Universitat de Vic
Programa de Doctorat Interuniversitari
en Innovació i Intervenció Educatives

Preservice teacher knowledge application: from model-centred instruction to lesson plan design.

Isabel Jiménez Bargalló

Dirigida per:

Dra. Mila Naranjo Llanos

Escola de Doctorat de la Universitat de Vic-Universitat Central de Catalunya.
Departament de Psicologia
Març 2016

Als homes de casa: en Biel,
en Martí i en Bernat

Nen (3 anys): "mama, tu saps que la sang també ha d'arribar aquí (assenyalant la boca) per poder fer "així" (obrint i tancant-la)?"

Mare: " I com s'ho fa per arribar a la boca?"

Nen: "tu saps? Quan respires i l'aire entra pel nas, va a la panxa i allà empeny la sang, així, a poc a poc! (inspirant a poc a poc) i va empenyent la sang que puja fins a la boca i va a la mà i al peu i a tot arreu..."

"The whole of science is nothing more than a refinement of everyday thinking."
Albert Einstein, 1936 in Physics and Reality

Table of Contents

Table of Contents 1

List of figures 3

List of tables 4

List of charts 5

Acknowledgements 6

1. Introduction 8

2. Theoretical framework 11
   2.1. Model Cantered Instruction epistemologies: a merge of contributions. 12
      2.1.1. Cognitive psychology 12
      2.1.2. Conceptual change theory 14
      2.1.3. Social-constructivism 18
      2.1.4. Model-Centred-Instruction 24
   2.2. Model Centred Instruction a general overview. 28
   2.3. Preservice Teacher education for MCI 37

3. Problem Statement, research questions and hypothesis 41

4. Study design 43
   4.1. Research approach 43
   4.2. Research strategy 47
   4.3. Research methodology 49
      4.3.1. Study context 50
      4.3.2. Instruction design 51
      4.3.3. Researchers' role during investigation 59
   4.4. Instruments for data collection 60
   4.5. Procedures, units and instruments for data analysis 63
      4.5.1. Procedures for data analysis 63
      4.5.2. Instruments for data analysis 66
      4.5.3. Reliability, validity and transferability of procedures and results 87

5. Results 88
   5.1. Nature of science (NOS) underlying lesson plans 88
   5.2. Performance in the identification of target models 91
   5.3. Activities' sequencing 95
   5.4. Planned Join Activity structure 98
      5.4.1. Planned join activity structure: general overview. 98
      5.4.2. Planned join activity structure: facilitate the representation of the task PAS. 112
      5.4.3. Planned join activity structure: activating prior knowledge PAS. 114
      5.4.4. Planned join activity structure: providing information PAS. 123

5.4.5. Planned join activity structure: planning of assignments elements PAS. 128
5.4.6. Planned join activity structure: work execution PAS 132
5.4.7. Planned join activity structure: elaboration-conclusion PAS. 137
5.4.8. Planned join activity structure: metacognition PAS. 146

6. Discussion 149
6.1. Discussion of results in relation to the first question of research. 149
6.2. Discussion of results in relation to the second question of research. 155

7. Implications and directions of further research 157
7.1. Implications.. 157
7.2. Directions for future research.. 159

8. Limitations of the study 160

9. Conclusions.. 161

10. References 163

Appendix 1: initial questionnaire 175

Appendix 2: instructions to perform and review lesson plans.............................. 181

Appendix 3: examples of activities performed during instruction.......................... 190

Appendix 4: instructions given to pre-service teachers in order to plan and reflect on classroom intervention 231

List of figures

Figure 1. Conceptual framework for the emergence of Model Centred Instruction. 12
Figure 2. Process of thinking and reasoning as understood by cognitive science. 13
Figure 3. Constructivist conception of the school teaching and learning. 19
Figure 4. Hierarchical organization of the explanatory principles within the constructivist conception of the school teaching and learning 20
Figure 5. Modeling practice as the interaction of the elements of the practice and the metamodelling knowledge.. 29
Figure 6. Scientific modelling process 30
Figure 7. Components of metamodeling knowledge 31
Figure 8. Learning and Instruction-design pathways for MCI. 32
Figure 9. Nested structure established between target and subtarget models leading to a complex concept 34
Figure 10. Components of pedagogical content knowledge. 38
Figure 11. Components of PCK for scientific modeling.. 39
Figure 12. Overview of the general research strategy. 47
Figure 13. Research schedule. 60
Figure 15. Analysis units hierarchical levels. 64
Figure 16. "Ideal lesson plan diagram".. 72
Figure 17. Example of a join activity map showing the structure of join-activity planed by students in a specific lesson plan. 85
Figure 18. Maps 1112.03.01i to 1112.03.14i corresponding to initial lesson plans, performed before instruction, in CASE A. 100
Figure 19. Maps 1112.03.01f to 1112.03.14f corresponding to modified lesson plans, CASE A. 101
Figure 20. Maps 1213.04.01 to 1213.04.14 corresponding to lesson plans performed during the second period of instruction, CASE A. 105
Figure 21. Maps 1213.03.01i to 1213.03.10i corresponding to initial lesson plans, performed before instruction, in CASE B. 107
Figure 22. Maps 1213.03.01f to 1213.03.10f corresponding to initial lesson plans, performed before instruction, in CASE B. 109
Figure 23. Map of programmed activity segments found in all plans corresponding to the second period of instruction in CASE B (planning of class intervention). 111

List of tables

Table 1. Strokes' types of research according their goals.. 46
Table 2. Program course overview.. 52
Table 3. Timeline of main instructional activities performed during the modeling experience focused on the corpuscular theory of matter. 56
Table 4. Summary of main activities done during module 3... 57
Table 5. Summary of main activities done during module 5... 59
Table 6. Differences between case A and case B assignments. 62
Table 7. NOS aspects and definitions used to characterize preservice teachers' NOS views......... 68
Table 8. Categories and corresponding operational criteria used to characterize preservice students' NOS.. 69
Table 9. Categories, subcategories and operational criteria used to inform about preservice teachers' ability to select and plan activities according to target models. 70
Table 10. Codes used to qualify preservice teachers' ability to select and further develop target models.. 70
Table 11. Correspondence between the 5E Learning cycle and the Model-centred instruction phases 71
Table 12. Categories and subcategories used to qualify preservice teachers' ability to design learnig cycles according to MCI. 73
Table 13. Categories and operational criteria used to define and delimitate programed activity segments (PAS). 79
Table 14. Actions and operational criteria within "Facilitate the representation of the task" PAS. . 80
Table 15. Actions and operational criteria within "Activating prior knowledge" PAS.................... 81
Table 16. Actions and operational criteria within "Providing information" PAS. 81
Table 17. Actions and operational criteria within "Planning of assignment elements" PAS. 82
Table 18. Actions and operational criteria within "Work-execution" PAS................................... 83
Table 19. Actions and operational criteria within "Elaboration-conclusion" PAS.......................... 84
Table 20. Actions and operational criteria within "Metacognition" PAS...................................... 85
Table 21. NOS views inferred from lesson plans. 88
Table 22. Characterisation of activities' sequencing in CASE A and CASE B lesson plans. 95
Table 23. Comparative table showing the total amount of planned sessions within LP1 initial and reviewed (CASE A and B) and LP2 (CASE A)... 110
Table 24. Tendencies of relative frequencies of 5c and 5d actions through instruction............. 134
Table 25. Tendencies of relative frequencies of 5a and 5b actions through instruction. 134
Table 26. Tendencies of relative frequencies of 6.A.a. actions through instruction................... 139
Table 27. Tendencies of relative frequencies of 6.A.b. actions through instruction. 139
Table 28. Tendencies of relative frequencies of 6.A.c and 6.A.d. actions through instruction..... 141
Table 29. Tendencies of relative frequencies of 6.B.a and 6.B.b. actions through instruction..... 141

List of charts

Chart 1. Chart 2. Relative frequency of actions in Frt PAS. 112
Chart 3. Chart 4. Relative frequency of actions in Apk PAS. 115
Chart 5. Chart 6. Relative frequency of actions in Pi PAS. 123
Chart 7. Chart 8. Relative frequency of actions in PAE PAS 128
Chart 9. Chart 10. Relative frequency of actions in WE PAS. 132
Chart 11. Chart 12. Relative frequency of actions in EC PAS. 137
Chart 13. Chart 14. Relative frequency of actions in M PAS. 146

Acknowledgements

M'agrada visualitzar el procés de confecció de la tesi com una excursió a un gran cim. Doncs bé, ja hi som. He arribat al cim i em sento ben feliç tot i que encara no m'ho acabo de creure. Ara és moment d' expressar el meu agraïment a totes aquelles persones que, al llarg d'aquest trajecte ple de revolts i sotracs, m'han ajudat i recolzat en tots els sentits, tant a la universitat com a casa. Perquè la tesi, malgrat semblar un repte solitari, només es pot fer acompanyat.

Seria injust començar els agraïments amb un altre nom que no fos el de la Mila Naranjo Llanos, la directora d'aquesta tesi. He de confessar que sempre m'havia sabut greu no haver-la tingut com a professora mentre aprenia a fer de mestra. Tenir-la com a directora de tesi ha estat un privilegi i un gran plaer. D'ella n'he après bona part del que avui puc defensar en aquest informe. Les reflexions, l'ajuda incondicional sempre amb bon humor i, sobretot, el suport moral en els moments de crisi han estat imprescindibles perquè aquesta recerca arribés a bon port.

La continuació dels agraïments també té un altre nom propi: en Jordi Martí Feixas, el meu "mestre". Ha plogut molt des d'aquelles primeres classes on en Jordi ens parlava de les "lliçons de coses" basades en els idees de Pestalozzi! Sense la seva visió de la didàctica de les ciències jo no m'hauria embrancat mai en una aventura com aquesta i, si ell no hagués confiat en mi ara fa uns anys donant-me l'oportunitat d'entrar en "l'apassionant" món universitari, res d'això no hauria estat possible.

Agrair també la col·laboració a tots els estudiants que han participat en aquest estudi. Sense ells aquest treball no hauria existit. Amb ells he crescut com a professora i com a recercaire. Gràcies per les reflexions, gràcies pels treballs, gràcies per les hores compartides.

Tampoc puc oblidar la resta de companys del departament. Amb ells vaig començar a fer, ara fa uns anys, les primeres passes dins el món acadèmic. Vull agrair, especialment, els ànims i consells de la Isabel Sellas amb qui, malgrat la distància, hem pogut compartir el repte de fer una tesi sent mares, treballant...

Igualment, m'agradaria donar les gràcies a totes aquelles persones de la Universitat de Vic, del Casal del Mestre, del Moviment de Renovació Pedagògica que, com a estudiant o com a companys, m'han permès compartir la inquietud i motivació pel coneixement i millora constant dels processos educatius dels infants. No els puc citar un per un perquè la llista seria interminable: gràcies a tots!.

També hi ha un munt de companys i amics que no han intervingut directament en el treball de recerca, però que sí que han participat del meu dia a dia durant aquests anys. Els amics són un puntal en la vida de qualsevol persona, i la meva seria molt més difícil sense gent com la Montse, la Cristina, la Fina, l'Ariadna o la colla de la Garriga al meu costat. Gràcies pel suport en els moments difícils. Gràcies per cuidar-me sempre i per ser a l'altra banda del mail o de l'skype quan ho he necessitat.

Bona part d'aquesta tesi ha estat feta a Àustria, on ja fa tres anys que hi vivim… aquí també he trobat noves amistats que han ajudat a que aquest camí fos més planer. Gràcies a tota la gent del "grup de jocs de Viena" (al Mon i l'Andrea també). Gràcies per acollir-nos, gràcies per compartir "el dia a dia d'immigrant" i fer-nos l'adaptació molt més fàcil. Gràcies Llum, per ser una "Mary Poppins" tant fantàstica... ara que això s'acaba, els nens et trobaran a faltar, segur!

Ein herzliches Dankeschön an Johannes und, insbesondere, an Sibylle. Danke für viele Gespräche, Lacher und für die hilfe in entscheidenen Momenten. Danke Anna und "merci", Xavier (oder sollte ich "muchas gracias" sagen?). I am sure we are going to be able to share many "open house" from now on.

He deixat pel final la part més important i més sacrificada de totes: la família. A vosaltres també us toca un bocí ben gran dels agraïments d'aquesta tesi. Gràcies per tot el que m'heu donat i em doneu, gràcies per cuidar-me i estimar-me, pel suport, pel disseny de les figures (Núria)... i per no deixar de preguntar una vegada i una altra: "com ho portes?"… gràcies i mil vegades gràcies a tots!

Martí i Biel: la tesi m'ha robat moltes estones d'estar amb vosaltres… però tingueu-ho clar, sempre heu estat amb mi. I, sí, ara sí que ja estic. Ara és de debò. Ja puc venir a jugar amb vosaltres.

Finalment, no puc escriure res que expressi tot el meu agraïment pel que en Bernat ha posat en aquesta recerca. És molt... molt més del que ell s'imagina!. Gràcies per la paciència i els ànims, gràcies pels consells, l'escolta, les discussions, les revisions, l'estar sempre al meu costat, aguantar els nervis, la impotència, compartir els patiments i les pors, patir els mals humors... Gràcies, Bernat, per compartir amb mi la vida. Espero que el camí que fem plegats sigui ben llarg!

1. Introduction

Elementary teacher education involves learning to teach science. However, even in elementary school, teaching science is a demanding work: teachers must orchestrate a complex set of teaching practices to promote "scientific literacy" in students. This dissertation reports results and reflections on how do preservice teachers' ideas about and abilities for teaching science change when they experience a model centred instruction (MCI) during their undergraduate courses.

In the past 30 years, "scientific literacy" has emerged as a key topic across the world. Many international reports on the state of science education indicate the convenience of engaging Kindergarten and Primary students in authentic scientific practices to develop a deep understanding of what science is and how science works (e.g. Duschl, et al., 2007; Rocard, et al., 2007; Osborne & Dillon, 2008). Under this framework, science education focus on the development of the scientific ways of thinking, "(…) in order to interpret the information received and to predict and make decisions with initiative and personal autonomy..."(BOE, 2006).

In accordance with different contributions (Harlen, 1998; Izquierdo et al.,1999; Pujol, 2003; Zimmerman, 2007) this entails different interrelated skills, such as:

a. Build, increase and revise students' explanatory models (those that emerge from their intuitive knowledge) taking, as a reference, the scientific information available;

b. Develop general knowledge skills as well as specific knowledge abilities typical from scientific reasoning;

c. Construct an epistemological conception of science more in line with the current view of the nature of science.

Such indications have been incorporated in many scientific curricula worldwide (e.g. Charpak et al., 2006; Osborne & Dillon, 2008; NGSS Lead States, 2013). This dissertation focuses in the undergraduate elementary teachers' courses of a Catalan University. The new Catalan curricula (DOGC, 2015) also includes the above mentioned guidelines. In particular it specifies the need to:

a. Recognize that children develop their own intuitive ideas about the natural world well before being taught any science.
b. Understand science learning as a gradual process involving the child's pre-existing knowledge of everyday physical phenomena gradually being enriched and restructured.
c. Involve children in science practices such as the formulation of inquiry questions, the identification of evidences, the deduction of conclusions that enable to act, or the communication of findings using different channels.

It is well known that the successful development of scientific literacy depends on the context of learning and teaching experienced by students (Metz, 2004; Vosniadou et al., 2001). The most effective environments are found to be those where students can use and improve scientific reasoning in the context of authentic scientific inquiry with appropriate fidelity to real scientific activity (Chinn & Malhotra, 2002; Metz, 2004; Appleton, 2006; Ford & Wargo, 2007), but specific to school science (Izquierdo et al., 1999). Furthermore, one of the teaching strategies that best satisfies this request is a Model-Centred Instruction (MCI) that introduces emphasis both in model-based inquiry and in metamodeling knowledge (e.g. Schwarz & White, 2005; Windschitl et al., 2008b; Kenyon, et al., 2008; Schwarz, 2009). If teachers are expected to use such reform-oriented practices, it is a challenge for them to develop a solid Pedagogical Content Knowledge -PCK- (Shulman, 1986) base regarding them during their preservice training.

Therefore, to meet the challenge of developing fully professional and competent teachers, it is imperative to invest in their preparation. Undergraduate teacher institutions need to rethink their instructional approaches. New models of professional development are required to support teachers and preservice education students in developing the deep craft of knowledge, skills, and confidence necessary to teach in agreement to the above mentioned reform initiatives. Likewise, it is also an important target promoting research to understand and interpret the ways in which teachers make sense of and adjust this new knowledge in order to create consistent environments in schools (Clement & Rea-Ramírez, 2008). Research on professional development and preservice education should be the foundation upon which new models of professional learning are built.

Although in the past few decades there has been a broad production of literature related to Mental Models, Scientific Modelling, Model Centred Instruction, etc., relatively few studies have been conducted within the context of real undergraduate science-teaching. It is fair to conclude that current research has not generated robust evidence to understand how to facilitate PCK for MCI on preservice teachers. This lack of evidence is a notable gap in the literature and is the main focus for this research.

This study seeks to contribute to the current state of knowledge on science-teacher education by examining the development of preservice elementary teachers' PKC for MCI when they receive model centred instruction during their university science courses. More specifically, it elucidates the difficulties to translate preservice teachers' understandings of MCI into model-centred science lesson designs. To this end, specific MCI for preservice primary university courses has been designed and performed; and initial (prior to instruction) and modified lesson plan designs (performed during and after MCI instruction) have been compared.

