the richness of the didactic intervention he had developed.

The teacher planned and developed an educational intervention that consisted of an interdisciplinary inquiry sequence, with the River Tinto as the center of interest. This sequence addressed different aspects of the river as the backbone of the natural and social environment where it is located. The intervention was carried out in a secondary education school in the province of Huelva (Spain). The participants were 18 female and 11 male pupils from the fourth year of ESO (16 years old) in the 2022-2023 school year.

Data Collection

Interview

This is a semi-structured interview, which was audio-recorded, with questions about his training and experience and about the educational intervention implemented. The interview question script was agreed upon by the team and subjected to review by experts. All the suggestions were considered.

Actions of the educational intervention

The intervention analyzed consists of an investigative sequence that follows the indications of the current secondary education regulations to develop inquiry-based learning situations (Strat et al., 2023), in line with the proposal by Cañal et al. (2005). The intervention has an interdisciplinary approach with the River Tinto and its environment as center of interest. The sequence revolves around the question "Conserve or restore the environment of the River Tinto?", which is addressed by solving four subproblems, following the phases of motivation and activation, exploration, structuring, application and conclusion-communication (Lorca-Marín, 2025).

Figure 1 shows a diagram that summarizes the actions carried out by the teacher during the classroom intervention about the River Tinto, organized according to the aforementioned phases. It was prepared based on the programming designed by the teacher.

