INFLUENCE OF EPISTEMIC KNOWLEDGE IN THE DEVELOPMENT OF SCIENTIFIC PRACTICES: THE EPIS-PRACT PROJECT

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Abstract

EPIS-PRACT is a three-year project funded by FEDER and the Spanish Ministry of Science, Innovation and Universities. It seeks to analyse the influence of epistemic knowledge in the development of scientific practices (inquiry, modelling and argumentation). The main hypothesis that guides this project is that the epistemic knowledge involved in the development of scientific practices is necessary to meaningfully engage in the practices because it is required, for instance, to understand how scientific claims are supported by data and reasoning in Science (argumentation), the use and role of physical, system and abstract models and their limits (modelling) or how measurement error affects the degree of confidence in a scientific research (inquiry). The project comprises a set of studies framed in different types of design and different orientations: theoretical and practical. In this communication we address part of the theoretical perspective, identifying the aspects of epistemic knowledge that are examined in Science Education empirical research and the epistemic criteria considered in the development of scientific practices.

Keywords: epistemic knowledge, scientific practices, research project.

1 INTRODUCTION

EPIS-PRACT project is framed in the approach of learning Science through students’ engagement in scientific practices, understood as the practices used to establish, extend and refine knowledge. This approach is in line with promoting a Science education coherent with the way in which scientific knowledge is developed. This approach does not mean that students have to carry out all the processes that scientists do, but to understand the key aspects of the scientific reasoning. In general, learning through the engagement in scientific practices means doing the work of building knowledge in science and understanding why we build, test, evaluate and refine knowledge as we do. The main hypothesis of this project is that the epistemic knowledge involved in the development of scientific practices is a key element for engaging in them.

Epistemic knowledge makes part of epistemic cognition, understood as an array of understanding, practices, and motivations related to topics such as what counts as knowledge and how knowledge claims are justified. Epistemic knowledge has been studied in the last decades because it is related to the students’ approaches to learning Science, as well as to their performances of scientific reasoning. In Science Education, it is particularly relevant due to its incorporation to the PISA survey 2015 framework as type of knowledge to be assessed. In this framework, epistemic knowledge is defined as “the understanding of the rationale for the common practices of scientific inquiry, the status of the knowledge claims that are generated, and the meaning of foundational terms, such as theory, hypothesis and data”. According to this framework, this type of knowledge involves an understanding of the function that questions, observations, theories, hypotheses, models and arguments play in science; a recognition of the variety of forms of scientific inquiry; and the role peer review plays in establishing knowledge that can be trusted. Although the importance of epistemic knowledge of science is recognized by science educators, few studies to date have discussed how to assess students’ understanding of the epistemic knowledge of science. The EPIS-PRACT project seeks to analyse the influence of epistemic knowledge in the development of scientific practices (inquiry, modelling and argumentation). The general purpose is subdivided into three specific goals: 1) to characterise the aspects of Epistemology and Nature of Science involved in the development of the inquiry, modelling and argumentation practices in the classroom; 2) to examine the influence of epistemic knowledge in students’ performances in inquiry, modelling and argumentation practices; and 3) to analyse the influence of epistemic knowledge in the teaching strategies utilised to promote students’ engagement in scientific practices.

This communication focuses on the first research goal of the project, and in particular, the research questions that guide the investigation are:
1 Which aspects of epistemic knowledge are examined in Science Education empirical research?
2 Which epistemic aspects are considered in the development of scientific practices?

2 METHODOLOGY
To answer the research questions, a systematic review of empirical literature in the area of Science Education was carried out. First, we conducted a search in relevant databases for Science Education, which was in ERIC, Web of Knowledge and SCOPUS. The keywords used for the search were “epistemic”, “epistemology”, “science”, “modelling”, “inquiry” and “argumentation”.

The initial search produced 575 documents. After that we applied inclusion and exclusion criteria. The inclusion ones were empirical papers in the context of Science education, papers published in peer-reviewed journals, indexed in SSI (Thomson Reuters) or Scopus and written in English. The exclusion criterion was reviews or theoretical proposals illustrated with empirical examples from previous work.

After applying the inclusion and exclusion criteria, the final sample for the analysis of the first research question was 50 papers. Regarding the second research question, the sample was refined by applying another inclusion criterion: to examine only those papers that focus on epistemic aspects when participants engage in the argumentation, modelling and/or inquiry practices. The final sample for this second analysis was 19 papers.

3 RESULTS
The results corresponding to each research question are addressed separately.

3.1 Epistemic aspects addressed in Science Education Research
The review corresponding to the epistemic aspects addressed in Science Education research is summarized in table 1.