The approach adopted for this investigation is a case study with mixed quantitative-qualitative methods being utilised for data analysis. As will be discussed broadly in chapter 4, this provides a more complete picture of the changing confidence and abilities of the students and allows a deeper understanding of the complex world that supposes a real context of an undergraduate course.

Findings of this research appear to be significant in different ways, having implications for classroom practice, teacher education, and research. As already mentioned before, this study provides an exciting opportunity to advance on our knowledge in the field of MCI. Results of this study make a major contribution to fill the existing gap in the literature related to our understanding of the way in which preservice elementary teachers acquire the required skills to put Model-Centred Instruction (MCI) into practice. Specifically, it provides major evidences on:

a) The main difficulties in the development of preservice teachers' PCK for MCI;

c) Whether or not it is possible to predict the success/difficulties for preservice teacher knowledge application through the revision of initial lesson plan design.

The overall structure of this thesis takes the form of nine chapters, including this introductory chapter. Chapter 2 introduces the theoretical framework of the research, and chapter 3 sets the problem statement, condensed in two research questions and hypothesis that underlie this thesis. The fourth chapter is concerned with the methodology used for this study. In different sections, the epistemological position that guides the study, a general description of the research as well as the data sources, data instruments and data analysis used, are clarified. In chapter 5 the results from the research are presented, and chapter 6 discusses them, focusing on the two key research questions that have been identified in chapter 3. The final chapters draw upon the entire thesis, tying up the various theoretical and empirical strands that have been presented so far. Chapter 7 outlines the implications of this thesis and suggests ideas for related future work. Chapter 8 describes the scopes and limitations of this research and Chapter 9 is a summary of this thesis, including the conclusions drawn from research. Finally, three appendices containing supplementary material derived from the study are provided for the sake of completeness.

2. Theoretical framework

The current paradigm of Model Centred Instruction –MCI- (also referred as Model-Based Co-construction; Model Based Science Teaching and Learning or Model-Cantered Inquiry Approach, among others) is an instructional approach in which learners are encouraged in scientific inquiry focused on the creation, evaluation and revision of scientific models in order to understand and predict the natural world (Lehrer & Schauble, 2000; Schwarz & White, 2005; Stewart, Cartier & Passmore, 2005; Rea-Ramírez, et al. 2008; Windschitl, M. et al., 2008a; Schwartz et al., 2009).

The aim of this section is to review briefly the outstanding literature to:

a. Present a general overview of the main different studies and theories that provide a base for the current theory of MCI underlying this study.
b. Introduce the basic concepts on MCI.
c. Examine requirements to effectively develop PCK for modelling practices.

2.1. Model Cantered Instruction epistemologies: a merge of contributions.

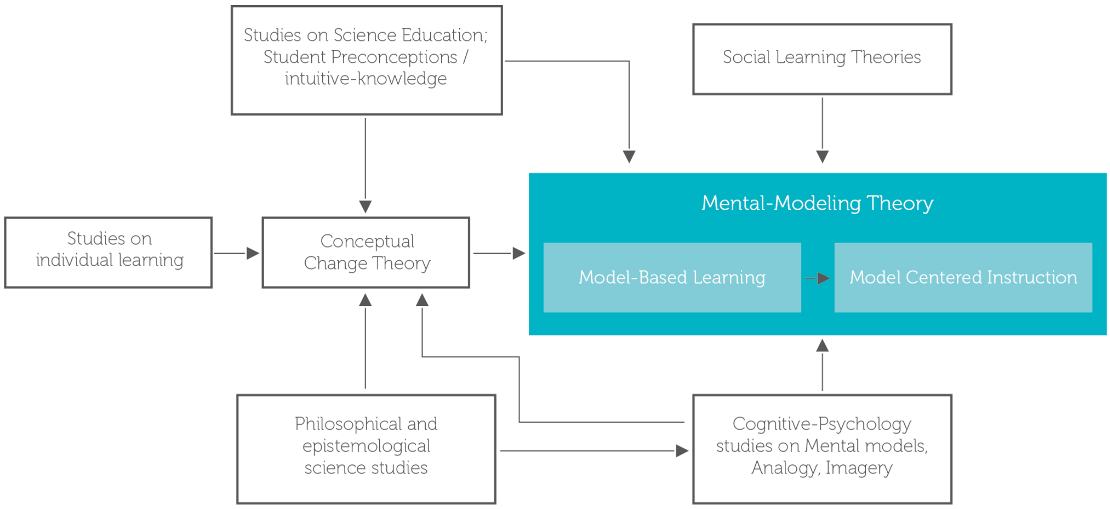


Figure 1. Conceptual framework for the emergence of Model Centred Instruction (adapted from Rea-Ramírez, et al. 2008).

As shown in figure 1, MCI is framed on the Mental Modeling Theory (Johnson-Laird and Byrne, 1991) which emerges in the 2nd half of the 20th century as a response to gaps in prior theories of reasoning and representation (Rea-Ramírez, et al. 2008). Numerous different studies and theories have contributed to progress and develop MCI. In any case, and as also presented in the same diagram, three major research lines converge and provide their basis: cognitive psychology; conceptual change theories; and social-constructive learning theories. In order to locate the research presented in this dissertation, a brief review of the most influential literature held in these fields is described below.

2.1.1. Cognitive psychology.

The first half of the twentieth century gave rise to many important pioneers who, in very different ways, laid the foundations for the psychology of thinking and reasoning. Among them, in 1943, the psychologist Kenneth Craik was the first to introduce the notion of "internal models". He based his hypothesis on the predictive power of thought and the ability of humans to explore mentally the real-word and imaginary situations. Craik argued that, in many instances, people reason and experience reality by carrying out thought experiments on internal models. He considered as a model a structural, behavioural or functional analog to a real-world phenomenon (Craik, K., 1943). Craik made his proposal at the height of the behaviourist approach in psychology so at this point his ideas received little notice. Later on, in the 1960s and 1970s, the development of "cognitive psicology" allowed the resurgence of his ideas.

A fundamental presupposition (still in force) within this paradigm of cognitive science is that humans think about real and imaginary worlds through internal representations. To cognitive scientists (challenged by researchers in the areas of connectionism, dynamic cognition and situated cognition), our sensory receptor cells receive sensory stimuli and act as transducers to convert external energy into electrical signals that travel along the nerves to different areas in our brain, to be processed and converted in symbol structures in memory. This physical symbol system (Vera & Simon, 1993) cause motor actions that, in turn, modify symbol structures in memory (figure 2).

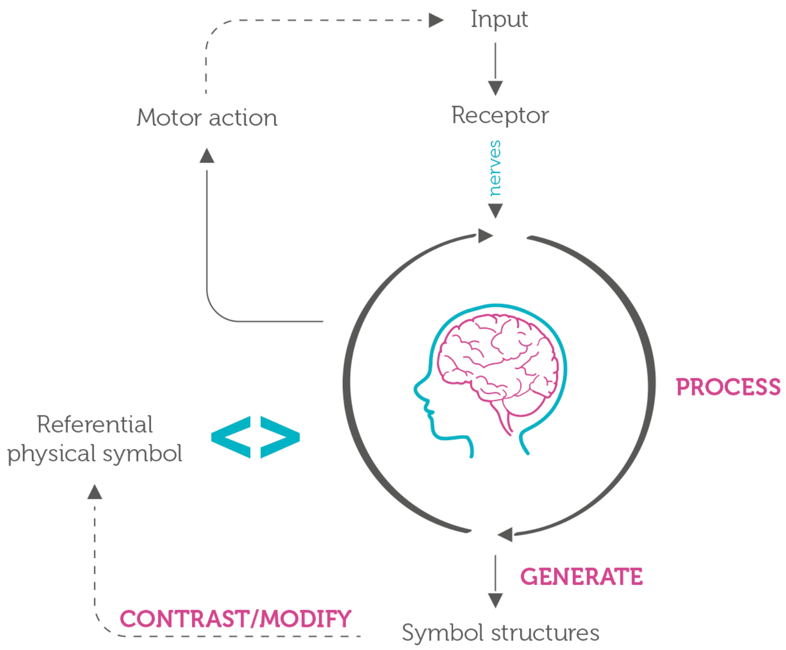


Figure 2. Process of thinking and reasoning as understood by cognitive science.

Nevertheless, since its inception, there has been a deep division in order to elucidate the nature of these symbols' structure. Two main positions have been hold: the "propositional-like" representation and the "iconical-like" (Neressian, 1999). Despite its importance (because different kinds of representations enable different kinds of processing operations), the issue remains still unsolved.

Thus, traditional philosophical accounts for reasoning have been deeply identified with logic and argumentation. Similarly, the classics of psychological views (like those exposed in Inhelder & Piaget, 1958) restricted reasoning to logical operations performed on language/propositional-like representations. Critics of this position defended that this paradigm was, in fact, ill-equipped, for example, to explain reasoning involved in response to complex issues without clear-cut solutions, or the systematic errors displayed by people with no training in logic (e.g. Wason, 1960; Johnson-Laird, 1980). Instead, they proposed adopting Craik's hypothesis of reasoning via "mental modelling" (Johnson-Laird, 1983; Gentner & Stevens, 1983). Since then, this has been an explanatory framework to examine understanding and reasoning in various domains, and several independent strands of research on cognitive science have emerged.

As a part of this broader trend by which cognitive psychologists seek to understand the "natural cognition", a general account of scientific reasoning was not proposed until the beginning the 1970s. Foundations for this contemporary research on scientific thinking lay on the work of authors like Jerome Bruner, Peter Wason and Newell & Simon. Already in the late 50s, Bruner and his colleagues (Bruner, Goodnow, & Austin, 1956) identified testing of hypothesis as a key component of scientific thinking. They proposed a paradigm in which people were required to formulate hypotheses and collect data to test their hypotheses. Using this approach, they identified different types of strategies people use to formulate and test hypotheses. Later on, Wason et al. (Wason, 1968) focused their research on whether people adopt a strategy of trying to confirm or disconfirm their hypotheses. Finally, at the beginning of the 70s, Newell & Simon (Newell & Simon, 1972) proposed scientific thinking as a form of problem solving. They argued that discovery and scientific thinking is not a "mysterious magical process", but a process of problem solving, and they tried to articulate at a fine-grained level the heuristics used in scientific research. Since it is not possible to go in depth into these ideas within the confines of this section, it is worthwhile to say that an exhaustive summary of the themes that have dominated early research on scientific thinking can be found at Tweney and colleages (Tweney, et al. 1981). Detailed summaries on main recent studies on cognitive science can also be found at Giere (Giere, 1993) and Carruthers (Carruthers, et al., 2002).

Among the large available recent literature on science cognition, a direct theoretical groundwork for MCI is provided by studies on imagery and analogy as a reasoning process in science discovery (Clement, J. 1988; 1989 and 1998; Giere, 1988, 1999, 2004); studies on mental model application on scientific problem-solving and comparing expert-novice problem-solving strategies (Chi et al., 1981); studies on the role of mental simulations in scientific learning processes (Clement, J., 2003); and above all, Neressian's extensive work on historical and contemporary scientific practices (Nersessian, N. 1992a, 1992b, 1999, 2002, 2006, 2008). These studies set up the foundations for research on conceptual change presented in the next section and represent the base for the conceptual backbone on MCI presented in section 2.2.

2.1.2. Conceptual change theory

For many centuries, researchers have been interested on scientist's ways of acquiring knowledge. They have noted that an important component of science is the generation of new concepts and the modification of existing ones and they have tried to explain how this growth of knowledge occurs either in a filed of study (over the course of history, developing new theories) and in an individual's lifetime. The large-scale changes that occur in conceptual structures have been labeled as conceptual change.

As it can be seen in figure 1, understanding conceptual change requires an interdisciplinary and collaborative work. Contemporary developments in the academic fields of science education, history and philosophy of science, and in cognitive science have produced research results that address the interest in the growth and restructuring of scientific knowledge. Before considering present perspectives and direct implications in MCI, a brief review of early foundations coming from these disciplines is presented below.

Within cognitive science, interest in conceptual change emerged in response to problems in Piaget's stage theory of cognitive development. Conceptual change models are in many ways similar to the Piagetian theory (Piaget, 1958) as they present analogies between Piaget's concepts of assimilation and accommodation. Nevertheless, instead of considering that concept development reflects broad transitions between stages, they explain conceptual development in terms of distinct developmental trajectories for each conceptual domain considered. In a general way, it can be said that they take a more domain-specific view of individuals' growth and restructuration of concepts.

Researchers of students' concepts and conceptual change also frequently draw analogies to the history of science. The analogy is generally presented when comparing the process of students' growth of scientific concepts to similar ones in the history of science. The background of this field of research can be found on Kuhn's (Kuhn, 2012) ideas on how scientific concepts and theories change over the course of history and, mainly, in his ideas of "paradigm" and "paradigm shift". According to the author, scientists' work is entrenched within a certain paradigm (what Kuhn called "normal science"). This paradigm can be understood as a worldview -the integrative set of theoretical concepts and methods taken for granted by a particular research community, their implication, and so on- in which research is performed. When scientists encounter abnormalities that cannot be explained by the universally accepted paradigm, they question the paradigm's assumptions, and a new paradigm emerges (what Kuhn called "a paradigm shift"). Bearing in mind Kuhn's work and that of other philosophers and historians of science, concepts have been increasingly seen as embedded within their own set off relationships with other concepts. In this sense, learning task has been compared as a kind of paradigm shift.

Finally, in the field of science education, origins on conceptual change theories are based on studies on what has been traditionally called "misconceptions" (also referred as alternative conceptions, preconceptions, intuitive knowledge, alternative frameworks etc.). Initial studies such as carried out by Rosalind Driver (e.g. Driver, 1981, 1983, 1985), or Novick and Nussbaum (Novick, S. & Nussbaum, J., 1981,1982) showed that student's intuitive concepts about natural wolrd influence and difficult the way to understand and reason about new scientific concepts presented in a learning context. Being occurred into, and influenced by the above background of cognitive scientists and philosophers and historians of science, researchers in science education sought to identify these intuitive concepts. They also explored instructional strategies to help to transform them into more scientific alternatives.

As already mentioned, all these claims and developments coming from such different academic fields of research served as initial hypothesis and as theoretical and empirical basis for a larger debate on conceptual change that emerged around the early 1980s. Since then, many models of conceptual shift have emerged which can be broadly characterized as either (a) knowledge-as-theory perspectives or (b) knowledge-as-elements perspectives (Özdemir, G., & Clark, D. B., 2007). Despite the existence of core differences between these two views of conceptual change, both lines of research provide key tools to interpret transitions in understandings and have clear implications for instructional design. Therefore, main theoretical perspectives within these two positions are briefly clarified and implications for MCI are discussed.

To explain conceptual shifts, proponents of knowledge-as-theory perspectives often present analogies between Piaget's concepts of assimilation and accommodation and

Kuhn's (Kuhn, T.S., 2012) concepts of normal science and scientific revolution. Authors like Carey or Poster and colleagues, for example, view the process of conceptual change as a "theory change" (Posner, et al., 1982; Carey, 1985, 1999; Wiser & Carey, 1983). Concepts are seen as embedded within existing intuitive theories (resembling some early concepts in the history of science) that require substantial restructuring to resemble those of scientists'. Those authors pose that learners do not feel a need to change the existing conceptual schemas if they can solve problems with them. Even when the existing conceptions are unable to successfully solve some problems, learners may only make moderate changes to their conceptions (referred as "weak restructuring" by Carey 1985). The main goal for education is to create a cognitive conflict to make learner dissatisfied with his/her existing knowledge (Posner, et al., 1982). In cases of missing and incomplete knowledge conditions, knowledge acquisition is of enriching kind, without requiring conceptual change (Carey, 1991). In line with these ideas, other authors make a boarder interpretation of the notion of conceptual change and consider not only changes into learning processes but also those in the history of science (Thagard, 1992; 2008).

A second view within the hallmark of knowledge-as-theory perspectives of conceptual change is that supported by Chi and colleagues (Chi, 1992; Chi & Slotta 1993). Chi focuses on differences between naïve and scientific concepts and on higher-level ontological shifts. She arguments that conceptual change is difficult to occur because either:

- A new concept is assigned to a different ontological category from the scientific one (e.g. the earth is thought "as an Object" rather than "as an astronomical object").
- there is not an appropriate category to which a new concept can be assigned.

Therefore, on this view, conceptual change involves the awareness of ontological commitments (to become aware of how a new concept doesn't fit with existing knowledge); constructing new ontological categories; and assigning the concept into a correct category by revising ontological commitments, categories and presuppositions.

Drawing from some of the basic ideas of these first two perspectives, Vosniadou and colleagues (Vosniadou, S., & Ioannides, C., 1998; Vosniadou, S. et al., 2001) provide a third and more dynamic account of the formation of new concepts. These researches explore conceptual spontaneous changes and instruction-based changes in terms of mental models (Vosniadou & Ioannides, 1998). Similar to Carey's (Carey, 1999) argument that even very young children develop theories and make predictions about phenomena, Vosniadou supports that spontaneous change can occur in young children through the enrichment of observations, language learning, etc., and without specific instruction. According to this argument, causal explanations reflect ontological commitments that are subject to revision and radical change. Moreover, instruction-based change focuses on the evolution of children's mental models. Akin to Carey's opinion, Vosniadou claims that children's generation of scientific models is constrained by their framework theories. Furthermore, she suggests that ontological change (Chi's main focus) is only one of the changes required in the process of changing these framework theories.

Conforming to the authors, we possess intuitive framework theories due to our everyday experience. With instruction a new scientific theory is partially synthesized with initial intuitive theory. We partially change our intuitive beliefs with the new information acquired. As a result, we construct synthetic mental models that are still inconsistent with the scientific theory due to ontological and epistemological commitments. Consecutive cycles of instruction are needed to refine ontological commitments and fully restructure a naïve framework theory. Thus, as non-experts are guided through instruction, they slowly revise their initial conceptual system, they add elements of scientific explanation and they create larger theoretical constructs with greater explanatory power.