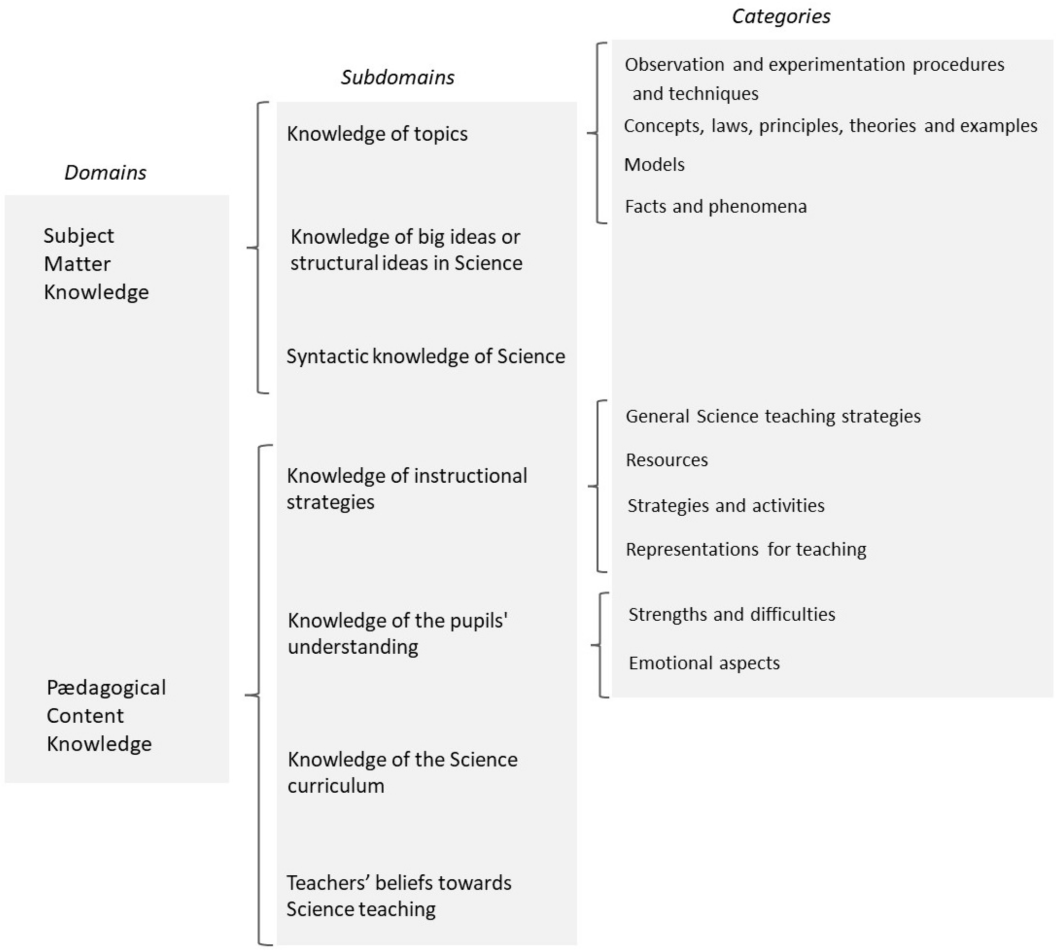

Figure 2. Analysis instrument (Source: Authors)

Data Analysis

In order to extract the knowledge that the teacher possesses, both instruments described were analyzed.

To analyze the content of the interview, first, a literal and linear transcription was made. Next, it was divided into information units (U), that is, fragments with semantic unity. Regarding the intervention, the actions carried out by the teacher in the different phases of the intervention were extracted.

The system of categories used in the analysis (**Figure 2**) is taken from a review of the literature about science teachers' knowledge (Luís, 2021; Park & Oliver, 2008). 2 domains are differentiated: content knowledge and PCK. Within the first domain, as explained in the introduction, the focus will be on: Knowledge of topics, *knowledge of big ideas or structuring ideas in science* and syntactic knowledge of the discipline. On the other hand, within the PCK domain the following subdomains are differentiated: Knowledge of instructional strategies, knowledge of pupils understanding and *knowledge of the science curriculum*. Finally, the teachers' orientations towards the teaching of science are included. The subdomain categories were also taken from the literature review, with the exception of combining specific *strategies and activities* for teaching content in the same category and incorporating resource knowledge in the same subdomain of knowledge about instructional strategies. Both modifications arose from the data analysis. Likewise, given the importance of emotions in science learning, in the subdomain of knowledge of the pupils understanding, a category about the teacher's knowledge of the pupils emotions towards content is included.

Associations were established between the information units and the teaching actions, respectively, for the interview and for the sequence and subdomains of the analysis instrument, developing emerging indicators of the analysis associated with the information units. This analysis was first carried out individually by each author and was subsequently discussed until they reached a degree of consensus of over 90%.

Table 1. Indicators of the category *observation and experimentation procedures and techniques* and some associated information units

Indicator		Information unit
Knowledge about procedures and techniques to measure different physical-chemical aspects of a river to determine its water quality	Measurement sensors	*If we want to work on physical-chemical aspects, obviously we first have to say which physical-chemical aspect we want to work on [...] We have to know what sensors we have available to be able to measure it (U1).*
	Flow measurement	*[...] but for the topic of flow it seemed to me a super didactic way of working as a team, of using instruments, of taking data, of doing mathematical calculations, of measuring areas, sections [...] I know that there are different ways of measuring flows. And when I saw the float method, I saw it clearly and I wanted them to take it [...] (U2).*

Table 2. Indicators of the category *concepts, laws, principles, theories and examples* and some associated information unit

Indicator		Information unit
Knowledge of scientific concepts related to rivers	Main parts of a river	*[...] so that they could understand with the instruments that they had built and with the samples that they had already taken in situ, to be able to make a model of that source of the river (U3).*
		To understand the river and how it works and why the river hardly varies and remains constant until its mouth (U4).
	pH concept	*[...] being able to make a model of that source of the river, mixing the waters, measure them and understand by adding more or less from one place to another how the pH level is modified and realizing that it was not a linear scale, but a logarithmic scale (U5).*
	Water pollution	*[...] characterize what pollution is, if it is natural, if there is anthropogenic pollution ... (U6).*

RESULTS

The analysis of the interview and the actions developed in the sequence provides the following results, which are organized according to the knowledge that the teacher manifests when teaching about the River Tinto and its environment, both those linked to the subject matter knowledge domain and the PCK domain.

