Metascience in pre-service primary teacher education

Enhancing teachers' science conceptions

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Context

- The study of the nature of science (NOS) has been receiving a renewed attention as a major contribution to attain the aim of scientific and technological literacy for all.

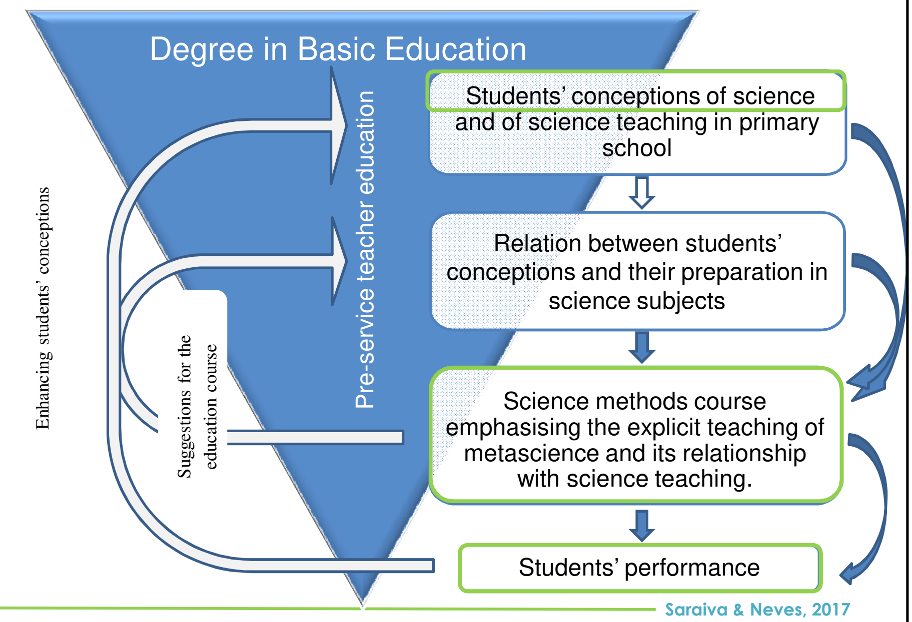
  (e.g., Lederman, 2007; McComas, 2014)

- Empirical support has been obtained for the effectiveness of an explicit, reflexive and contextualized approach in enhancing students' understandings of 'how science works' and of the complex nature of scientific knowledge.

  (e.g., Abd-El-Khalick, 2012; Lederman et al., 2012)

- A science methods course, that explicitly focus on a conceptualized view of metascience and its sound relation to science teaching, is a context that may contribute to enhance pre-service primary teachers' science conceptions.

General diagram



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Problem

What is the extent to which a teaching context explicitly focused on a conceptualized view of metascience and its sound relation to science teaching may contribute to the development of students' conceptions of science?

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Theoretical framework

Epistemological grounds

Model of science construction

. Metascientific dimensions

(philosophical, psychological, historical, sociological internal and external)

(Ziman, 1984, 2000)

Sociological grounds

Model of pedagogic discourse

. Sociological characteristics of the pedagogical practice

(*the what* and *the how* of PD)

(Bernstein, 1990, 2000)

Methods

Mixed methodology

(e.g., Creswell & Clark, 2011; Teddlie & Tashakkori, 2009)

Case study

Participants

25 pre-service primary teachers (third year) involved in a science methods course in a Portuguese School of Education

Evolution of participants' science conceptions

Questionnaire – 12 items (open and closed)/Model of analysis

Analysis of pedagogical practice

Construction of analytical instruments

Methods

Questionnaire structure

General data

(e.g., gender, age, academic formation, …)

Participants' science conceptions

A - **Conception about scientific knowledge (ScK)**, taking into account the epistemic values conceptualized by McMullin (1982).

B - **Conception about metascience,** according to Ziman's theorization.

B1- Metascientific dimensions (MScD) involved in the construction of scientific knowledge B2 to B5 – Characteristics of each metascientific dimension: **philosophical – PhiD** (B2); **psychological – PsyD** (B3); **internal sociological – ISD** (B4); and **external sociological – ESD** (B5).