Another similar and very influential approach is made by Neressian. This author provides evidences of the cognitive processes involved in individuals' conceptual change through, what has been called, cognitive-historical analysis (Neressian, 1992a, 1992b, 1999, 2002, 2006, 2008). Based on the ideas above exposed and on his own historical cases-studies of important episodes of theoretical change in the history of science (see section 2.1.1), Neressian uses the analytical tools of cognitive science to highlight the importance of model-based reasoning process as sources of conceptual change. Instead of studying the end point or products of science, Neressian studied and described how scientific models are constructed and reconstructed. The cognitive part of her method uses the psychological concept of mental model to describe the core of scientific theories as a flexible and dynamic entity. The historical part of the approach is provided by case studies given by the examination of scientists' historical data (as described in section 2.1.1.).

While the aforementioned knowledge-as-theory perspectives have wide support within the science education community, critical researchers have also proposed "knowledge-as-elements perspectives" for conceptual change. In this alternative point of view, students' understanding is characterized in terms of collections of multiple quasi-independent elements and conceptual change as a piecemeal evolutionary process (Özdemir, G. & Clark, D. B., 2007).

Hence in this theoretical position, naïve and scientific conceptual understanding is seen as grounded in multiple, small knowledge resource structures at various stages of development and sophistication. These knowledge structures (consisting on multiple conceptual elements such as phenomenological primitives, facts, facets, narratives, concepts and mental models) originate from abstractions from sensory-motor schemas. Novice can spontaneously connect and activate these knowledge pieces according to the relevance of the situation. Rather than a broad theory-replacement process, during conceptual change the elements and interactions between elements are revised and reorganized in order give a gradual increase in the degree of coherence and consistency in the application of the knowledge. Among these viewpoints, diSessa's perspective is the most accepted (diSessa, A., 1993; 1988).

Most current conceptual change researchers can be seen as adhering to one or other of the above four perspectives. Anyway, the descriptions presented above only outline the key features of the different perspectives in conceptual change. They are simplifications of the current perspectives, which, in fact, are more nuanced than what is exposed. In addition, theoretical accounts of conceptual change also consider, as part of the process, other dimensions such as the inclusion of emotional, motivational, sociocultural and meta-cognitive awareness (Pintrich, P.R, 1993;

Linnenbrink, E. A., & Pintrich, P. R., 2002; Sinatra, G. & Pintrich, P. R., 2003; Mason, L., 2007; Vosniadou, 2007).

Probably the complex processes of conceptual change are more like a convergence of all these ideas than a single truth (Özdemir, G. & Clark, D. B., 2007). Nevertheless, the identification of sources of conceptual change and research findings on this field have several implications for the design of curricula and pedagogical interventions. The awareness of the importance of intuitive knowledge, for example, challenges instruction to activate reasoner's representations. Instruction must search ways to make students aware of their ideas, and find ways to challenge them to abandon misconceptions and/or refine them over time by addition, modification, elimination, reorganization, etc. Many curriculum designs and instructional strategies to promote deep conceptual understanding of challenging concepts have been inspired by these reflections. As explained in detail in section 2.2., MCI is a clear example of that.

2.1.3. Social-constructivism

MCI is conceived within a constructivist paradigm of the teaching and learning practices. Nevertheless, and in the field of science education, there is a wide range of contrasting propositions and approaches under a "constructivism label" (e.g.: inquiry approach; problem-based, self-discovery, etc.). The basic principles underlying these different learning-instructional frameworks are not always the same, nor the implications for the analysis and proposal of specific school teaching and learning practices.

The aim of this section is, therefore, to clarify the background and general ideas essential to this thesis. This is basic to understand: (a) how MCI instruction for preservice teachers' has been conceived; and (b) which parameters have been considered to analyse preservice teachers' lesson plans. Further analysis of the specific implications to the understanding of MCI derived from these principles are later on discussed in section 2.2. Dimensions, categories, subcategories and operational criteria for lesson plan analysis are developed in section 4.5.2.

Several theories and principles constitute the backbone on which is based the constructivist conception of school teaching and learning held by this work (Coll, 1997, 2001). Among them worth mentioning: Piaget's theory of genetic epistemology (Piaget, 1970); the meaningful verbal learning subsumption theory and the use of advance organizers (Ausubel, et al., 1983); the cognitive schema theory and the modern information-processing theory evolved from the "Pittsburg School of cognitive psychology (highly influential from the 1970s through early 1990s); and the sociocultural theories of development and learning first announced by Vygotski and colleagues and then enriched by several authors within the 70's (Vigotsky, L.S., 1978; Bruner, J.,1986 …).

The core commitment of these theories and research traditions is that knowledge is not transmitted directly from one knower to another, but the learner actively builds it up. However and based on Driver and colleagues' ideas (Driver, et al., 94), this study recognizes that learning science involves both, personal and social situated processes. It considers that the above mentioned individual knowledge construction process is indissoluble from the communicative and cultural activity given in a school context. It agrees therefore, with the ideas developed by Coll and colleagues: that students' learning takes place in the context of their joint activity with their teacher, revolving around specific school tasks and content. It stresses, as well, teacher's mediating role in guiding and orienting these processes (Coll, 1997, 2001; Coll, et al., 95).

The specific constructivist conception of the school and learning practices that arises from the above statements it is not only a catalogue of the explanatory concepts and principles extracted from the developmental and learning theories named above. In addition, it aims to provide a genuine constructivist explanation of teaching and learning processes at school, through the inclusion of the aforesaid contributions into a whole logical scheme and through their reinterpretation on the basis of nature, functions and characteristics of schooling (Coll, 2001). Such idea can be schematized as in figure 3.

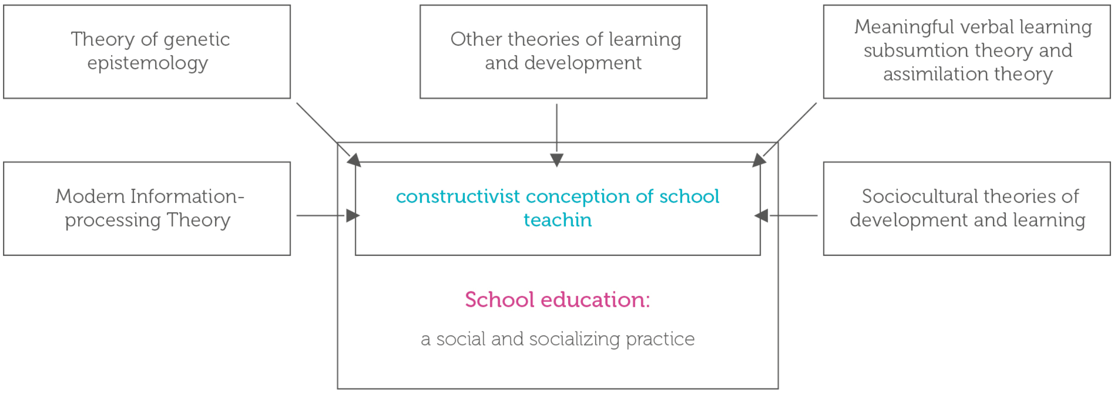


Figure 3. Constructivist conception of the school teaching and learning (Coll, 2001).

As a result of this reinterpretation and organization, the explanatory principles that constitute this conception are organized in a hierarchical structure with three levels (figure 4). As Coll argues, this structure overcomes the eclecticism from other constructivism approaches apparently similar. It also provides a strong internal consistency making it a particularly suitable instrument to derive from it implications for both practice and challenges for the development and theoretical research (Coll, 2001)

The first hierarchical level sets the coordinates within which the rest of principles are can be organized, integrated and interpreted. It conceives school education as an educational practice with its own specificities. It underlines its social nature and its socializing purpose. It also considers the relationship between personal development processes, learning, culture and education that help to define the social nature and socializing purpose of school education.

As a social practice, school education is conceived as one of the instruments held by a certain community to promote the personal development of their members. At the same time the development of personal skills occurs through the access to certain knowledge and skills considered essentials for the active participation within this community (Coll, 1997, 2001; Onrubia, 1996). Socialization and individualization are two sides of the same coin: the internalization of cultural content is ultimately the factor responsible for the development of capabilities that allow the live in a certain society (Coll, 1990, 2001).

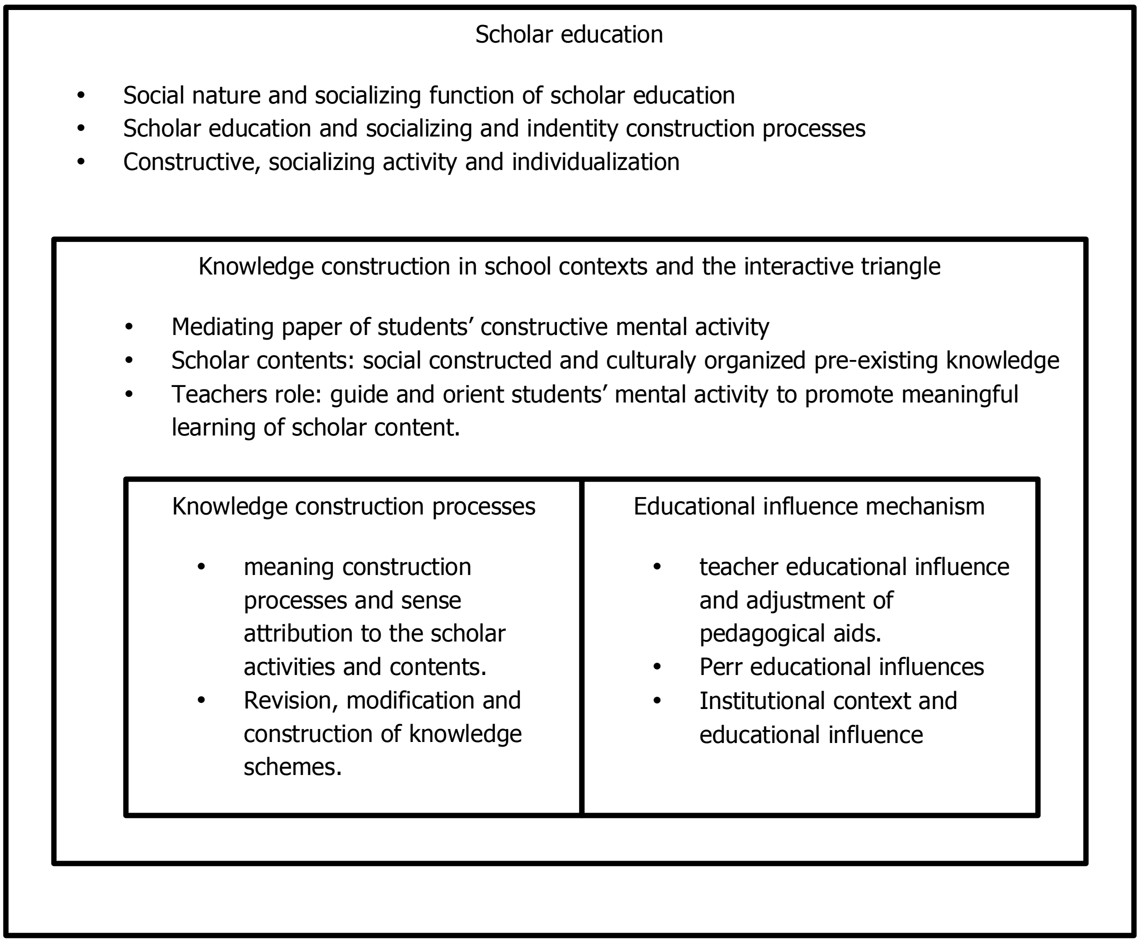


Figure 4. Hierarchical organization of the explanatory principles within the constructivist conception of the school teaching and learning (Coll, 2001).

The second hierarchical level identifies and outlines the relationships between the basic elements that are responsible for knowledge construction in a scholar context: the teacher, the students and the school contents. The ideas related to each of these three components are (Coll, 2001):

- The constructive mental activity of the students becomes the mediator element between the teaching and learning of school contents. Student contributions are indispensable to understand school learning as a process of personal construction or reconstruction of cultural knowledge. This idea is contrary to the passive and receptive roles of students in learning processes attributed in other conceptions (Coll, 1997).

- The constructive mental activity of the students applies over the school contents. These contents (established by the standards) inform of the cultural knowledge, rated as socially useful and adequate, that a certain community has selected, accepted and largely developed so that their members develop their personal skills and enter in this specific community. Students, therefore, do not have to generate new knowledge. They have to re-build and attribute meaning and significance.

- Although students can only learn contents deploying a constructive mental activity, attributing meaning and sense to pre-selected cultural knowledge, this is not enough for students to really learn what school aims them to learn. A third element is necessary: the teacher.

- The teacher's role is to favour the emergence of the student's constructive mental activity, guiding it through the design of adequate instructional processes, so that meanings and sense of scholar content can be constructed and attributed progressively by students. The teacher not only participates in the selection and proposal of what must be learned. It also acts as a mediator and modulates of the students' mental activity ensuring that the new knowledge builds in a way that reflects social and cultural content.

As above described, learning is not only the result of an active and constructive process held by students, nor a reflection of the teachers' intervention. Learning has to be understood within the context of the joint activity that teachers and students do, within a more or less prolonged period of time, and around specific school activities and content.

The interplay students-content-teacher allows to draw an interactive triangle that evolves over time. This interactive triangle represents the core elements of the teaching and learning processes that take place at school (Coll, 2001). This triangle has guided the proposed science preservice teachers' instruction plan (section 4.3.2.) and the analysis of lesson plans (section 4.).

The third and last hierarchical level refers to the interpsychological and intrapsychological processes involved in school teaching and learning. These are the factors specifically addressed in this research and, therefore, they are considered with a special interest. In this section, general commitments are presented and clarified. Section 2.1.4. discerns how these ideas and principles are framed within MCI.

Within this level, principles relate to: (a) knowledge construction processes; (b) mechanisms of educational influence. As it has been seen, those processes are, in fact, inseparable. Therefore, the purposed distinction responds to an analytical consideration rather than a real way to understand their relationship (Coll, 2001).

- From a constructivist point of view, acquiring a new knowledge requires that students establish substantial and not arbitrary relationships between their initial cognitive structure (conceptual knowledge, procedures, attitudes, expectation, motivations, interests, academic self-concept…) and the new knowledge. Experience and previous knowledge is used to anchor new knowledge in the existing schemes, thus building new meanings and making sense of new experiences and contents. A logical extension of the view that new knowledge is constructed from existing knowledge is that teachers need to pay attention to the incomplete understandings, the false beliefs, and the naive renditions of concepts that learners bring with them to a given subject. Teachers then need to build on these ideas in ways that help each student achieve a more mature understanding.

- Being activated by a new scholar content/activity, the "initial status" of the student may be totally or partially unsuitable. Then, it is necessary for a meaningful learning to occur, a "knowledge reequilibrium". This reequilibrium does not occur (as postulated by Piaget, 1978) spontaneously. To occur in accordance with the social and cultural meanings, it needs that an "expert" helps to develop it.

- Knowledge of a large set of disconnected facts is not sufficient. To develop competence, students must learn with understanding. Deep understanding of subject matter transforms factual information into usable knowledge. This understanding depends on the amount and quality of the relationships established between new and prior knowledge.

- To develop competence, must be also emphasised the importance of helping students to take control of their own learning. Learning to regulate one's learning, implies becoming increasingly autonomous in the processes of planning, control and assessment of learning. As it is later on discussed, the teacher plays a crucial role in guiding and orienting students' regulatory processes (Mauri & Rochera, 1997; Coll, 1997, 2001).

- Ausubel and colleagues (Ausubel, et al., 1983) point out three conditions for meaningful learning to occur:

  (a) the logical potentiality of the content: the new content must have an internal structure and consistency, it has to be relevant and meaningful.
  (b) the psychological potentiality of the content: the students must be able to put the new knowledge in relation with their previous knowledge and believes.
  (c) a favourable disposition of students: the student must be willing to learn significantly. He has to be deliberately and consciously decided to establish substantive relations between new and prior knowledge.

- This three conditions are pick up and reinterpretated by the constructivism view of the learning and teaching processes that reconceptualises them in relation to the interactive triangle and the relationships between its components.

- The quality of a meaningful learning is related with the capacity to organize new knowledge in a way that facilitates retrieval and "transfer"; that is, to allow the student to apply what he has learned in new situations and to learn related information more quickly and efficiently.

- Students' willingness to learn meaningfully is related to the sense that we can attribute to the content. This, in turn, is related to the affective, relational, motivational and emotional components of the learning processes (Solé, 1993).

  Therefore, knowledge construction and sense attribution become two inseparable aspects of the school learning process where cognitive, effective and emotional aspects are involved. Furthermore, those processes appear as a consequence of the interactions between the components of the interactive triangle. Within these interactions appear the mechanisms of educational influence.

  From the constructivist point of view, the educational influence can be defined as the general interpsychological processes that underlie specific scaffoldings and that help to promote and guide the construction of shared meanings around school contents

(Coll & Onrubia, 1999). To be effective, they are seen as aids offered to students within zone of proximal development (ZPD). The concept of ZPD was originally proposed by Vygotsky (Vygotsky, 1979) and designates the distance between what a person can do or learn by itself and what he/she can do or learn with the help and support of others with whom interacts.