Subject Matter Knowledge

Knowledge of topics

In the interview, we find evidence that David has knowledge about procedures and techniques to measure different physical-chemical aspects of a river that would help to determine the water quality. Specifically, he knows which sensors to use (U1) and can decide which one is the most appropriate (flow example: U2). All of this constitutes knowledge related to the category *observation and experimentation procedures and techniques* (**Table 1**).

On the other hand, David knows scientific concepts related to rivers, such as the main parts of a river, i.e., the source and the mouth (U3 and U4), as well as pH and its measurement (U5) or water pollution (U6) (all knowledge related to *concepts, laws, principles, theories and examples*) (**Table 2**).

Likewise, during the teaching sequence he again shows knowledge about the procedure to take data from the river of the pH, turbidity, temperature and total and dissolved solids, urging the pupils to take data at three different points, both in the river and in two of its tributaries. This activity was developed during the field trip carried out by the pupils (**Figure 1**).

David takes the River Tinto as a model to study the physical-chemical parameters and biotic elements of any river as an ecosystem, thus showing some knowledge about *models* (U7) (**Table 3**).

Also, in the teaching sequence, the comparison of the River Tinto with other rivers in the province such as the River Odiel is proposed, studying the same parameters to characterize each river. Likewise, on the field trip, the pupils take data on both the biocenosis and the biotope in their field book (**Figure 1**). Both aspects are the constituent elements of any river ecosystem.

Table 3. Indicators of the *models* category and some associated information units

Indicator	Information unit
Knowledge of models	*We are going to try to characterize an ecosystem by studying ecosystems. We are going to try to characterize the physicochemical characteristics to know how to characterize any river in the world (U7).*

Table 4. Indicators of the category *facts and phenomena* and some associated information units

Indicator	Information unit
Knowledge about the factors that characterize rivers and their environment	*First we have to say what physical-chemical aspect we want to work on [...] to characterize the water quality of a river or the type of aquatic ecosystems that a river can have (U8).*
	Here we are going to work on ecological and biological aspects [...] (U9).
Knowledge of the influence of the geology of the area on the characteristics of the river, such as pH and turbidity	*[...] that they knew that there is a scale of ... that at lower values, the pH is more acidic and that this conditions the life of the ecosystem (U10).*
	Turbidity if the light passes through, that the light is also a limiting factor for the development of life and the dissolved solids depending on the mineral salts, metals that may have been dissolved (U11).
Knowledge about the use of the river by humans throughout history to understand the consequences on the ecosystem	*[...] the mining of the area that has influenced the river (U12).*

Table 5. Indicators of the category *knowledge of big ideas or structuring ideas in science* and some associated information units

Indicator	Information unit
Knowledge of interrelations between contents within the sciences, both experimental, such as physics, chemistry and biology, and social sciences	*[...] in the end it could be seen that everything was interconnected, that [...] the physicochemical aspects conditioned the ecosystem, and the ecosystem conditioned the type of life and type of fishing and type of cultures [...] and that have characterized the province, have characterized its economy, characterized everything (U13).*
Identification of key ideas that allow different contents to be related	*There are a series of values [...] to know the quality of the waters and to know [...] what type of ecosystem can exist. And there are some values that [...] are always the subject of turbidity, pH, temperature, dissolved solids, conductivity, oxygen, [...] they are the values that are usually used to characterize any river (U14).*

Finally, within this subdomain, clues and evidence can be observed in relation to the category *facts and phenomena*, since David shows some knowledge about the factors that characterize rivers and their environment (U8 and U9), the influence of the geology of the area on the characteristics of the river, such as pH (U10) or turbidity (U11); as well as the use of the river by humans throughout history to understand their consequences on the ecosystem (U12) (**Table 4**).

Knowledge of big ideas or structural ideas in science

It was noted that David shows some knowledge about the interrelations between contents within the sciences, both experimental, such as physics, chemistry and biology, as well as social sciences (U13). In **Figure 1**, during the development of the sequence, David organizes a structured debate in which the pupils argue using in an integrated way the knowledge they have acquired in the different subjects.