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Example – Item B2

B.2 PhiD	**What are the characteristics of the investigative processes leading to scientific knowledge?**
	(a) Check with a circle the statement or statements that can answer to the question.
I	**They are procedures based on theories with great explanatory power on natural phenomena and events. [rationalist]**
II	**They are rigorous observation, measurement and experimentation procedures associated with an interpretation of the results. [empiricist]**
III	**They are procedures of critical analysis of knowledge, subjecting it to rejection by any new observation or result. [refutation]**
IV	**They are rigorous and controlled procedures of observation and experimentation designed to obtain data that will allow to describe and explain the reality. [objectivity]**
V	**They are rigorous procedures that follow precise norms to repeatedly. test and validate knowledge. [confirmation]**
VI	**They are rigorous, imaginative, and critical procedures based on the scientists' ideas and beliefs about he subjects they investigate. [subjectivity]** (b) Explain the reason (s) of your (s) choice (s).

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Example of answers to item B2

PhiD AJ	**Statements checked:** **II , IV and VI** **(empiricist, objectivity and subjectivity)** ***Sara***	The investigative processes are rigorous and controlled procedures because only in this way it allows the validation of results. Moreover, they [procedures] must be based in the imagination because only in this way they [scientists] can think of something based on the observations […] and critical thinking because only in this way they are able to analyse former scientific knowledge and to examine other scientists research.
PhiD PAJ	**Statements checked:** **III and IV** ***(refutation and* objectivity)** ***Clara***	… , because in the case of the first hypothesis, the scientists risk, because when they try to discover something important, there can be another point of view and thus overturn the work that was developed by the other. In the case of the second answer, I think that the procedures of observation and experimentation will make a great contribution to discover reality and truth.

AJ – Appropriate justification; PAJ - Partially appropriate justification

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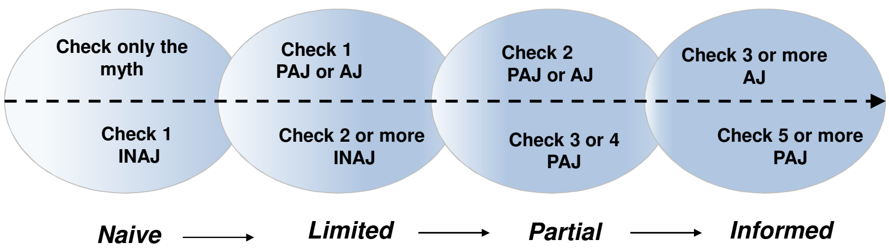
Methods

Conceptions about science – Model of analysis



Saraiva, 2016 (adapted)

INAJ - inappropriate justification
PAJ- partially appropriate justification
AJ – appropriate justification

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Curricular materials

Teacher guide

General structure	Type of activity	Intended message	PD
Each activity is organized in three topics: Objectives Materials *(students' worksheets)* Description *(teacher' informations/ suggestions)*	**Learning activities (experimental/ discussion)**	**Broad conception of MSc (knowledge and skills)**	***The What***
		Strong relation between metascience (MSc) and science (Sc) (Weak classification)	***The How***
	Additional readings	**Strong relation between metascience (MSc) and science teaching (ScT) (Weak classification)**	
	Evaluation activities	**Strong metascience explicitness (Strong framing)** **Strong explicitness of MSc – ScT relation (Strong framing)**	

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Instruments – Pedagogical practice

Instrument – Metascientific dimensions (excerpt)

Increasing level of conceptualization →

Level 1	Level 2	Level 3	Level 4
The teacher does not refer the metascientific dimension. **Or** **The teacher refers the metascientific dimension in an ambiguous way.**	**… only refers to knowledge of a general nature, …** **Or** **… only refers to skills, …**	**… refers to knowledge of a general nature and skills, …** **Or** **… only refers to knowledge of a specific nature, …**	**The teacher refers to knowledge of a specific nature and skills, related to the metascientific dimension.**

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Instruments – Pedagogical practice

Instrument – Intradisciplinary relation between MSc-ScT (excerpt)

Increasing degree of relation →

C^{++}	C^{+}	C^{-}	C^{--}
The teacher only addresses the metascientific knowledge and/or skills included in the activities.	....	....	The teacher addresses, interconnecting them, the relationship between metascientific knowledge and/or skills and knowledge about teaching and learning of the sciences included in the activities.