Thanks to the interactions established with teachers and peers in the classroom, the students build ZPD that constitute the "spaces" where to put in place the processes of shared meaning construction and sense attribution (Onrubia, 1993). These processes can be favoured, encouraged and oriented through three different ways (Coll, 2001): with help and support of classmates; with teachers' interactions; and through the organization and functioning of the educational institution (Colomina Onrubia 2001; Colomina, et al., 2001)

Research on teacher-student interactions (Edwards i Mercer, 1988) has shown two basic mechanisms of educational influence (Coll, et al., 1995; Coll, 1997; Colomina, Onrubia & Rochera, 2001):

- Processes of progressive construction of shared meanings: refers to those scaffoldings used to help students to build knowledge. Implies a continuous process of negotiation between teacher and students around a particular task or content. Teachers' scaffoldings aim to connect with student's initial representations in order to modify them to some degree in the direction set by the educational intentions. Through a process of representation, elaboration and re-elaboration, teacher and students create and maintain shared knowlegde resources and a common frame of reference for their joint activity. This shared meaning is then gradually expanded, enriched, complexified… so that the student approximates to the cultural meanings of the social group.

  In this negotiation of shared meaning language occupies a pride place due to its dual function of representation and communication (Edwards & Mercer, 1988; Mercer, 1997, 2001). This dual fuction means that via language humans can present, contrast, negociate and modify their repreentations of reality in the course of their relationships with others (Coll & Edwards, 1997). Language is thus an essential tool in the construction of knowedge.

- Processes of progressive fading and transfer of responsibility: involve those scaffoldings aimed to promote students' increasingly autonomous and self-regulated learning process. Scaffoldings seek both: to increase students' capacity to use and manage the new knowledge; to help them to learn how to deal with the activities proposed. The main goal is learning to regulate one's learning process.

Both above mentioned processes can not be identified with one-time interventions within specific moments of the teaching-learning processes. They are described as complex, non-linear/discontinuos, differential and sometimes problematic processes that underly a wide range of actions that students and teacher perform while working jointly within a specific content or when solving a task (Colomina et al., 2001).

Rather than a theory "stricto sensu", the socio-constructivist conception presented in this section appears to be an explanatory framework that integrates various inputs whose common denominator is an agreement on the constructivist principles based on the constructive, cultural and communicative character of teaching and learning practices. MCI embaraces such conception, not as a "recipie book", but as an articulated set of principles from which diagnose, make judgments and take decisions about teaching. Specific details on how it is done, are considered in section 2.2.

2.1.4. Model-Centred-Instruction

MCI concerns a complex phenomenon, which occurs on many levels (individuals, groups, diverse cultures) and in both, informal learning (museums, zoos, activity centres…) and classroom education (Seel, N., 2003). In the field of research on mental models we can find a strong pedagogical impetus from the very beginning. The question on how can we create effective learning environments and materials as well as a variety of time and space structures to influence model-building activities of learners has been at the core of various educational approaches for a long time. The state of theory building on MCI has become more and more sophisticated and the learning and teaching strategies developed have become more and more complex over the past 25 years. According to Seel (Seel, N., 2003) this has led to the differentiation of several paradigms of MCI that can be, to a large extent, differentiated as:

(a) Self-organized discovery and exploratory learning: based on the idea that learners can construct models in an inductive manner either from a set of basic components of world knowledge or from analogous models already possessed.
(b) Externally guided discovery learning: based on the idea that learners can construct models based on everyday observations of the outside world.
(c) Receptive learning oriented toward an expert's behaviour or a teacher's explanation: based on the idea that learners can construct models based on other people's explanations.

In a general way it can be said that the conceptions of MCI include a broad spectrum of different facets and "visions". Furthermore, what also becomes evident in reviewing the literature on MCI is the general polarisation of researchers within those different paradigms and/or with different research backgrounds. It is not the aim of this dissertation to give a broad review of this literature, neither to shed light on the existing discrepancies between positions. The objective of this section is to review the background research to clarify and make salient the theoretical ideas that guide the present work. Therefore, literature review on this section focus on research with particular relevance for de development of the MCI framework that underlies this PhD dissertation, that is: the development of MCI according to socio-constructivism and conceptual change approaches in formal education.

Thus, and as already mentioned, the studies and theories reviewed in previous sections configure the background for the beginning of science model-based theories of learning and instruction that emerged during the last decades of the 20th century. On one hand, the crucial role of models in reasoning and in science practice (, Giere, 1988, 1999, 2004; Clement, 1988, 1989, 2003; Nersessian, 1992a, 1992b, 1999, 2002, 2006, 2008) provided the justification for the inclusion of models in science teaching.

On the other hand, the growing concern of educators and researchers about the importance of taking into account the ideas that students bring to classroom and the studies on how students change their preconceptions bringing them to scientific ideas established the basis for MCI according to socio-constructivism and conceptual change approaches (see previous sections).

Some of the first attempts to join model theory ideas with conceptual change are found on early works on using analogies to foster conceptual change in instruction (Glynn 1991; Clement, 1993; Treagust et al., 1996). Since then, there has been an increasing recognition of the role of models as important representational tools in science and science learning (Grosslight, et al., 1991; Gilbert, et al., 1998a, 1998b; Harrisson & Treagust, 2000; Adúriz-Bravo; 2009) as well as in describing instructional strategies (Justi and Gilbert, 2002a; Acher, A. et al., 2007; Rea-Ramírez, et al. 2008).

Research on mental models has led to the identification of important factors in learning and instruction. Several initial studies, for example, recognize that students create mental models in order to understand a new concept (Driver, et al. 1994; Neressian, 2002). However, educational research suggests that explanatory models may not be generated spontaneously from laboratory activities if the learning environment does not encourage and works explicitly the construction of such models (Schauble et al., 1991). Other studies pay attention on the process of understanding new concepts via model construction and criticism (Neressian, 1992b, 1999; Vosniadou, 2001). Differences between mental models held by experts and students have been also studied (Snyder, 2000).

In the process of learning and teaching science, it has been acknowledged that models and modeling practices make students develop higher order scientific thinking and skills. They enable, for example, explanations to be developed (Erduran, 1998; Gilbert et al., 1998c). They also provide a basis for the interpretation of experimental results and for predictions (Erduran, 1998). Furthermore, they provide a link between "real science" and "scholar science" (Erduran, 1998, Gilbert et al. 2000). Science education based on models and modeling practices reflects the nature of the parent discipline. Parallelisms between "expert-science" modeling practices and "scholar science" modeling practices can be found in works such as Justi, R., & van Driel, J. (Justi, R., & van Driel, J., 2006). Therefore, acquiring and understanding the role of models contributes on the development of metacognition to understand the inquiry process in the science community, getting familiar with the development and construction of knowledge, and individually reflecting on the understanding of scientific knowledge (Gilbert et al. 1998; Erduran, 1998; Clement, 1989; Harrison & Treagust 2000; Schwarz & White, 2005; Windschitl et al., 2008a).

More recent studies reveal that model instruction enables students to transfer modeling abilities to science learning and inquiry (Schwarz & White, 2005; Windschitl et al., 2008a). To this aim, research reveals that these modeling practices need to be systematically and cumulatively built and fostered, starting as early as kindergarten, rather than taken them for granted or simply being "injected" at a specific high school level (Lehrer & Schauble, 2010). Supporting this argument, different studies demonstrate the possibility of implementing this type of practice in primary schools (e. g. Acher et al., 2007; Schwartz et al., 2009).

From the very beginning, all the above mentioned research has oriented different single students/class-experiences and curriculum reform efforts, some of them with remarkable success (e.g. Clement & Steinberg, 2002). Nevertheless, it was not until the beginning of the 21st century that started to appear unifying comprehensive frameworks to develop an expanded pedagogy and a set of teaching strategies for fostering model construction in science classrooms (e.g. Clement, 2008; Neressian, 2002).

Contemporary studies of scientific work demonstrated that inquiry is becoming routinely situated in model building, testing and revising (Clement, 1989; Neressian, 1992b). Scientists generate knowledge by using refined versions of non-formal representational practices that result from ordinary reasoning and representational processes (Nersessian, 1992b). Neressian called this process "constructive modeling" (Nersessian, 1995), while Clement described it as "generation, evaluation, and modification cycles" (Clement, 1989, 1993). Both authors stated that these kinds of practices were relevant to learning, and encouraged the use of these iterative processes for fostering learning in science. Nevertheless, none of the authors provided, at this time, descriptions about how this process of model construction-revision takes place when two or more subjects are interacting. They did not provide, as well, specific guidelines about how to guide instruction.

Some time later, Clement & Rea-Ramirez (Rea-Ramirez & Clement, 1998) converged with Nersessian (Neressian, 1999) in that the learning process about model construction involves the emergence of successive intermediate models. This fact was explained by using the idea of "cognitive dissonance". Rather than being replaced or eliminated through disequilibrium (as it was postulated by Piaget's equilibrium theory), they stated that models might be transformed through the introduction of successive cognitive dissonances which create mild or strong episodes of dissatisfaction between the new acquired knowledge and the existing one (Rea-Ramirez & Clement, 1998).

They proposed that the existing model might be compared with external sources (i.e. counterexamples, discrepant events, analogies…) or internal sources (i.e. incoherence between two conceptions). This comparison may cause dissatisfaction because either: (a) students sense a gap in what the initial model can explain (the initial model cannot explain some events); or (b) students sense presence of a conflict between the new/old ideas.

Rea-Ramirez emphasized, as well, the key role of the teacher as "a co-constructor of knowledge with the students". Through the study of students' specific reactions to specific teaching strategies she was able to describe the underlying model based reasoning that occurred. She defined the teacher/student co-construction process as a highly complex process where both, students and teachers contribute ideas to build and evaluate a model (Rea-Ramirez, 1998).

In 2000, Clement presented a linear framework for thinking about cognitive aspects involved in model construction during instruction (Clement, 2000). Based on these factors, he elucidated basic knowledge and skills required to produce a scientific model successfully and provided practical guidance on how to promote them within an instructional environment. He postulated that the learning-instructional process of model construction should be directed at moving students from an initial model (Mn) to a more sophisticated one (Mn+1). Based on the ideas of Scott (Scott, 1992), he also described the emergence of intermediate models as "learning pathways".

Other theoretical comprehensive rationales appeared concurrently. Neressian for example, proposed a theoretical framework to explain how model-based reasoning could be generative of conceptual change in science (Neressian, 2002). Justi and Gilbert also presented their "model of modeling diagram" which enlarged Clement's schemes introducing new elements and making explicit the relationships between them (Justi & Gilbert, 2002a). All these studies supposed a new and modern approach to model construction in classrooms. More encompassing ones had been suggested before (i.e. Strike and Posner, 1992), but those works unified previous research providing basic vocabulary and common foundations and representing a step forward to provide guidance to teachers.

From this turning point in the MCI research onwards, several studies have seek to describe in more detail the interaction between teacher and students while building a model (see Rea-Ramírez, et al. 2008). Efforts have also been directed to contribute to develop a learning progression for scientific modeling (Schwartz et al., 2009). Different instructional frameworks have been used and tested in classrooms (Acher et al., 2007; Kenyon, et al., 2008; Windschitl, et al., 2008a; Couso, D. et al., 2009; Schwartz et al., 2009;). And, recently, research has focused on the design, use and investigation of in-service and preservice teacher learning experiences and materials regarding models and modeling practices (Schwarz, C., 2009; Kenyon, L. et al., 2011).

Overall, all these researches contribute to build a cognitive theory of conceptual change based on models. Furthermore, they add evidences to construct coherent instructional frameworks to develop teaching-learning environments that make the modeling practice accessible and meaningful for learners. They also explore how to help teachers to achieve learning goals associated with scientific modeling. All these foundations constitute the reference for the instruction design and analysis held on this research. Therefore, details are presented in section 2.2.

2.2. Model Centred Instruction a general overview.

Based on areas of agreement in the literature above reviewed, the objective of this section is twofold:

(a) To present the modeling instructional framework that underlines this research.
(b) To clarify and make salient the theoretical ideas that guide the present work.

Teaching-learning with and through scientific modelling –here referred as Model-Centred Instruction (MCI)- implies a serious reconceptualization of schooling in which teachers play a crucial role. Model centred instruction (MCI) makes three basic contributions to science education (Nelson & Davis, 2012):

- First, the formation and evaluation of mental models is central to construct an epistemological science conception more in touch with the current view of the nature of science.
- Second, the development and experimental testing of models supports authentic science inquiry-based learning. Students gain experience with multiple authentic procedural aspects of learning and doing science, including making sense of data, generating and revisiting predictions, and engaging in scientific argumentation, consistent with science education standards and reform-oriented goals for students' science learning.
- Finally, scientific models are major outcomes and products of scientific inquiry, and understanding the nature of science requires an understanding of these models within a philosophical, scientific and historical context.

In addition, the MCI framework presented in this research and situated into a social constructivist paradigm, entails a challenge not always considered in other science learning-teaching approaches: the recognition of the importance of the mechanisms of educational influence in terms of assisting students' constructive activity. The acknowledgment and acceptance of this statement implies focussing in both learning and teaching processes. The aim, therefore, is to better understand how students learn a specific content and, above all, to understand how mechanisms of educational influence within a science classroom help students to construct these understandings.

As explained in section 3, this is one of the main objectives in this research and, therefore, this aspect is further developed later on in this section. First of all, however, some of the cognitive aspects of this teaching-learning framework are highlighted.

In a general way it can be said that MCI provides understandings of specific underlying reasoning mechanisms that allow to explain how scientific ideas can change throughout instruction and how materials and/or interactions can affect to this change. As mentioned in the literature review (see section 2.1.1), in this theory, reasoning depends, not on logical form, but on mental models.

Model creation and model-based reasoning are key processes of both human cognition and the development of scientific knowledge (Schwarz & White, 2005; Justi & Gilbert, 2002a). Mental models are produced by the ability of human mind to mentally picture the reality (Johnson-Laird, 1983) and can be considered as structural analogs of real-world or imagined situations (Neressian, 1992b). The structure of the mental model maintains the perceived structure of the external system (Johnson-Laird, 1983). At a fist instance, mental models are internal but they can be shared and released becoming expressed models when any symbolic representation system is used to outcome them.

In the construction and use of scientific knowledge, regardless of the form of representation used, models are representations through which the scientists reason (Clement, 1989; Giere, 1999; Gilbert & Boulter, 1993; Nersessian, 1999). A "scientific model" is an abstracted representation of objects, systems or phenomena, whose central features are highlighted, and which may be used to make explanations or predictions (Harrison & Treagust, 2000; Gilbert, et al., 2000). Therefore, and as outlined by Schwartz and colleagues and as shown in figure 5, models can be used to help scientists (and learners) generate new understandings (sense making) or communicate their understandings to others (Schwarz, et al., 2009).

Furthermore, scientific modeling process (also referred as model practices) entails two interrelated and mutually supportive aspects: elements of the practice and metamodeling knowledge (see figure 5). Both aspects often occur simultaneously, although one or the other may be foregrounded at a particular time (Schwarz, et al., 2009).

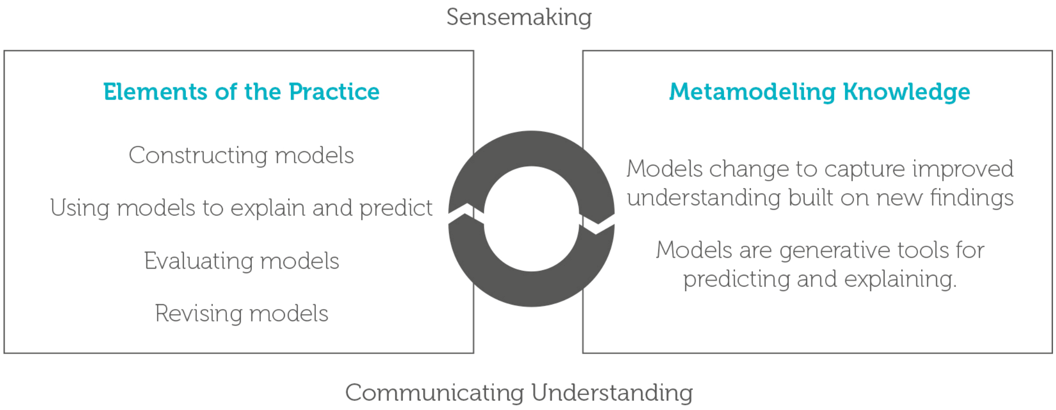


Figure 5. Modeling practice as the interaction of the elements of the practice and the metamodelling knowledge. The two types of goals, sense making and communicating understanding, each emerge from the use of the practice elements and metamodeling knowledge (Schwarz, et al., 2009).

Modeling elements imply creating, testing, revising and using scientific models. Constructing a model entails identifying the salient features of the system or phenomenon under consideration and determine how those, and the relationships among them, can be depicted or represented. The model is then used to illustrate/explain a system, explain a system or phenomenon, or to make predictions about a phenomenon. The model is evaluated and revised in light of findings, to attend new evidence, address additional aspects of a phenomenon, or increase their explanatory or predictive power.

As it can be seen in the diagram proposed by Justi and Gilbert (Justi & Gilbert, 2002a) shown in figure 6, a "scientific modeling process" establishes a dialogic relationship between model and phenomenon. Data obtained from experimentation/observation are subsequently analyzed for patterns and then used as evidence to support or disprove aspects of a scientific model. That makes possible to refine the model in relation to its elements, relationships and operations, while indicating its limitations. Anyway, any proposed model must be coherent with the available evidence and has to account for canonical constructs.