In addition, he identifies the idea of ecosystem as a key idea that allows us to relate different content and different environments with the same concept (U14). In this way, the River Tinto is for David a particular example of a river and this, in turn, of an ecosystem (**Table 5**).

Syntactic knowledge of science

Finally, regarding his content knowledge, David shows that he knows the ways in which, within science, knowledge is created and validated both in the interview (U15) and in the teaching sequence where he presents the pupils with characteristic actions such as posing problems, data collection, building models and preparing reports (**Figure 1**), with a parallelism to the way a scientist proceeds (U16) (**Table 6**).

Table 6. Indicators of the category *syntactic knowledge of science* and some associated information units

Indicator	Information unit
Knowledge of the ways in which, within science, knowledge is created and validated	*[...] the fact of carrying out methodological strategies of inquiry, modeling, rational thinking, [...] that are intrinsic to scientific practice itself (U15).* *So we are putting into practice the first block of the scientific method. We are carrying it out with all aspects and of how data is taken (U16).*

Table 7. Indicators of the category *general science teaching strategies* and some associated information units

Indicator	Information unit
Knowledge of the strategy starting from the pupils questions	*I tried to get the research questions to come from them [...] And the kids started to tell me different things they wanted to see (why was it red, if it was contaminated, that we don't know if we put our hands in it, whether it can hurt us) (U17).*
Knowledge of different methods	*[...] I have had to learn that there are different methods related to experimental sciences, beyond applying the scientific method to inquiry processes, modeling, project-based learning (U18).*

Table 8. Indicators of the category *resources* and some associated information units

Indicator		Information unit
Knowledge of various resources to address the teaching about the river	To collect information in the environment: guides, bibliography, researchers, field book ...	*[The field book] was conceived as a research notebook in which they had to fill in certain data [...] [...] I like that they are really researching and characterizing a river, [I wanted] [...] to give them material that really made them feel [...] like researchers (U19).* *I think that what has been most useful to me as a geologist is that [...] I know which books have specifically been about the River Tinto, [...] the main researchers (U20).* *The Bellavista Museum itself already has a guide (U21).*
	To represent and interpret information: mockup, graphics ...	*I knew where to find all the resources which then I could then put into practice in maps, columns with geological profiles ... (U22).* *A mockup was made [...] For them to be able to [...] make a model of that source of the river, mix the waters, measure them and understand, by adding more or less from one place to another, how the pH level was changing and realizing that it was not a linear scale, but a logarithmic scale (U23).*
	To design their own resources for the pupils to collect data about the river	*[...] they designed so that the sensor could measure the temperature [...], they liked it, seeing that it worked, that it was real, that it was providing data ... (U24).*
	To build and communicate knowledge about the river	*We were going to use digital instruments. [...] they themselves were taking photographs [...] that I tagged with the hashtags and [...] it was a repository of information that they themselves had collected with the idea that then they can put it on [...] their websites (U25).*

Pedagogical Content Knowledge

Knowledge of instructional strategies

Within this subdomain, various units of information have been detected in which evidence and indications of the four categories that compose it can be observed.

Specifically, in the information units U17 and U18, indications of the category *general science teaching strategies* when approaching teaching about a river can be observed, such as starting from the pupils' questions (**Table 7**). It is also seen in the phased itinerary that David proposes in his sequence based on school research (**Figure 1**).

On the other hand, it was noted that the teacher knows various resources to approach the teaching about rivers. Thus, to collect data in the environment: the field trip with the use of a field book or other bibliographic or personal sources, such as guides who participated in the field trip (U19, U20, and U21); to represent and interpret data (with graphic records U22 or a model of the river, U23); resources so that the pupils could design and collect data about the river (U24) and build and communicate knowledge about the river (U25) (**Table 8**).