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Instruments – Pedagogical practice

Instrument – Explicitness of the relationship between MSc-ScT (excerpt)

Decreasing degree of explicitness →

F^{++}	F^{+}	F^{-}	F^{--}
The teacher adresses very explicitly the meaning of metascientific knowledge and/or skills in the teaching / learning of sciences, and/or their importance for the success of learning.	.....	.....	The teacher does not address or does it with confusing / incorrect ideas about the meaning of metascientific knowledge and/or skills in the teaching/learning.....

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Discourse in the classroom – Example (PhiD)

Level MScK	Explic. MSc	
		Professor- [Scientific laws] They should have unifying capacity. *Student*- Capacity what? *Clara* - Unifying! As in Lavoisier's law. *Professor* - We saw this in the last class. Lavoisier unified the concepts of oxidation, rust and respiration, in addition to enunciating the Law of Conservation of Mass. *Sofia* - Teacher, are there laws usually associated with formulas? [….] For example. Newton's 1st law. I do not know... *Professor* - The first law and the others that Newton enunciated can be expressed with formulas that relate the variables under study. *Rui* - All laws related to quantitative problems have formulas. [...] *Student* - I do not remember any that is not represented ... {by formula}! *Professor* - Rui is right: in many cases laws ... can be represented by mathematical expressions. [Lesson 6, UA 71]

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Discourse in the classroom – Example (ESD)

Relation MSc-ScT	Explicit. Relation MSc-ScT	
		Professor –[...] this debate about science education and about the scientific learning that children are supposed to carry out at the level of basic schooling ... is long overdue .... As we saw earlier, [...] we should contribute to the education of participatory citizens who have a word to say when asked to speak on certain socioscientific issues and to understand the importance of the relations that are established between science, technology and society. [Lesson 10, UA 114].

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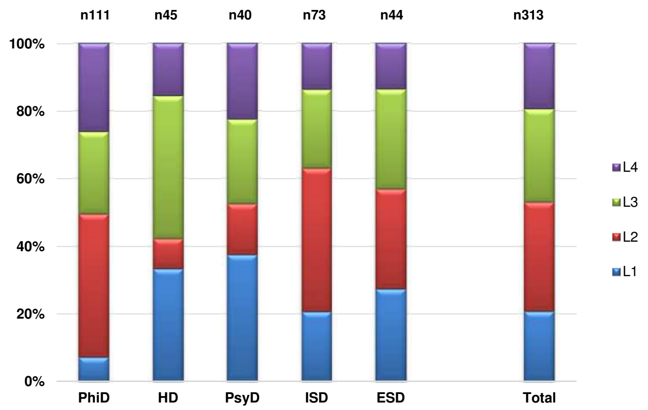
Results – Modality of pedagogical practice

Conceptualization level of metascience – *The what*



In the pedagogical practice, the metascientific knowledge of a generic nature or skills related to metascientific dimensions were more present.