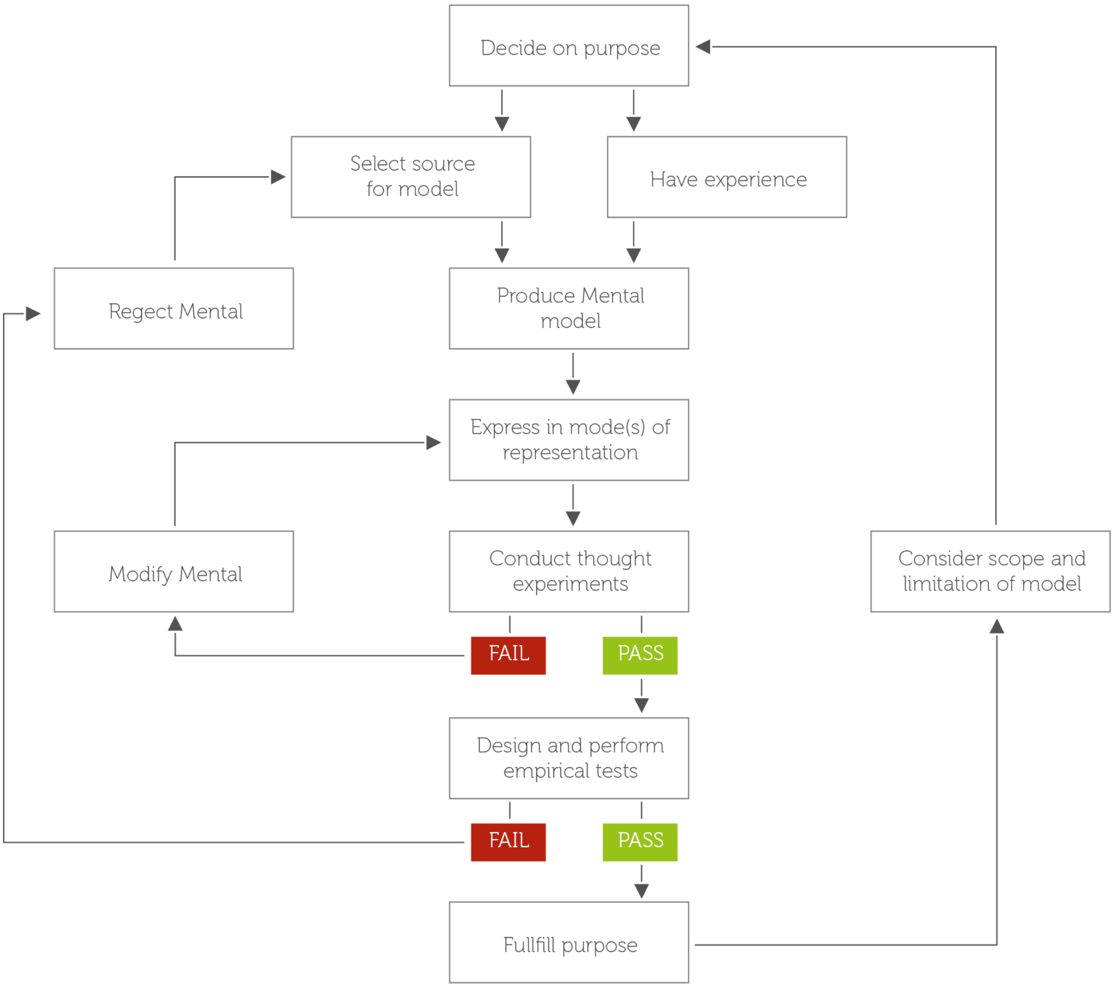


Figure 6. Scientific modelling process (Justi & Gilbert, 2002a).

In practice, these four elements of model practice are non-sequential and iterative. One can go through multiple rounds of evaluation and revision before using the model to make further predictions. Or, one might take a model previously constructed for a different purpose and retool it to explain an alternative phenomenon. Throughout the process, the emphasis lies not only in the usefulness of models for communicating ideas, but also in the power of modeling for constructing new explanations.

Metamodeling knowledge is the underlying understandings about scientific models and modeling processes that inform and strengthen the practice (Schwarz & White, 2005). This meta-knowledge includes an awareness of the nature and purpose of models as well as the inherent characteristics of the modeling elements. A compilation of main aspects of metamodeling knowledge is proposed by Schwarz and colleagues and it is summarized in figure 7 (Schwarz, et al., 2009).

Nature of models

- Models can represent non-visible and non-accessible processes and features
- Different models can have different advantages
- Models are representations that have limitations in what they represent about phenomena
- Models can be changed to reflect growing understanding of the phenomena
- There are multiple types of models: diagrams, material models, simulations, etc.

Purpose of models

- Models are sense-making tools for constructing knowledge
- Models are communication tools for conveying understanding or knowledge
- Models can be used to develop new understandings, by predicting new aspects of phenomena
- Models are used to illustrate, explain, and predict phenomena

Criteria for evaluating and revising models

- Models need to be based on evidence about the phenomena
- Models need to include only what is relevant to their purpose

Figure 7. Components of metamodeling knowledge (Schwarz et al. 2009)

The above paragraphs and schemes summarize main cognitive process of knowledge constuction within MCI. However and as already mentioned at the beginning of this section, the MCI framework assumed by this research seeks to place cognitive processes of knowledge construction in close continuity and interaction with teaching processes with the aim to understand how mechanisms of educative influence aid personal knowledge construction. Thus, the next paragraphs describe the in detail the teaching-learning processes as understood within this MCI framework and situate the mechanisms by which teachers adjust their assistance within context of the join activity that takes place within science MCI classrooms.

As a pedagogical tool and as it has been previously noticed (section 2.1.3), one of MCI's theoretical starting points is the constructive, cultural and communicative character of the teaching and learning processes. Science learning is seen as a process of enculturation rather than self-discovery. Learning science involves students entering into a new community of discourse, a new culture. It implies being introduced into a different way of thinking about and explaining the world; becoming socialized to a greater or lesser extent into the practices of the scientific community with its particular purposes, ways of seeing, and ways of supporting its knowledge claims (Driver et al, 1994).

Within MCI the learning and instructional pathways become indissoluble (figure 8). Learning is considered to involve both personal and social processes (Driver et al, 1994; Coll, 2001). It is true that, ultimately, students have to make personal sense of these newly ways of viewing the world. Thus, learning is a personal process in so far as the learner constructs-attributes meaning to the content as internal dynamic of his her own. However, this appropriation of scientific ways of knowing is not something that students discover for themselves. On a social plane, the cultural nature of the content marks the direction in which this personal constructive process should be guided from outside. Likewise, the teacher becomes responsible for presenting classroom activities that offer suitable guidance for the personal construction processes.

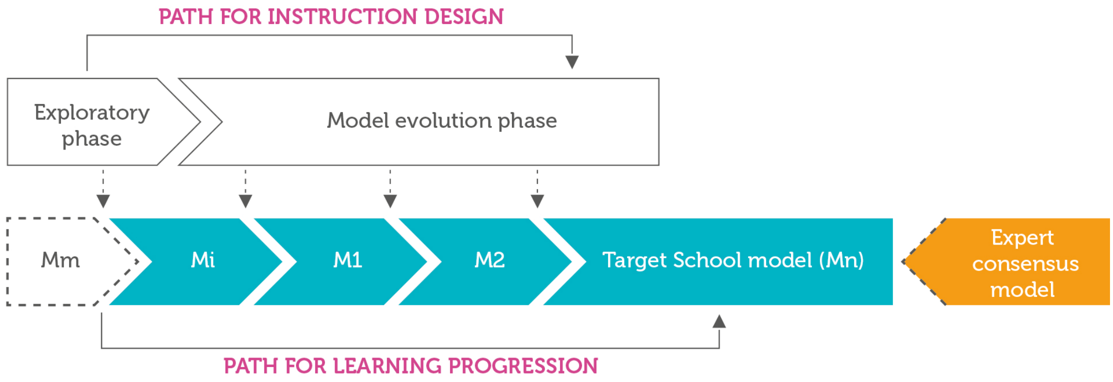


Figure 8. Learning and Instruction-design pathways for MCI (adapted from Clement, 2000).

Students' initial mental models (Mm) are seen as the starting point for the learning-instruction design pathways (figure 8). As above noted, MCI considers that knowledge cannot be transmitted but must be constructed. It believes, as well, that meaning is made by individuals and depends on their current "internal representations". This "internal representations" have been broadly referred as preconceptions, intuitive knowledge, alternative ideas, intuitive ideas, misconceptions…. They represent the natural reasoning skills presented before instruction and, in MCI, they are considered to depend on mental models (see above and sections 2.1.1. and 2.1.4. for larger explanation).

Mental models (Mm) are individually drawn on to interpret the phenomena of daily lives. Initially, they appear as "commonsense" ways of explaining phenomena, and represent knowledge of the world portrayed within everyday culture. They are strongly supported by personal experiences and socialization. Research has also shown that they are not completely idiosyncratic: within particular science domains there are commonly occurring informal ways of modeling and interpreting phenomena that can be either in accordance/compatible or in conflict with the knowledge accepted by the scientific community (e.g. Driver et al., 94; Clement, 2000; Vosniadou, 2001).

Initial mental models can be either in accordance/compatible or in conflict with the accepted scientific knowledge. Lingering incongruent mental models form a faulty basis for future learning and can thwart understanding of new content and concepts. On the contrary, compatible knowledge, can serve as the foundation in which to construct new shared meanings. The implications of this for teaching is that there is a need to elicit learners' mental models (referred as Mi, in figure 8) in order to design appropriate instruction.

Students' intuitive ideas and informal reasoning skills can differ from the knowledge of the scientific community in a number of ways. First of all, everyday and scientific discourses differ in the ontological entities they contain. Secondly, commonsense reasoning (although it can be complex) tends to be tacit or without rules. In contrast, scientific reasoning is characterized by the explicit formulation of theories that can be communicated and inspected in the light of evidence. Finally, everyday reasoning is characterized by pragmatism: ideas are judged in terms of being useful in specific situations/for specific purposes. They do not seek to construct a general and coherent picture of phenomena, like happens with science. On the contrary, the scientific endeavour is to strive for models with the greatest generally scope (Driver, et al. 1994).

For this reason and as broadly supported by research (Chi, 1992; Pozo 1999, Vosniadou, 2001), addressing the challenge of conceptual change in science, is a very large and challenging task (see section 2.1.2). Intuitive conceptions that differ from scientific knowledge are often very difficult to overcome. Most of children's (and non-expert) intuitive ideas about science are persistent. They undergo no change in response to teaching or, if they do change, it is not in the direction intended by the teacher. Furthermore, and based on ideas on zone of proximal development (see section 2.1.3.), lessons of instructive actions that attempt to cause students giant leaps from initial models to scientific conceptions often fail to succeed.

However, and according to different researches (Driver et al. 1994; Pozo 1999), learnig of science does no entail, necessarily, abandoning commonsense reasoning. Human beings take part in multiple parallel communities of discourse each of with its specific practices and purposes. Learning science implies integrating thosehierarchically and devise ways of representing the world in a new system in which scientific knowledge take on new meaning, leaving commonsense ideas available to them for communication within appropiate social contexts.

With all these ideas in mind, which concepts are determined to be important and how instruction is structured becomes central. There appears to be a need to set up realistic goals for instruction that take into account students' initial models and, regarding these objectives, develop a series of appropriate strategies that will allow the students to gradually test and modify their models (figure 8). Within the MCI framework underlying this research, this involves the identification of target models (referred as Mn in figure 8).

Target models are built on core ideas/concepts of science. They are powerful exploratory models that have the far-reaching ability to explain a board range of observable phenomena. They involve concepts and principles that help to make sense of a broad variety of phenomena, situations and problems, and that may encompass knowledge within a single or across multiple disciplines (Rea-Ramirez, M. A., 2008).

Target models mirror on expert consensus models but they are less sophisticated than them. In some cases, they may reflect qualitative, simplified, analogue, or tacit knowledge not recognized by experts. Therefore, once achieved, target models become internal mental models that are more scientifically correct than students' initial ones and that can be effectively used to explain real life situations although they may not be absolutely correct or complete at the expert level (Clements, 2000; Rea-Ramirez, M. A., 2008).

To be appropriate, target models do not only have to fit with science. They also have to be aligned with the Standards and with the developmental level of the students. In addition, final target models represent the upper anchor at one end of a learning progression but, along an instructional pathway leading to a complex concept (e.g. density) and in order for meaningful learning to take place, teachers need to identify which intermediate ideas must be selected and taught (e.g. matter is made of particles; mass as quantity of particles, etc.), with an eye to how these will connect with and inform the more sophisticated models that students are building toward understanding. As shown in figure 9 Rea-Ramírez (Rea-Ramirez, M. A., 2008) represent such nested set of target models as tree.

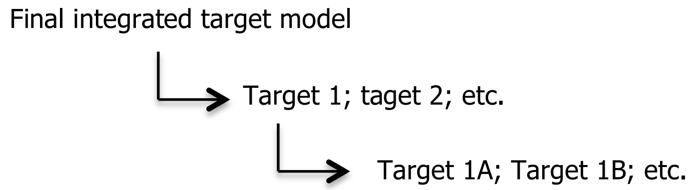


Figure 9. Nested structure established between target and subtarget models leading to a complex concept (Rea-Ramirez, M. A., 2008)

Once a set of subtarget models and the final target are established, the mechanisms of education influence can operate. It is at this point that the instructor can focus on designing reasonable strategies to assist students in moving from one model to another.

Since the constructivist statement of apprenticeship and education views learning as a process of constructing meaning and sense attribution that occurs as a result of constructive mental activity of students (see section 2.1.3), it is obvious that educational influence can not replace it. This educational influence can only be understood as an aid to the learning process. However, this aid is both necessary and essential, as it is thanks to it that the students construct meanings and attribute sense to the contents in the direction set by target models (Coll, 1987; 1990b; 2001). Nevertheless, for this aid to really help to construct meaningful learning it is necessary that teachers adjust their assistance over the course of the joint activity.

According to Coll and Onrubia (Coll & Onrubia, 1999) and taking into accound the specificities of science content and MCI, this entails different conditions:

a. the teacher must take, as starting point, students' elicited mental models, which represent the set of meanings and sense from which students address new learnings.
b. instructor must help students criticize their current models, make modifications, and test the new mental models. To do so, he must pose affordable challenges, which means creating zones of proximal development within the join activity and provide help within these areas (Onrubia, 1993).
c. aid must be varied in quantity and quality and must be modified in accordance to students' responses.
d. aid must be, obviously, coherent with target models (and therefore expert knowledge).
e. aid must promote, as well, the dialogic relationship between model and phenomenon outlined in "model of modeling diagram", figure 6.

Hence, in developing a learning pathway, the instructor needs to not only determine the final target and intermediatge target models, but think about which strategies will help in the criticism and revision cycles necessay to move students to the next target model. These small instances of model construction result in what has been called "intermediate models" (M1, M2…. in figure 8), which act as stepping-stones for the students construction of target models that are progressively more complex and expert-like (Clements, 2000; Neressian, 2002; Rea-Ramírez, et al., 2008).

As above described, learning appears as an outcome of a model evolution process with different cycles of model creation-evaluation-revision-use in light of obtained data-evidence. Likewise, instructional efforts are focused on helping students to make this progression on mental models through a series of systematic, planned strategies and activities that promote specific transitions between the initial states of the learning process (initial mental models) and the desired end states of learning (target models).

Within the context of the join activity, the teacher (familiar with the "scientific way-of-seeing"), makes the cultural tools of science available to learners and supports the (re)construction of students' ideas through the creation and maintenance of shared meanings. Therefore, the mechanisms of educational influence take place in the scope of the joint activity that students and educators display around the contents and learning tasks, doing so via the organization patterns adopted by this activity and the existing semiotic resources in the participants' language. Nevertheless, for communication and joint activity to be possible, the participants must share perspectives and a certain representation of the situation, which can be attained only through a process of negotiating the different definitions or inter-subjective representations that participants have in the interaction. This fact can be attained only through an adequate evaluation of the context of construction of shared meanings and the use of appropriate forms of semiotic mediation.

Curriculum guides and research literature are full of strategies that have proven benefitial in helping students' construction of understandings (e.g. Izquierdo et al., 1999; Clements, 2000; Schwarz & White, 2005; Windschitl et al., 2008b; Kenyon, Schwarz, & Hug, 2008; Schwarz, 2009). Nevertheless, unlike target models, students' intermediate models may vary in response to the preconceptions hold by students and their specific needs (Rea-Ramírez, M.A, et al. 2008). Knowledge on science intuitive reasoning (see section 2.1.2.) can help us to determine some of these intermediate models prior to instruction. Therefore, having a sound basis, grounded on research, to design strategies of adjusted assistance prior to instruction, will promote more efective model construction "than simply relying on a collection of activities without thought to what intermediate model is to be constructed next and what the effect of the strategy is on the model constrcution process" (Rea-Ramírez, M.A, et al. 2008).

However and regardless their initial planification, during the context of the join activity, the instructor must ultimately adjust their assistance, making an "on the spot" decision regarding to students response. It is just at this point that emerges the essential point of the adjusted assistance which must take into account the temporal dimension of the learning-instructional processes.

To sum up it can be said that, as a pedagogical tool, modeling practice is a non-linear, iterative approach to learning science content, in which students take an active, evidence-based role in reshaping their own conceptual understandings of the science content (Schwarz et al., 2009). In a scholar context, modeling practice also involves cycles of model construction, exploration of model characteristics, applying the model to a specific problem, evaluation and revision, resembling authentic activities of scientists and mathematicians.

Engaging in these elements of modeling practice can promote the development of epistemological metamodeling knowledge (MMK) (Schwarz & White, 2005) about models and modeling. Indeed, and in order not to turn the practice into a senseless sequence of steps, involving learners in modeling practice requires that they understand the what are models, why are they useful/how can they be useful as well as the rationale norms that govern the modeling practice.