Finally, there are signs of the categories of *strategies and activities*. In this sense, David takes into account the field trip to the river as an activity and its planning, through the delimitation of the area to be explored

Table 9. Indicators of the category *strategies and activities* and some associated information units

Indicator		Information unit
Knowledge about the field trip as an activity to teach about the river	Planning the field trip, through the delimitation of the area to explore	*You have to plan a lot about which areas and [...] what things they are going to find [and] that maybe they can't find, because there were also certain aspects that they couldn't see or photograph (U26).*
	Preparatory activities with the pupils for the field trip	*I think there was a bit of contextualization, because [...] we didn't just want them to design instruments, we wanted them to design their own instrument. We have to know what sensors we have available to be able to measure it. [...] I [...] raised in class what parameters or physicochemical aspects we need to characterize a river. And it was the pupils who looked for the parameters in class (U27).*
		So they already had a context, it is not just about going there and measuring, but they know that they do it because they want to define the River Tinto and know if it is drinkable ... (U28).
	Activities that guide the pupil's work: field books	*[...] they had to write down, depending on [in] which areas they were, [...] answering questions that they did not know at what exact moment they would be able to give the answer. [...] We knew that we were going first to the head of the river, that is why the data collection was at the beginning. We knew that we were then going to... It made sense in that aspect (U29).*
Center of interest		*The river is starting point of learning situation to mobilize a lot of content (U30).*

Table 10. Indicators of the category *strengths and difficulties* and some associated information units

Indicator		Information unit
Knowledge about his pupils' prior conceptions and the difficulties they have when faced with scientific content	About river pollution (unexpected)	*But when after the initial tests, [...] before starting to carry out the project, I realized that they already knew a lot, they knew concepts about pollution, they even talked about a contaminated river (U31).*
	About the difficulty of the pH concept	*But we considered that it was important to define the pH because there were many doubts... the issue of mixing water. [...] Then we saw that there were conceptions that... and problems with the pH (U32).*
	About strengths of the knowledge shown by the pupils on the concept of flow	*Regarding physicochemical parameters, there was no problem with the flow (U33).*

(U26) and the development of preparatory activities with the pupils, which included both the selection of the physical-chemical parameters necessary to characterize the river, the design and construction of the sensors to be able to measure them (U27) and, therefore, the need to visit the natural environment to take real data (U28). In addition, within the sequence, for the field trip, David prepared a field book, structured according to the different aspects to be observed and moments of the trip, with guidelines that aided the pupils' work (U29).

David uses the study of the River Tinto as a focus of interest through which to address, in an interdisciplinary way, biological, geological, physical-chemical, and even social content of the environment in which it is located. (U30) (**Table 9**).

Finally, no clues were obtained from the category *representations for teaching* in the interview.

Knowledge of the pupils' understanding

We found evidence of the category *strengths and difficulties*, as the teacher shows knowledge about his pupils' prior conceptions and the difficulties they have when faced with scientific content. Specifically, he refers to the unexpected knowledge that his pupils have regarding river pollution (U31), the difficulty of the pH concept (U32), as well as strengths of the knowledge shown by the pupils regarding the concept of flow (U33) (**Table 10**).

In addition, evidence of the category *emotional aspects* can be observed, since David argues scientific content linked to the river or its environment that he uses to awaken the interest of his pupils (U34). Likewise, he is aware of the emotions that certain activities generate in the pupils (U35, U36) (**Table 11**).

Table 11. Indicators of the category *emotional aspects* and some associated information units

Indicator	Information unit
Knowledge of the convenience of using certain scientific content linked to the river or its environment to awaken his pupils' interest	*I think that it does reveal a lot of characteristics that can attract [the attention] of the pupils […]. It is no longer just a red river, [it is] there are many things behind it (U34).*
Awareness of the emotions that certain activities generate in the pupils	*[referring to the field book] I set missions that they loved being able to complete different activities that were asked of them […]. That is like […] an incentive not to stand still. They know that they have to do things (U35).*
	They were using the programs, the algorithms that they had designed were already installed and I installed them, I gave them the devices and they liked […] that it was real, that it was providing data (U36).