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Results – Modality of pedagogical practice

Sociological relations – *The how*

	Characteristics studied				Curricular materials	P Practice
The how	Relation between discourses	Intradisciplinarity		MSc-ScT	C^-	C^+ C^- (PhiD, ESD)
	Relation professor-students	Discursive rules	Evaluation criteria	MSc Explicitness	F^+	F^- F^- (PhiD)
				Explicitness of MSC-ScT relationship	F^+	F^-/ F^+ (PhiD)

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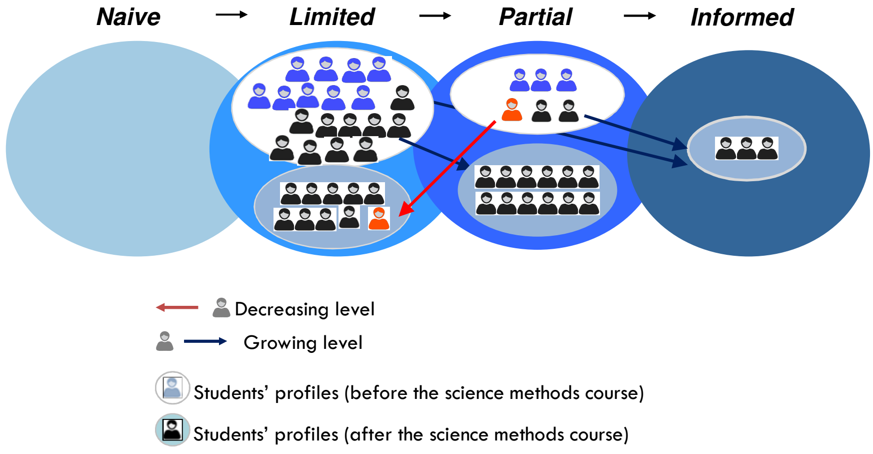
Results – Participants' science conceptions

Evolution of the global profiles (tendency)



Saraiva, 2016 (adapted)

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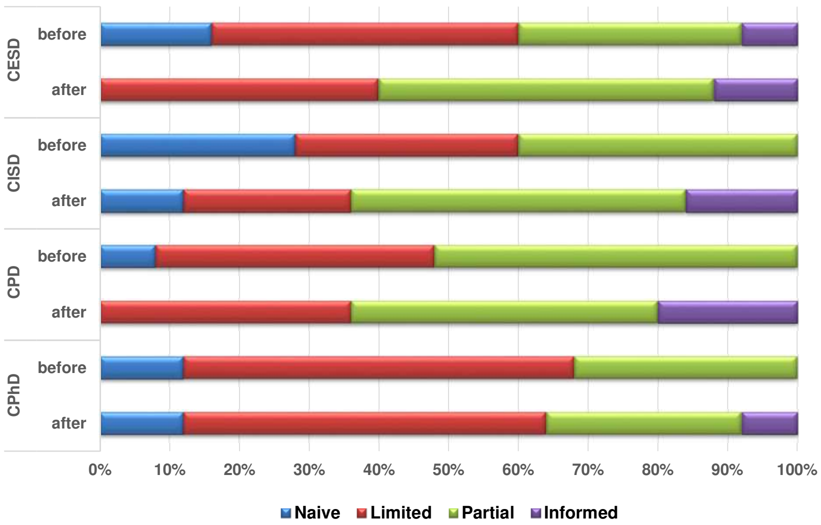
Results

Evolution of MSc conceptions



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Conclusions

- The pre-service primary teachers' global profiles of conceptions about science, showed a differential tendency of evolution towards the conceptual profiles of greater comprehensiveness, according to the metascientific dimension under analysis.

- The teacher education course focused on metascience and on its relation to science teaching and directed to pre-service primary teachers showed to have potential for promoting a broad conceptualization of science.

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Conclusions

- The research points out to some difficulties of the teacher to implement the message contained in the curricular materials. He moved away from this message with regard to some sociological relations, in particular, the weak relation between MSc and ScT and the weak explicitness of the text to be learned.

- The research raises questions about the importance of teacher education institutions in promoting the learning of a metascientific component in science education, in order to achieve scientific literacy for all.

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Contributions of the study

- The study provides elements for reflection on the inclusion of metascience in pre-service teacher education courses and in science teaching-learning in primary school contexts.
- It allows, also, a reasoned reflection on the issue of the academic preparation of science teachers' educators.
- The study gives a methodological contribution to the design and analysis of curricular materials centered on metascience and on its relation to science teaching, based on a sound theoretical framework that combines epistemological and sociological aspects of science education.

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