Finally, within this context, the instructor appears as a key element to ensure that knowledge construction is carried out in the appropriate direction and degree of significance. In developing a learning pathway, the teacher must determine not only the target models but also think what sort of aids; in which sense and orientation; and when and how they have to be offered in order to promote an educative influence adjusted to the different moments and situations that appear within the constructive process held by students.

To conclude this section, just notice that the above review reveals us the essential features of the MCI framework underlying this research. These issues have been used as a basis to determine the different dimensions for lesson plan analysis as detailed in section 4.5.2.

2.3. Preservice Teacher education for MCI

On the basis of the literature available, learning how to model and about models appears to be an ambitious, lengthy and not so easy process (van Driel & Verloop, 2002; Justi & Gilbert, 2002a i b; Windschitl, et al., 2008b, Schwarz, 2009). The progressive introduction of students to the understanding of scientific models and modeling practices requires that their teachers have, themselves, an appropriate understanding of what scientific models and modeling process are. At the same time, it entails that teachers know how to apply this knowledge for pedagogical purposes (Windschitl, 2003; Windschitl & Thompson, 2006; Kenyon, et al., 2011; Nelson & Davis, 2012).

When they come to the university, many preservice elementary teachers lack of experience with reform oriented science teaching-learning strategies such as MCI (e.g., Haefner & Zembal-Saul, 2004; Windschitl, 2003). Furthermore, while many scientific practices (such as experimentation; forming-testing hypothesis) are somewhat familiar to them, many others, like scientific modelling, are not (e.g. Harrisson & Treagust, 2000; Justi & Gilbert, 2002a; Justi & Gilbert, 2002b; Windschitl & Thompson, 2006; Windschitl et al., 2008a; Windschitl et al., 2008b; Schwarz et al., 2009; Kenyon et al., 2011). In addition, most of them have weak science subject matter knowledge (Abell, 2007) and are unfamiliar with learners' ideas about science content and scientific practices (e.g., Gomez-Zwiep, 2008; Otero & Nathan, 2008).

On the other hand, and although things have slowly begun to shift, many of these preservice students have not still the chance to experience effective, reform-oriented science teaching during their training period in schools (e.g., Lotter, 2004; Crawford, 2007; Watters & Diezmann, 2007). Indeed, many studies demonstrate that scientific modeling is rarely incorporated into educational experiences of elementary or middle school students for anything other than illustrative or communicative purposes (Kenyon, et al., 2011). Teachers typically employ models to reach science content goals and not to teach about the nature of science or scientific practices (Justi & Gilbert, 2002b; van Driel & Verloop, 2002).

Model-based pedagogy approaches are often unfamiliar and struggling for teachers, specially beginning ones (Justi & Gilbert, 2002b; Windschitl and Thompson 2006; Windschitl et al. 2008; Schwarz, 2009; Nelson & Davis, 2012). Novice (but also many experienced) teachers have weak metamodeling knowledge. They have a limited experience with sophisticated models and hold flawed ideas about the practice of modeling (Justi & Gilbert, 2002b). Overall, this restricts their ability to structure quality modeling experiences for their students.

Based on these statements, it seems evident the urgency to enhance the development of a solid pedagogical content knowledge –PCK- (Shulman, 1986) base regarding these instructional strategies (Windschitl & Thompson, 2006; Windschitl, et al., 2008b).

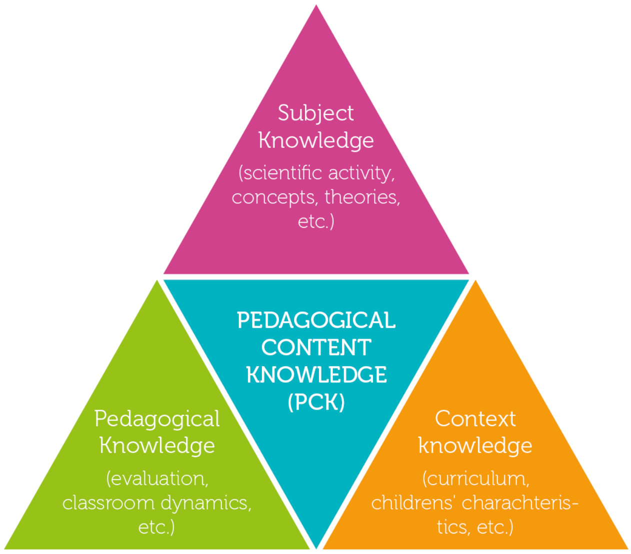


Figure 10. Components of pedagogical content knowledge (Magnusson, et al., 1999).

Although theorists still debate the semantics of PCK, most agree that it is the amalgam of specialized knowledge and skills needed to teach an specific subject, involving, somehow, the merger of subject matter knowledge, pedagogical knowledge and unique characteristics of the specific instructional context –see figure 10- (e.g. Magnusson, et al., 1999; Shulman, 1986). Regarding this general idea, the notion of PCK for scientific modeling –see figure 11- (Schwarz & White, 2005) builds upon the theoretical and practical work of many others, both in science education and in education more broadl.

Magnusson and colleagues (Magnusson, et al., 1999) have described pedagogical content knowledge in science teaching as consisting of five components: orientations toward science teaching, knowledge and beliefs about science curriculum, knowledge and beliefs about students' understanding of specific science topics, knowledge and beliefs about assessment in science, and knowledge and beliefs about instructional strategies for teaching science. Others have described PCK for scientific modeling with respect to these five aspects and using science modeling as a lens (Justi & Gilbert, 2002; Justi & van Driel, 2005; Schwarz & White, 2005). Building upon this knowledge base, components of PCK for scientific modeling can be schematized as shown in figure 11.

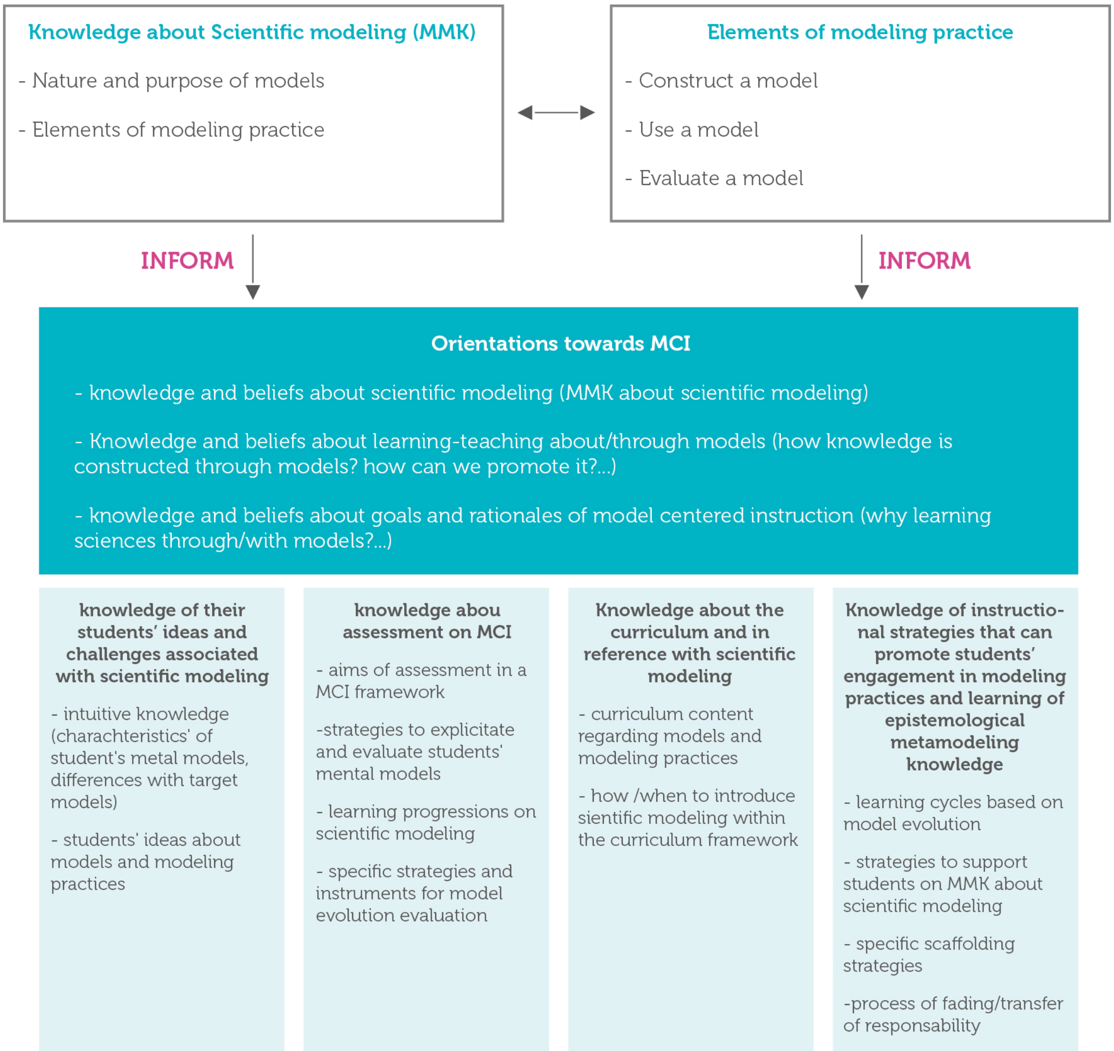


Figure 11. Components of PCK for scientific modeling. Based on the general PCK for science education proposed by Magnusson, et al., 1999 and adapted from Cotterman, 2009.

As it can be seen, MMK of scientific modeling and modeling practices inform PCK for scientific modeling that incorporates general orientations towards modeling practices. PCK for scientific modeling is filtered through teachers' context and curriculum. Therefore, knowledge about both aspects is essential and would have a clear impact on how to enact modeling in a specific classroom. It also incorporates teachers' knowledge of students' ideas and the challenges they face associated with elements of modeling practice and metamodeling knowledge. Finally, it also includes instructional strategies that can promote students' engagement in the elements of modeling practice (i.e., constructing, using, evaluating, and revising models) and learning of metamodeling knowledge; as well as knowledge about aims, rationales and specific strategies for assessment in MCI. Although these different aspects of a teachers' knowledge base appear as separated items; of course, in reality, they are (or should be) all integrated and closely linked.

We still know little of *which* experiences influence the thinking of novice educators and *how* different forms of scaffolding used in multiple learning contexts support the development of more sophisticated epistemic discourses (Windschitl, et al., 2008b).

However, we know that carefully designed courses and experiences foster the development of teachers' and preservice teachers' PCK. Both implicit and explicit guidance help teachers to become more familiar with what scientific model is and what these inquiry-oriented pedagogies entail (Justi & van Driel, 2005; Kenyon et al., 2011; Schwarz, 2009; Windschitl & Thompson, 2006; Windschitl, et al., 2008b; Cotterman, 2009; Nelson & Davis, 2012).

Teacher educators can promote preservice teachers' PCK for modeling by using inquiry-based investigations that engage teachers as learners of science content and practice. In these experiences, teachers reflect on the nature and purpose of models, and they create, use, evaluate and review models (they experience, themselves, MCI). After walking through the experience as students, they leave his role and reflect on the instructional design and rationales that have framed their experience. Explicit guidance (lectures, discussions, readings, etc.) helps teachers to connect the associated pedagogy and provides overt rationales for specific instructional strategies (e.g., Cotterman, 2009)

Analysing, reviewing and modifying existing curriculum materials to infuse a modeling focus, can also help teachers and preservice teachers to reinforce their PCK (Davis, 2006). Instructional curriculum science materials do not align with current ideas on MCI and lack in authentic representations of scientific modeling (Kenyon, et al., 2011). In learning how to effectively critique and adapt these materials using a modeling lens, preservice teachers not only engage in an authentic teaching task, but they also reinforce ideals about how students should

On the same way, different authors have point out the fundamental role of planning in linking curriculum to instruction. The process of planning is seen as an integrated way to deepen scientific knowledge and incorporate didactic innovations didactic (Duschl & Wright, 1989). Furthermore, by developing, teaching and reflecting on their own model-based instructional designs teachers can also develop and reinforce their nascent PCK (Cotterman, 2009). Nevertheless, to effectively transfer their conceptions to the classroom, as well as academic knowledge, teachers need not only to have the opportunity to plan and teach particular topics, but also to explicitly have available the appropriate techniques and strategies to do so (Bell et al., 2000). In this sense, Lederman (Lederman, 1999) pointed out that beginning teachers have to develop a variety of instructional routines and schemes that allow them to feel comfortable with the organization and management of instruction.

Once the development of PCK is initialized, it is very important that teachers have the ample opportunity to put their knowledge into practice. Promoting and providing guidance to reflect on their own classroom teaching helps to internalize and further develop this basic understanding of the practice (Cotterman, 2009).

In closing, is worthy to mention that the above described frameworks for MCI and PCK for scientific modeling inform our instructional designs for promoting teacher learning (see section 4.3.2). At the same time, they have been used as a reference to create a new tool for students' lesson plan analysis (see section 4.5.2) and in order to discuss the obtained results (chapter 6).

3. Problem Statement, research questions and hypothesis

Building on the theoretical framework described in the previous section, this study examines the development of preservice teachers' PCK for MCI when given modeling centred instruction during their pedagogical science preservice university courses. As already mentioned in the introduction, the main goal of this thesis is to examine the ability of preservice teachers to translate their understandings on MCI into model-centred science lesson designs.

Therefore, this study explores the following research questions, for each of which, the corresponding hypotheses are also announced.

RQ1: When preservice teachers are engaged in MCI in their pedagogical science university courses, does their PCK for MCI improve? And, if so, how does it improve? Specifically:

RQ1a: How do their abilities to design appropriate lesson plan according to MCI improve?

RQ1b: Is it possible to identify common difficulties among students?

RQ1c: Is it possible to identify specific contents and instructional strategies that help students to improve PCK for MCI?

H1: On the whole, engaging students in MCI practices during their pedagogical science university courses will improve PCK for MCI. Nevertheless, those kinds of practices suppose a big reconceptualization of preservice students' prior ideas on science teaching-learning. They represent what it is known by Kuhn, as a "paradigm shift" (Kuhn, 2012). The beliefs/ideas that preservice students possess regarding science teaching-learning determine their teaching practices (Kagran, 1992; Pajares, 1992; Wilkins, 2008) and act as constraints in order to interpret the new experiences and innovations such as with MCI. Those beliefs are formed over many years of everyday experience as students and tied to years of confirmation (Albion & Etmer, 2002). Therefore, they are very reluctant to change but, without changing them, it's not possible to produce significant changes on teaching behaviours (Kagran, 1992; Pajares; 1992). Furthermore, as it has been broadly demonstrated by studies on conceptual change, shifts will be not abrupt but slowly and gradually produced (Vosniadou, 2007) and strategies to critically recognize their own beliefs as well as gives alternative ones would result indispensables (Kagran, 1992).

Therefore, it is possible to conjecture, that some strategies, tools, etc. in accordance with MCI will be easily incorporated but some others (those that suppose a revision of fundamental beliefs-presuppositions) will be difficult to achieve. Specific scaffoldings received during instruction (i.e. metaknowledge strategies analysing and revising lesson plans, analysing examples of good practice, etc.) can become key elements to overcome these difficulties and incorporate new strategies.

RQ2: Is it possible to identify initial predictors of success/difficulties for preservice teacher knowledge application?

RQ2a: Do the initial preservice teachers' lesson design skills serve as predictors of their success in lesson design skills for scientific modeling after instruction?

H2: In accordance with the idea of conceptual change, it might be expected that the more distant are the initial beliefs-presuppositions of preservice students regarding MCI, more distant would be their initial lesson plan regarding such novice practices and more difficulties to overcome would appear.

4. Study design

The way in which research is conducted may be conceived of in terms of the research approach adopted, the research methodologies employed and the research instruments utilised in the pursuit of the research objective/s and the quest for the solution of a the research question/s. We have outlined our research questions and research objectives in chapter 3. The purpose of this chapter is to:

- Present and discuss our research approach;
- Expound our research strategy, including the data sources and research methodologies adopted;
- Introduce the research instruments that we have developed and utilised in the pursuit of our goals.

4.1. Research approach

A research approach can be understood as the "research epistemology" (also referred as "research philosophy" or "research paradigm") that underlies-guides the study being developed. It represents the way authors think knowledge is constructed and, thus, shows their beliefs about the way in which data about a phenomenon should be gathered, analysed and used.

Having a clear philosophical position before embarking on the research design helps to choose an appropriate methodology in coherence with the questions being asked, as well as to interpret the data. When writing a thesis report, stating the guidelines that apply the research being exposed helps the reader to understand –and, therefore, to judge appropriately- the way the research has been constructed.

The following basic ideas and options, with their corresponding justifications, describe the overarching research approach from the study presented here:

- In this research project, data were gathered, analysed and discussed within a general inductive framework using, as explained in the next section, a case study methodology enriched by the use of quantitative results. Several compelling reasons made us to choose this option:

Since the latter part of the 19th century there has been much debate about qualitative and quantitative research paradigms (Onwuegbuzie, 2002). Quantitative researchers tend to express positivist assumptions, while qualitative researchers reject positivism and use interpretivism. Though recognizing the importance of the enduring philosophical debate between positivists and interpretivist approaches, the position taken in this research is a pragmatic one. Overall, and in accordance to Esterberg (Esterberg, 2002), we believe that qualitative approaches are found to be the best ones when striving to understand social (and thus, educational) phenomena in context. Nevertheless, and also in accordance to different contributors (i.e. Pintrich, 2000; Berliner, 2002; Onwuegbuzie, 2002), we think that quantitative and qualitative research methods can be appropriately integrated to make distinct and substantive contributions to knowledge in these fields.