<table>
<thead>
<tr>
<th>Epistemic aspect</th>
<th>Description</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epistemic beliefs and or views</td>
<td>Individual's viewpoints about the nature of knowledge and the process of knowing [11]</td>
<td>21</td>
</tr>
<tr>
<td>Epistemic reasoning and/or understanding</td>
<td>An understanding of what knowledge and knowing are [12]</td>
<td>10</td>
</tr>
<tr>
<td>Epistemic practices</td>
<td>The specific ways members of a community propose, justify, evaluate, and legitimize knowledge claims within a disciplinary framework [13]</td>
<td>9</td>
</tr>
<tr>
<td>Epistemic criteria</td>
<td>The standards scientists use to evaluate the validity and accuracy of scientific products such as models, arguments, and evidence [14]</td>
<td>6</td>
</tr>
<tr>
<td>Epistemic values</td>
<td>The “source of rules determining what constitutes acceptable scientific practice or scientific method” [15]</td>
<td>2</td>
</tr>
<tr>
<td>Epistemic learning</td>
<td>Student understanding of the nature of science [16]</td>
<td>1</td>
</tr>
<tr>
<td>Epistemic discourse</td>
<td>Questions heading for new insights and further elaboration of the previous knowledge [17]</td>
<td>1</td>
</tr>
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As summarized in table 1, seven epistemic aspects were identified in the literature: epistemic beliefs or views, epistemic reasoning and or understanding, epistemic practices, epistemic criteria, epistemic discourse and epistemic values. The most frequent aspect is epistemic beliefs, representing the 40% of the sample (21 out of 50 papers). Other aspects such as epistemic reasoning and epistemic practices represent the 20% of the sample (10 and 9 out of 50 papers respectively) whereas the epistemic criteria, epistemic learning, epistemic discourse and epistemic values are the less frequent (being 6, 2, and 1 out of 50 papers respectively). It needs to be noted that the aspects “epistemic practices”, “epistemic criteria” and “epistemic reasoning” are more aligned to the perspective of the EPIS-PRACt project than the others, since we pretend to examine the epistemic aspects in practice not the epistemic ideas isolated from the practice. Despite some studies about epistemic beliefs
consider students’ practical performances, most of them focus on their epistemic ideas before and after the practice.

### 3.2 Epistemic aspects considered in the development of scientific practices

For the analysis of the second research question, the sample of 51 papers was refined in order to examine only those papers that address epistemic aspects in the engagement of scientific practices. The results of this second part of the review are summarized in table 2.

<table>
<thead>
<tr>
<th>Practice</th>
<th>Epistemic aspect</th>
<th>Description</th>
</tr>
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</table>
| Inquiry  | Epistemic beliefs | Certainty of knowledge, simplicity of knowledge, source of knowledge and justification for knowing \([18]\)  
The role of predictions, subjectivity and creativity in science \([19]\)  |
|          | Epistemic understanding | Uncertainty in investigations \([20, 21]\)  
Role of idea, theory building and revision, theory-fact understanding and social processes of scientific progress \([22]\)  |
|          | Epistemic practice | The construction and evaluation of scientific explanations: causal coherence of their claims, their fit with available data, and with overarching disciplinary theories \([23]\)  
Coordination among data, theories and experiments \([24]\)  |
| Modelling| Epistemic beliefs | Epistemology of models in a context-based unit: 1) purpose and/or function of the model; 2) empirical versus mechanistic modelling approach, 3) modelling procedure; and 4) model features goodness of fit, reliability, and validity as criteria for evaluation \([25]\)  |
|          | Epistemic understanding | Students’ epistemological understanding about 1) Nature of models, (2 Purposes of models; 3) Design and revision of models; and Evaluation of models \([26]\)  
Nature of models, purpose of models, change of models \([27]\)  
Elements involved in a model: Modelling with many data points show more detail. A model should provide evidence. A model needs several pieces of evidence. A model with explanatory scope could explain a wide range of phenomena. A model coordinates data with related concepts to demonstrate conceptual reasoning. A high-quality model is unique and captures some sense of novelty. A high-quality model is simple and easy to understand \([28]\)  |
|          | Epistemic practice | The generality of scientific-knowledge \([29]\)  |
|          | Epistemic criteria | The epistemic considerations underlying scientific modelling: generality/abstraction, evidence, mechanism, and audience \([30]\)  |
| Argumentation | Epistemic reasoning | Selecting or generating data to become evidence, b) Using evidence to ascertain patterns of evidence and models, c) Employing the models and patterns to propose explanations \([31]\)  |
|          | Epistemic practices | Causal structure of the arguments, causal coherence, citation of evidence and evidentiary justification \([32]\)  
Epistemic operations identified in teachers’ discourse: argument, classification, comparison and contrast, counter-argument, definition, description, evaluation, exemplification, explanation, generalization, justification, modelling, prediction \([33]\)  
Epistemic levels for analysing students’ use of evidence, from specific data to general processes, in writings \([34]\)  |
|          | Epistemic criteria | Evidentiary justification, plausibility of causal mechanisms, persuasiveness of evidence \([35]\)  |
|          | Epistemic learning | Features of student understanding of the nature of science that might be affected by engaging in argumentation: source of knowledge, certainty of knowledge, development of knowledge and justification of knowledge \([16]\)  |
As summarized in table 2, the number of studies examining epistemic aspects is similar for each scientific practice, however the nature of the aspects is different. Studies focusing on inquiry and on modelling, examine more the nature of knowledge and knowing (epistemic beliefs and epistemic understanding) than epistemic knowledge in practice. However, the studies about argumentation focus more on the practical aspects, such as practices and criteria.

It needs to be noted that many of the studies use a questionnaire to get information about participants’ epistemic knowledge, however few of them examine it in the practice.

4 CONCLUSIONS

The literature review highlights that there are seven aspects about epistemic knowledge addressed in empirical studies in the field of Science Education, however most of them focus on student’s conceptions about knowledge and knowing related to the practices of inquiry, modelling and argumentation rather than examining how these ideas are developed when participants engage in the practices.

Since the EPIST-PRACT project seeks to analyse students’ epistemic knowledge when engaging in scientific practices, this review offers relevant information for the design of learning environments about which aspects we need to be highlighted in order to promote a meaningful engagement in inquiry, modelling and argumentation practices. The majority of the studies considered in this review focus on students’ performances rather than in teacher development. We consider that there is a need of teacher training in how to promote students’ epistemic learning while engaging in these practices, which is also one of the purposes of the EPIS-PRACT project.

It needs to be noted that one limitation of this work can be the possible missing studies about epistemic knowledge in scientific practices due to not making it explicit in the title of the work or in the key words.

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