Table 12. Indicators of the category *knowledge of the science curriculum* and some associated information units

Indicator		Information unit
Knowledge about expected learning outcomes in relation to the standards	He knows that ecosystems and the scientific method are content in subjects such as biology in 4th ESO curriculum	*The ecosystem was one of the things that had to be taught in biology and geology (U37).*
		It is not simply that they define what flow is or what pH is, or what temperature is […] it is that we wanted them to design […] their own research […] that they knew how to take data, then how to do calculations, knew how to do conversion factors if there were significant figures. That they knew how to graph, interpret the graph, interpret data. That is scientific knowledge that is in block 1 of all ESO levels (U38).
		The topic of pH […] is really something that is not developed. Acidity is defined […] at 4th ESO level, but there is no mention about base acids […] But we considered it important […] to define pH because there were many doubts (U39).

Table 13. Indicators of the category *teachers' beliefs towards science teaching* and some associated information units

Indicator	Information unit
Teaching science, also to develop identity with the heritage	*It was an ideal place to find out what that identity feeling was that they might have with the river, with everything that happened at the beginning of the industrial revolution in the area (U40).*
How science is learned: through inquiry, exploration by the pupils, given the need to study a phenomenon	*[in relation to the field book] I like that they are really researching and characterizing a river. […] I wanted […] to give them material that really made them feel […] like researchers. So I proposed something that was […] cool, fun, that would be a challenge for them and that they would feel that there are many things [to which] they have to give an explanation (U41).*
Importance of teaching science using situations close to the pupils, contextualizing the activities so that they have a meaning for the pupils	*Almost everyone in Valverde [the town where the school is located] not only knows the River Tinto because it is in the province, but they can also know that in the end the whole mining issue is associated with it and how mining also influenced the town of Valverde (U42).*

Knowledge of the science curriculum

There is evidence that David knows that ecosystems (U37) and scientific method (U38) are content in subjects such as biology in 4th ESO, but that pH is not (U39) (**Table 12**).

Teachers' beliefs towards science teaching

For David, teaching science also has the purpose of developing identity with heritage (U40), and science should be taught through inquiry (U41) and from situations close to the pupils (U42) (**Table 13**).

DISCUSION AND CONCLUSIONS

The results obtained from the analysis of the interview and the teacher's didactic actions have allowed to observe how the preparation of the sequence was based on his vision of the River Tinto as a model of a river, as well as on his knowledge of its particular characteristics.

Implication 1. Teachers' Knowledge of Teaching Through Modeling and Inquiry Promotes Their Teaching to Foster Holistic and Meaningful Learning

The teacher's vision of science is strongly linked to his knowledge of theories about its teaching, where inquiry and modeling have a central position as reflections of the scientific method.

The teacher shows the necessary knowledge to put into practice an inquiry sequence that meets the characteristics set out by Couso (2014), where the sequence revolves around a practical, research-based teaching-learning scenario, where the pupils observe, experiment, ask questions and obtain their own data with the design and use of measurement sensors that they use in the environment, specifically in the river. There are also actions where available data is used, such as bibliography or information provided by the guides.

The teacher gives a lot of importance to the attitude and motivation of the pupils, giving them a very active and leading role, for example, in the programming of the sensors to measure the river parameters. They were asked to work in groups and given a lot of autonomy and decision-making capacity. The teacher is a facilitator or guide of the pupils' inquiry. At the beginning of the sequence, they propose the research questions they want to solve, collect data, analyze information and communicate results.

The sequence planned by the teacher is organized into phases, following a certain cycle that emulates real scientific research, so that the pupils acquire a broader learning than a merely conceptual one (Caamaño, 2012). Therefore, it is important that teachers do not limit their knowledge to concepts, laws, principles and theories, but must know the procedures and techniques of observation and experimentation in order to be able to teach them, for example, those used by the teacher to measure different physical-chemical aspects of a river to determine the quality of its water. In addition, as occurs in scientific procedures, cooperative work facilitates the acquisition of knowledge (Yaşar et al., 2024).