To our understanding, given the specificities, richness, and complexity of educational practices (Coll & Onrubia, 1999; Coll, 2001), the methodology best suited to the problem under consideration, as well as the objectives of the researcher, should be chosen. The relevance of a research design will not be given for its qualitative or quantitative nature, but for its ability to help to obtain a contextualized understanding of the phenomena studied, its theoretical relevance, and its valid and reliable empirical capacity.

This study seeks to describe, analyse and understand preservice teachers' PCK development in a contextualised, professional development program, in their natural setting. In accordance with the previous statements, the use of a qualitative general framework allowed us to acknowledge for the typical sophistication of the teaching-learning processes under study. On the other hand, data collected through both qualitative/quantitative methodologies, provided us different level of evidences contributing to a more in-depth comprehensive picture than with any qualitative method on its own. Thus, a qualitative approach enriched by quantitative methodologies, appeared to be the most appropriate for the purpose of our research.

- This particular study was framed by a social-constructivist perspective of the teaching-learning processes. The overall research approach described above and the selected research methodology was compatible with and, at the same time, reflected this view.

As explained in detail in section 2.1.3., the socio-constructivist epistemology is grounded in the assumption of the fundamentally situated and constructive nature of knowledge. As a chief assumption, this perspective holds that knowledge is co-created/constructed through interaction with others and with the environment. Teaching-learning processes appear to be an inseparable unity, and learning appears to be an active and creative process that takes place within a social system and through interactions with that system and the people within it.

In general terms, the use of a socio-constructivist view involves clear consequences for the research methodologies and instruments to be used. As soon as it explicitly acknowledges the embededness of educational phenomena in social life, and it accepts the myriad of interactions that exist within the contexts where education takes place, it forces us to deal with particular problems, where local knowledge is needed. Learning-teaching processes can no longer be treated as objects that can be studied as independent and detachable from the specific individual and environment. In order to collect reliable evidence, intensive and continuous presence in the natural context is required.

In another vein, undertaking a constructivist inquiry necessitates a rethinking of the traditional role of investigators. They cannot be considered any more as objective observers. In order to enable a mutual construction of meaning and a meaningful reconstruction of the different stories into a grounded theory model, it requires the adoption of a position of mutuality between the researcher and the participant/s.

A social-constructivist perspective was reflected at different levels of the present work. The following points show how this approach was taken, to large stretches, under consideration. Details of the research design, methodology, data sources and instruments used, can be found in sections 4.2, 4.3, 4.4 and 4.5, respectively.

a. Research was developed in context. The processes of teaching-learning given in a specific undergraduate university science-teacher course became the focus of the study. This enabled us to gain access to a rich source of data and to acquire a deep understanding of the particularities and complexities of such kind of social activity.
b. When planning the undergraduate courses according MCI, a social-constructivist viewpoint of the learning-teaching processes was always taken into account. This perspective of education conditioned the way in which university professors developed their courses; the choice of activities within this courses; the messages transmitted to the undergraduate students; as well as the sort of dynamics proposed to preservice teachers to learn themselves and to develop in schools.
c. Sustained contact between the participants and the researcher was promoted throughout the study. The researcher participated in the planning of the undergraduate courses; acted –in the first phase of data collection- as a professor of the courses; and maintained continuous contact along the whole research with the other professors involved in the courses. In coherence with the aforementioned framework, this effort ensured the coherence among the whole project and allowed to collect a rich amount of different sorts of data which, in turn, provided a more in-depth comprehension of the knowledge constructions held by the different individuals under study.
d. The aforesaid methodological approach, as well as the data analysis methodology described in the next section, were chosen so that they were coherent with socio-constructivism. An inductive-qualitative research approach was found to be the most appropriate to promote an in-depth investigation within our particular research context. The use of case study and the use of different instruments to collect and analyse data offered us the potential to work in situ and to collect a great amount of different sorts of data. The combination of both quantitative-qualitative mixed methods for data analysis, allowed for a more comprehensive understanding of the realities given in the undergraduate courses under study.
e. Analytical reflection was promoted through the study in order to conceptually describe and understand, in detail, the meaning of the data collected.

- This dissertation focuses on use-inspired basic research (Strokes, 1997; Pintrich, 2000). Its goal is to enhance our scientific understanding of the phenomena under study and to develop practical and useful applications to improve education.

Traditionally, basic and applied researches have been conceptualized as opposite endpoints. Authors like Strokes or Pintrich question this dichotomy and propose two crossed dimensions that define a two-dimensional matrix with four types of research (Strokes, 1997; Pintrich, 2000). As can be seen in table 1, the first dimension concerns the goal of scientific understanding. Research in these quadrants varies from a high to a low concern for scientific understanding. The second dimension involves the goal of usefulness, and again research can vary from a high to low concern for utility and practical applications.

Stokes (see table 1) labelled "basic research" the quadrant that is interested with scientific understanding but has little concern with the practical applications of this research. In contrast, the quadrant defined as high utility but low in the goal of scientific understanding, was labelled "pure applied research". The quadrant that is low in both scientific understanding and utility goals was left unlabelled. Strokes suggested that it might represent research taken on by an individual to satisfy his or her own curiosity about a local phenomenon or research undertaken by novices to learn research skills. Finally, the remaining cell was called use-inspired basic research and reflects a focus on both goals of scientific understanding and utility (Stokes, 1997).

		Usefulness research goal	
		Low	High
Scientific understanding research goal	High	Basic research	Use-inspired basic research
	Low		Pure applied research

Table 1. Strokes' types of research according their goals. The position undertaken in this work is highlighted (Stokes, 1997).

According to the research objectives outlined in chapter 3, and as explained in the results discussion (chapter 6), this investigation makes contributions that are of practical value to improve the practices of the undergraduate preservice science-teachers courses and, at the same time, in developing theoretical knowledge on how preservice science-teachers deal-with and appropriate MCI in order to translate it in coherent lesson plans.

For the professors who participated in the planification and performance of the MCI, there was an element of action-research, whose aim was to promote a deep collaboration between the researcher and the community, with whom the research was working, to contribute to the existing knowledge and to enhance changes and innovation through these collaborative efforts. Interagency, innovative and reflective practices for change were promoted.

In this respect, this project proposed to improve the practices of the preservice science-teacher' courses by a new approach based on MCI. Through direct intervention in the environment and close collaborations with the university professors involved in the study, the researcher aimed to create practical and often emancipatory outcomes while also contributing to the existing theory.

Overviews of the theoretical perspectives that underpin this study were outlined in chapter 2. This section has described our research approach in light of the theoretical framework. We open, below, the door to a detailed description of the research strategy as well as the procedures and instruments used for data collection. All the options that are going to be described assume the already described theoretical and methodological options and thus, they must be understood within the context and constraints that the mentioned approaches provide.

4.2. Research strategy

For the pursuit of the objectives of this study and being inspired by the steps that Goetz & LeCompte (Goetz & LeCompte, 1984) identify for a qualitative research, a general research strategy was established as outlined in figure 12. Colloquially, such strategy supposed a "logical plan" for getting from the initial set of questions (section 3) to some set of conclusions ("answers", chapters 6-discussion of results-; 7 –implications- and 9-conclusions-) about these questions. It supposed a "blueprint" for our research that enabled us to ensure the adequate resources to complete the study in the available time, to make sure that the approach to the design of the study was the appropriate one to achieve the objectives, that there was the suitable methodology to manage and analyse the data collected, that the data collected was sensible so as to allow the required information to be extracted, etc. The diagram in figure 13 shows the development of this research strategy over time. Sections 4.3, 4.4 and 4.5, specify details for the overall schema.

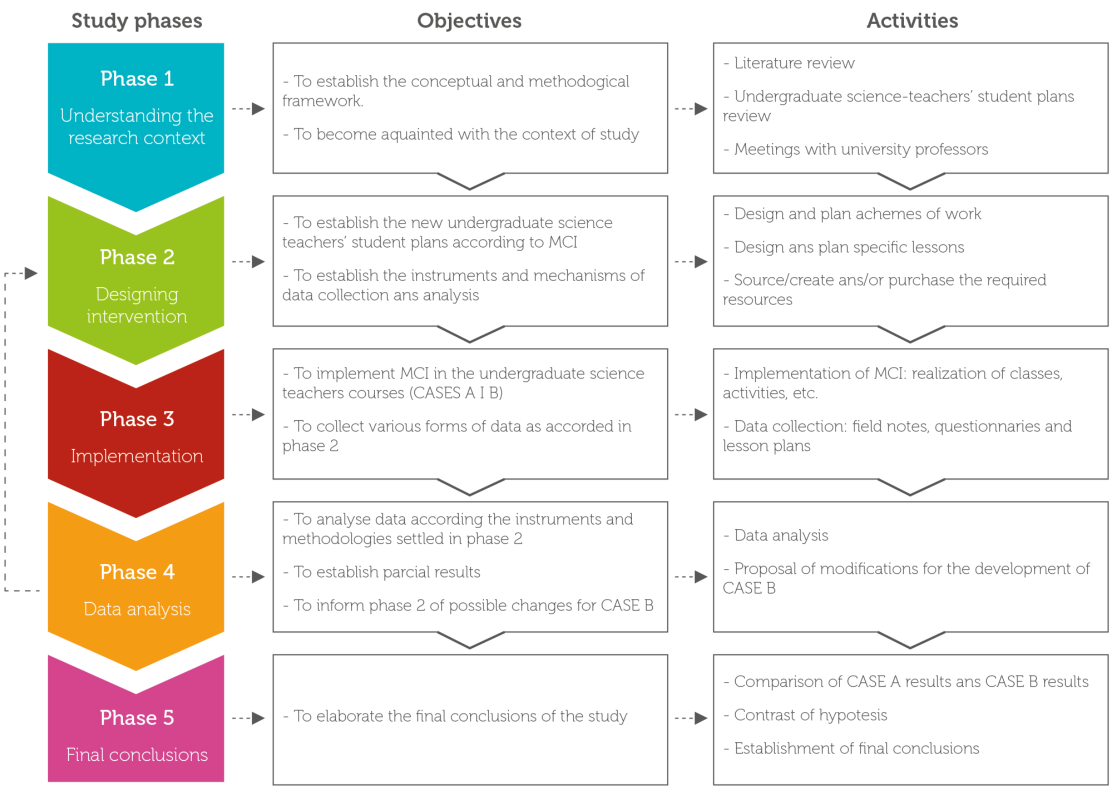


Figure 12. Overview of the general research strategy.

As a general overview, the study was divided into five consecutive phases, each of which informed the next phase of the research (Quecedo & Castaño, 2002). The main purpose of phase 1 was to understand the general context of the research prior to any intervention. Efforts in this phase move in two directions: to become familiar with the theoretical framework; and to explore the background of the research context (undergraduate science teachers' courses in the University of Vic –Spain-). An extensive literature review was done as well as different meetings with the professors covering these areas. Class programs, activities, resources, etc. were also revised. The data gathered established the practices and perspectives in the research context and in relation to science education. It also defined the desired instruction to be achieved and it identified the specific needs in relation to it.

The data gathered in phase 1 informed phase 2. This empirical phase supposed the design of the new undergraduate development program and the design of the analysis methodology. New lesson plan, activities and schemes of work for the undergraduate courses were designed and planed with the collaboration of the professors that taught the classes and in accordance to MCI. The necessary supporting resources to undertake the classes were also planned and produced. In parallel, cases under study were selected and instruments for data collection and analysis were also defined and prepared. Detailed description for this phase can be found in sections 4.4 and 4.5.

Phase 3 supposed the implementation of the new undergraduate students' plans programmed in phase 2 and the collection of data derived from this new instructional approach. Data was analysed in the interpretative phase 4. Although, as already said, much of the research design was established prior to its inception in phase 2, results in phase 4 informed about possible new aspects to be considered. These "emergent" aspects were primarily associated with the undergraduate program, and were incorporated for the development of the second case in our research. They supposed some changes in our instruments for data collection and analysis (shown as a loop from phase 4 to phase 2 in figure 12). Finally, phase 5 supposed a global evaluation of the impact of the MCI according with the research questions settled in section 3 of this document. All data gathered for CASES A and B was reviewed and compared to determine the impact, if any, of the new instruction methodology. Results were elaborated and can be found in chapter 6 of this document.

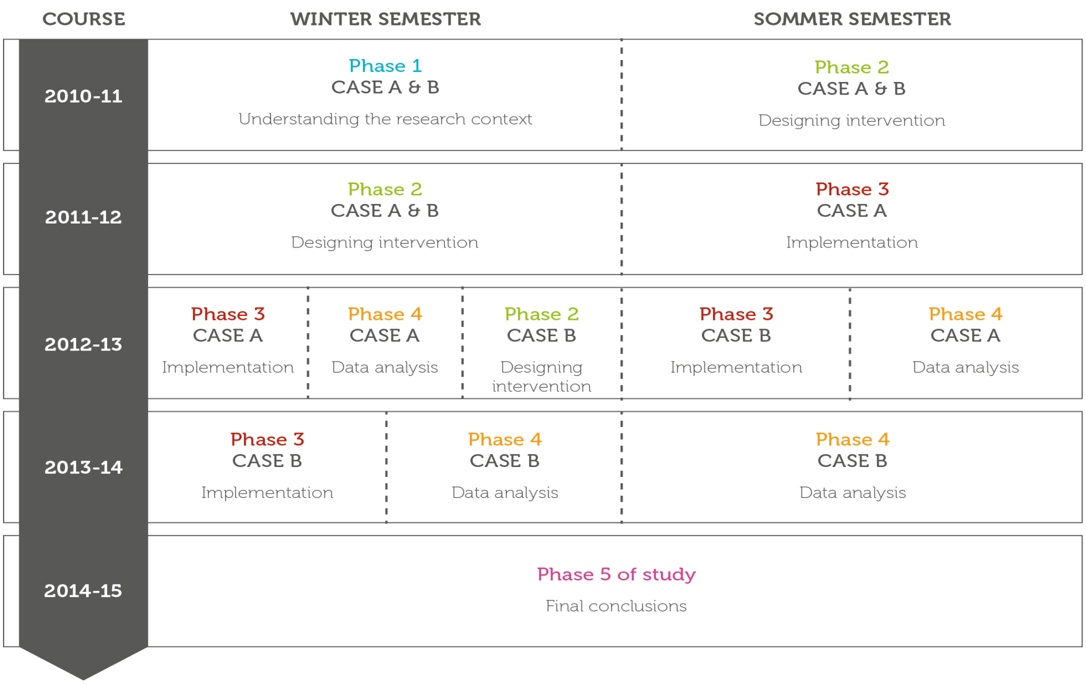


Figure 13. Research schedule. Outlined research phases specified in figure 12 are here organized into a timeline scale in order to give a general overview of the research agenda.

4.3. Research methodology

As already mentioned in section 4.1, it was decided that the best approach to adopt for this investigation was a case study with mixed quantitative-qualitative methods being utilised for data analysis. Specifically, this study adopts Stake's (Stake, 1995) and Yin's (Yin, 2013) approach to case studies as it is based on a constructivist paradigm. Elements of action-research are also combined with the dual intentions of both improving the practice and contributing to theory building/expanding (use-inspired basic research, table 1 section 4.1).

Yin defines a case study as "an empirical study that investigates a contemporary phenomenon within its real-life context: when the boundaries between the phenomenon and context are not clearly evident; and in which multiple sources of evidence are used" (Yin, 2013). According to the same author, a case study design should be considered when: (a) the focus of the study is to answer "how", "what" and "why" questions; (b) you cannot manipulate the behaviour of those involved in the study; (c) you want to cover contextual conditions because you believe they are relevant to the phenomenon under study; or/and (d) the boundaries are not clear between the phenomenon and context.

In agreement with these statements, our identification with case studies can be justified as follows:

- The phenomenon measured in this research appears to be too complex to be constructed and measured experimentally. This particular investigation, explores *how* do preservice teachers' abilities and ideas for teaching science change when they experience MCI during their undergraduate courses. It seeks to understand *how* do their PCK for MCI improve; *what* difficulties do they find; *why* appear such difficulties; *how to* predict them; *how to* help preservice students to uncover them.

The "how", "what" and "why" questions help to understand the nature of the process under study. They are characteristic from case studies. Asking "how to" questions assists to interpret the data collected in order to suggest adequate support to enhance changes and innovation and thus, implies the incorporation of those elements typical from action-research.

- As it will be explained in sections 4.3.1. and 4.3.2. with deeper detail, the focuses of this study are two undergraduate courses of the Universitat de Vic. This involves the observation and exploration of a complex reality within their regular environment without experimental manipulation or control.

- Finally, section 4.1 has already exposed the particular view of this thesis when referring to educational phenomena and in relation of the existing embedness between them and the environment where they occur.

The value of case studies is well recognised in many social sciences such as psychology and education. It allows intensive, in-depth, multi-faceted explorations of complex issues and in their real-life settings (Yin, 2013). In case studies, the issue is not explored through one lens, but rather a variety of lenses. This ensures for multiple facets of the phenomenon to be revealed and understood and thus, it becomes a valuable method to develop theory, evaluate programs and develop intervention.

4.3.1. Study context

A key feature of the design of a case study research is the number of cases included in a project. In order to ensure a more valid and generalizable description of the phenomena under study, results presented in this dissertation come from the monitoring of two group-classes over two semester courses at the Universitat de Vic (Barcelona, Spain). Detailed description cases can be found below.