Implication 2. Working From Structuring Ideas Facilitates an Interdisciplinary Teaching and the Pupils' Understanding of Complexity

The river is also related to a structuring idea in science: that of ecosystems. This abstract concept implies the understanding of complex interactions and events in different spatial and temporal dimensions. Thus, through their learning, the pupils can acquire a complex vision of the environment and the connections that exist within it (Del Carmen, 2010) as well as understand the harm of making changes to any global ecosystem.

Working in the classroom with structuring models/ideas encourages work to be done in an interdisciplinary way to respond to the problem, even though it is the work in science which guides the sequence of activities (Garriga et al., 2012). Structuring concepts, such as that of the ecosystem in this study, allow for the construction of a conceptual scheme in which specific items of content are more understandable and the relationships between them are more significant because these characteristics can act as bridges between the different disciplines in the area, thus facilitating their integration (Galfrascoli, 2017).

Implication 3. It Is Necessary for Teachers to Value and Include Direct Exploration of Nearby Environments in Their Teaching Interventions

The sequence includes a field trip that the teacher planned and worked on with the pupils, before and after. Direct exploration of the environment is an enriching activity since, as Del Carmen (2010) points out, it is very important that pupils can carry out the exploration as part of their educational activities. This activity will help in the adequate conceptualization of any natural phenomenon, since something which is unknown cannot be interpreted from a theoretical point of view.

Likewise, the teacher selected a river close to the pupils and focused on just a few aspects so that the pupil could spend time exploring, observing and collecting data in their field book. This interaction with the environment helps the pupils understand it and thus be able to value it (Castro Moreno, 2005). To this end, the teacher must carry out a prior task of documentation, planning which areas in the environment can be studied and what to find in them.

In his teaching sequence, the teacher generated in the pupils the need to go to the environment to measure, and to test their hypotheses. In this way we see how educational activities that use the environment promote the learning of skills and the understanding of the usefulness of certain scientific procedures, which are not acquired so easily in traditional teaching contexts in the classroom (García & Furman, 2014).

Implication 4. The Mastery and Use of Varied Resources in the Classroom Enriches the Educational Intervention and Favors the Pupils' Motivation and Attention to Diversity

The teacher shows mastery of different resources for the study of a river as an ecosystem. Treagust and Harrison (2000) indicated the convenience of using varied resources to facilitate the pupils' development of dynamic mental models. Furthermore, if the resources respond to the variability of the pupils, it will be easier for them to achieve the learning objectives (Alba Pastor, 2018).

To make the class more dynamic and attractive there are a variety of resources that teachers can use which contribute to the pupils' learning and motivation. It is the teacher who must adjust the use of these resources, from the simplest to the most complex, to the circumstances and demands of the classroom. This can be achieved, for example, by using a digital resource to identify different elements of an ecosystem (Robinson & Ash, 2014).

Implication 5. Teachers Must Know the Curricular Content and the Pupils' Possible Difficulties as a Starting Point for the Design of the Sequence

The teacher expected certain learning difficulties regarding the study of physical-chemical parameters. The study of prior ideas or misconceptions is a widely researched topic due to its importance in science teaching and learning (Campanario & Otero, 2000). These preconceptions or schemes are not seen as errors or as something negative but as cognitive structures that interact with the information coming from outside and play an essential role in learning. Thus, the teacher's objective would be to design strategies to change conceptual schemes and bring them closer to the desired knowledge.

His intervention is also justified by his knowledge of the curricular contents of the course he is teaching, and also in some orientations for teaching science, such as the importance of teaching using situations close to the pupils to develop an identity with their heritage (Morón-Monge & Morón-Monge, 2017). However, studies in the area of mathematics have found that the linear relationship between teaching orientations and teaching practice is not very clear (Guler & Celik, 2023).

These results show the interweaving of content knowledge and PCK necessary when working on a river as an ecosystem. Both content knowledge and PCK associated with teaching planning, the use of a variety of resources and the implementation of active methods such as inquiry and modeling can be considered good teaching practices in secondary education, just as they have been defined for the university setting (González-Castellano et al., 2023).

The identification of these elements of knowledge and their relationships can serve as a reference for designing training proposals for science teachers.

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