CASE A: data was collected during the 2nd semester of the course 2011-12 and the first semester of the course 2012-13 (see figure 13 section 4.2). Data was obtained from a class with 42 college students in their sixth and seventh semester of the Universitat de Vic undergraduate elementary teacher education program. All students but nine were female and most of them were in their early twenties although three were older. Any of the students had taken prior college-level science courses and most of them expressed little or relative interest in science.

CASE B: Data was collected during the 2nd semester of the course 2012-13 and the first semester of the course 2013-14 (see figure 13 section 4.2). Data was also obtained from a group of college students in their sixth and seventh semester of the Universitat de Vic undergraduate elementary teacher education program. In this case, there were a total of 31 students. All but 8 were female and most of them were in their early twenties although 5 were older. Any of the students had taken prior college-level science courses and most of them expressed little or relative interest in science.

The groups were selected according the following criteria:

a. Willingness of professors to participate in the research. As we wanted to implement MCI and that supposed changes in the undergraduate courses, we had to ensure the involvement of the professors in the project. Thus, the selection of the class-groups came from professors who chose to respond to a registration of interest.

b. Number of alumni in the class: among the available groups, we chose those with a larger number of students in order to obtain a representative sample.

c. Heterogeneity of alumni in the class: classes selected tended to typify the habitual general characteristics found in a preservice science primary class (Appleton, 2006), so that data could be easily generalized.

4.3.2. Instruction design

In both cases, the courses met for 2 hours three times a week for 12-15 weeks. Although they included two class periods of instruction, the courses were conceived as a whole. The following diagram (table 2) gives an overview of their organization. Detailed information is given below.

<table>
<tr><th>Semester</th><th>Module</th><th>Main Goals</th><th colspan="2">Main instructional tools</th><th>Duration</th></tr>
<tr><td rowspan="5">1</td><td colspan="2">Course presentation: goal setting, programme methodology, assessment information, etc.</td><td colspan="2">- Ppt presentation</td><td>1 session</td></tr>
<tr><td>Module 1</td><td>Exploration of preservice prior knowledge on science epistemology and science learning-teaching</td><td colspan="2">- Initial questionnaires
- Initial lesson plan</td><td>1 week</td></tr>
<tr><td>Module 2</td><td>Engagement in model centred instruction I – materials/physical processes –

Introduction on teaching-learning pathways for MCI (CASE B)</td><td>- Inquiry sequence on corpuscular theory of matter.
- Model construction, review, use.
- Comparison of alternative models.
- Presentation and use of aid tools to support DECV, argumentation…
- Analysis of children models on the same thematic. Presentation and use of tools to make explicit and analyse such models.</td><td rowspan="2">- Science notebook
- Ppts presentations for the theoretical foundations of the applied part of the module.
-Analysis and review of initial lesson plan and questionnaires.
- Course readings: book chapters, articles, etc.</td><td>6-7 weeks</td></tr>
<tr><td>Module 3</td><td>Engagement in model cantered instruction II – living things-: seeds and plants life cycles.</td><td>- Development and analysis of parts of inquiry sequences on plant life cycles: seed characteristics, seed dispersal, plant growth and nutrition.
- Examples of classroom artefacts on the same content.
- Application of learned tools regarding modeling, inquiry, etc.</td><td>4-6 weeks</td></tr>
<tr><td colspan="2">Final reflection/overview part I</td><td colspan="2">- Analysis on science notebooks data, questionnaires and lesson plans reviews and other classroom activities.</td><td>2 sessions</td></tr>
<tr><td rowspan="5">2</td><td colspan="2">1st semester reminder</td><td colspan="2"></td><td>1 session</td></tr>
<tr><td>Module 4</td><td>Go into detail about characteristics of children's science intuitive ideas. Introduce the idea of conceptual change.</td><td>- Examples of classroom artefacts.
- Presentation and use of tools to explicit and analyse them.</td><td rowspan="3">- Science notebook
- Ppts presentations for the theoretical foundations of the applied part of the module.
- Reflection on classroom intervention.
- Course readings: book chapters, articles, etc.</td><td>6-7 weeks</td></tr>
<tr><td>Module 5</td><td>Introduction- go into depth on teaching-learning pathways for MCI Giving specific strategies for MCI</td><td>- Presentation/analysis of classroom examples.
- Unit lesson plan.</td><td>6-7 weeks</td></tr>
<tr><td>Module 6</td><td>Application of acquired knowledge in a real classroom situation.</td><td>- Classroom intervention and reflection.</td><td>1 session</td></tr>
<tr><td colspan="2">Final reflection/overview</td><td colspan="2">Use of all the previous classroom artefacts.</td><td>1 session</td></tr>
</table>

Table 2. Program course overview. The two-semester course was conceived as a hole. Initially (case A), it included 5 modules plus different sessions used as presentations/partial-final summaries. Modules 1-3 correspond to the 1st semester classroom period and modules 4 and 5 correspond to the second one. In case A, learning cycles for MCI were introduced in module 5 while; in case B they were introduced earlier, in module 1 (highlighted in green). An extra module (also highlighted in green) was included in the second iteration of the course.

Generally, the program took a teacher-as-learner stance. It engaged preservice teachers in the practice of scientific modeling and reflected on the processes and practices of teaching and learning as participants themselves experienced them. It included instruction about science epistemology, science learning goals in elementary schools, science content standards for catalan schools, inquiry-based-science, science lesson planning and students' conceptions about science and science content. It also included, as a novelty regarding courses in previous years, instructional activities associated with modeling. The aim of this new thematic was double: to develop PCK for scientific modeling at the same time they developed metamodeling knowledge regarding MCI practices.

As it can be seen in table 2, all these contents were first structured, crossways, in 5 modules. Modules 1 to 3 were taught in the first semester of instruction while modules 4 and 5 were taught in the second one. An extra module (highlighted in green) was added after analysing results from case A and, consequently, was only present in case B. Furthermore, sessions used to present the course and to review/summarize what had been learned were also considered in both cases.

According to specific requirements, modules lasted variably and, although they were mainly conceived sequentially, some aspects were introduced in one module and then treated deeply later on (for example: although characteristics of children's intuitive ideas were mainly developed on module 4, they were introduced at the second module linking what students were doing themselves with what they would expect to find in a classroom).

Module 1: After the introductory session and prior to instruction, three to five sessions were designated to explore preservice students' knowledge on science epistemology and science teaching-learning. To this aim, students had to answer a questionnaire and they had to create an initial lesson plan.

The questionnaire was submitted individually. It featured a number of detailed questions, some of them requiring simple multiple-choice responses while others were open-ended, thus requiring qualitative answers (an example is included as appendix 1).

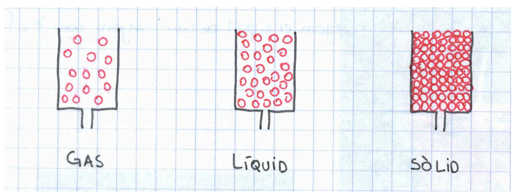
To make lesson plans, students had to work into small groups. The theme and age of children to address the lessons was given by instructors (appendix 2 contains initial indications and themes for lesson plan design). In case A, no more indications were given. Preservice students had complete freedom to decide how to address the designed theme on a fictitious sixth grade classroom, thus clearly reflecting their initial way of thinking about science learning-teaching a specific content. In case B, specific goals to work within lesson plans were also given to preservice teachers. As it is further explained in section 4.4. goals were given in the form of "big-ideas".

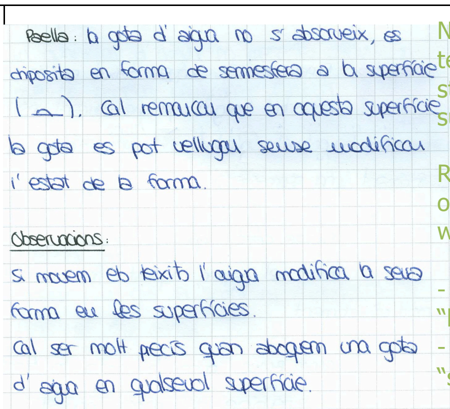
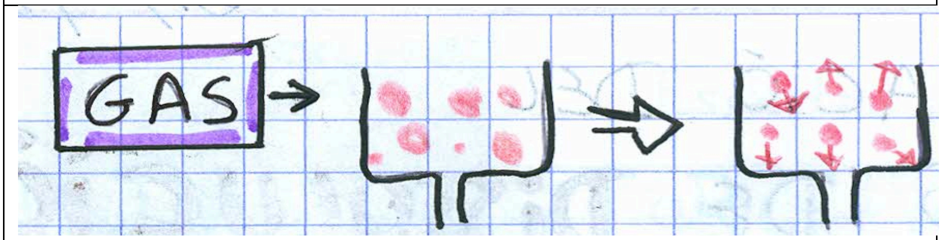
Both questionnaires and lesson plans, were submitted to student analysis, reflection and modification during the semester course in order to reflect the new knowledge acquired through instruction. In this case, specific guidance for lesson plan analysis and reflection was given to students (see appendix 2).

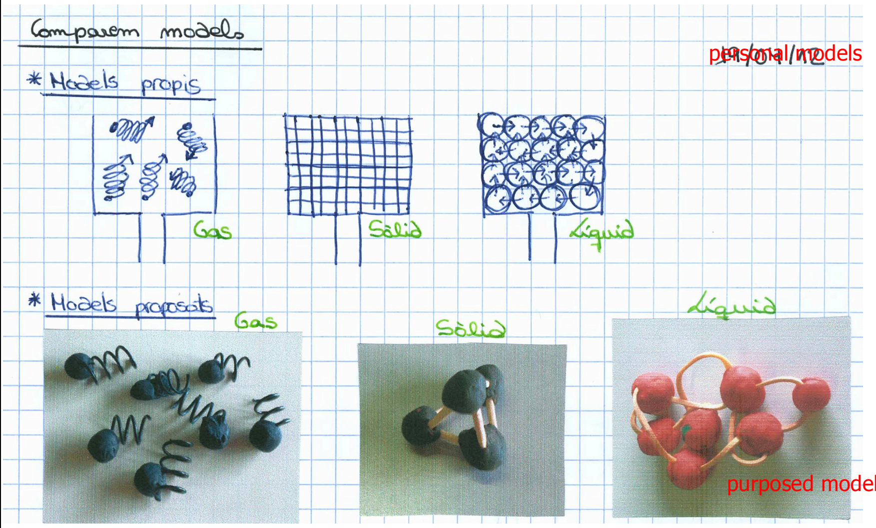
As explained in section 4.4 lesson plans have been used as data sources. Meanwhile, questionnaires and other classroom artefacts have been used to contrast information.

Module 2: module 2 supposed the first period with instructional activities associated with modeling. It focused on the practice of scientific modeling and it started to develop instructional strategies and other PCK for model instruction. At the same time, this module (as well as the next one), aimed to reflect about science epistemology as well as to introduce students on school scientific practices.

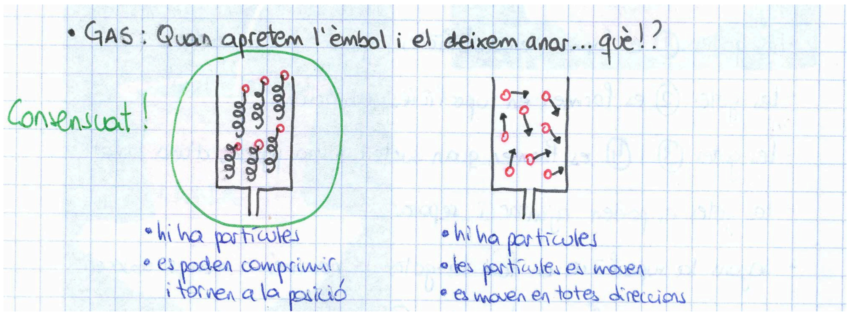
The module combined theoretical and practical classes. Specifically, preservice students were engaged, as learners, in a scientific modeling experience focused on the corpuscular theory of matter (table 3). This set of activities were based on a unit designed to teach elementary students and, through it, preservice students created, used, evaluated, revised and applied models at the same time that they reflected on the nature/use of models in science. The instructional sequence was designed in accordance with the ideas outlined in section 2.2.

Instructional Sequence	**Description**
Anchoring Phenomenon	Introduction of the thematic doing an experience of compressibility. Students put air, water or sugar (one at each time) in a sealed syringe, and tried to compress the substance.
	 Observations done in this experience were: *"Air can be squeezed into a smaller space; it is compressible. Water and suggar cannot be visibly compressed. When the syringe is full of air and we unpress the plunger, it turns back to how it was before."*
Create an initial model	Individual models were created to explain the observed phenomena. Discussions on the purpose and nature of scientific models were hold on.
	 After doing the initial experience of compressibility, preservice studentswere required to create initial models to explain the difference in the compressibility of gasses, liquids and solids, representing what would they see at a particle level. These models were drawn, individually into science notebooks. As it can be seen initial preservice teachers' models usually failed to accurately explain the observed phenomena. In this case, for example, the liquid model does not explain that a liquid (water, in our concret casse) cannot be visibly compressed. The model lacks any representation of how structural components help to explain the observations done.
Test de model	Models were tested. Other experiments were conducted to gather more empirical evidence.

	 New experiences were suggested in order to test initial models. In this specific example students made water drops on different surfaces and observe them. Reflection on empirical data and evidences obtained within this and other experiences was guided so as to conclude that: - within liquids and solids particles had to be "bonded". - "bonds" between solid particles had to be "stronger" than those in "liquid particles. Data/evidences from different experiences were recorded individually in science notebooks and shared afterwards. After the development of experiences, reflections on how to guide such experiences with primary-school students were promoted. Within those reflections preservice students were introduced in how to help to plan and perform an experimental design with children; how to help to help them to record data using tables, graphs, diagrams… ; the importance of accurancy on data recording; or how to scaffold students on writing conclusions and giving arguments. Specific scaffoldings such as "splitting-up" instructions for planning experimental designs were discussed
Revise the model	Initial models were revised to take account of the new evidence. Discussions on models as changeable entities were hold on. Importance of concordance of empirical evidence and models was highlighted.  In this specific example, the student changes his/her initial model to another one that takes into account the movement of gas particles. In this case, arrows attached to particles and pointing to all directions symbolize movement of particles. Similar model revisions were done for solids and gases. Emphasis on how models fitted with data/evidence obtained and how good were they in order to explained the phenomena observed/data obtained was allways outlined. When revising models, the professor outlined those scaffolding strategies that could be useful when trying to foster students' models (discrepant events, anchoring….).
Evaluate the model	Models were evaluated to highlight strengths and weaknesses. Different alternative models of students/given by the professor were compared. Discussions on models as tools for sense making, and communication were hold on.

<table>
<tr>
<td></td>
<td>


Alternative models for a solid/gas/liquid were given to students so that they had to compare/contrast them with their own models, reflecting on and argumenting which ones explained better the observed phenomena and recorded data.

Once more, reflection on how to manage this kind of process in a school class was hold on. Discussions about the usfullness of questions, notebooks, etc. completed this activity.
</td>
</tr>
<tr>
<td rowspan="2">Construct a consensus model</td>
<td>A consensus model was constructed as a group, taking into account the different ideas emerged in previous discussions.</td>
</tr>
<tr>
<td>


After the hole process, a consensus model was created. In this example, the students highlights, in green, the consensus model. Below, he/she gives outlines what can explain each model, thus giving reasons for the choice. The student also poses a question "***Gas: When we push the plunger and release it... what?!***" that referes to the observation that was not explained by the previous model.

At this point, discussions on intermediate models and target models took place. The idea of models as changeable entities, the explanatory power of models, the
</td>
</tr>
<tr>
<td>Use the model</td>
<td>The consensus model was used to explain other phenomena such as a solar distiller or the increase of solubility with temperature.</td>
</tr>
</table>

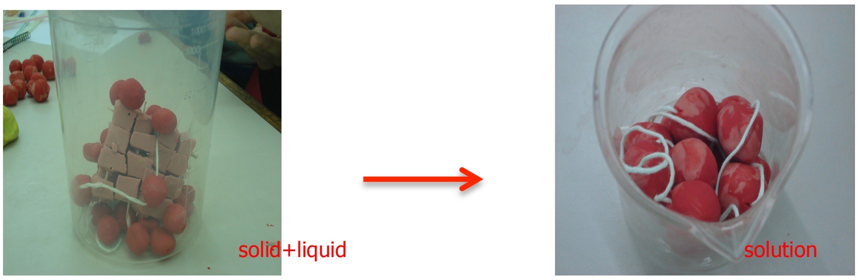
	 In this specific example, preservice teachers used the consensus models for a solid and a gas to explain solubility and the increase of solubility with temperature. One more, the professor guided students on using their models to explain new phenomena and become a model for them on guiding such processes in a classroom.

Table 3. Timeline of main instructional activities performed during the modeling experience focused on the corpuscular theory of matter.

As it is described in table 3, within the development of the modeling experience, preservice teachers were engaged, as learners, in inquiry activities, discussions and explanations that outlined the basic ideas of scientific models, modeling and metamodeling knowledge. Furthermore, as future novice teachers, they started to acquire tools such as to conduct experimental designs, help to write conclusions or start to interpret students' intuitive ideas. In case B, the same experience was also used to introduce a learning pathway for MCI. In case A, the learning cycle was not explicitly addressed until module 5 (see table 2).

During practical classrooms, students used scientific notebooks to report experimental data, models, explanations, questions, hypothesis and predictions… in a similar way as scientists do and as it should be promoted in schools. Those notebooks were further used in all inquiry activities and they were periodically used by professors to gain information on students' progressions and challenges among the courses.

Theoretical classes were used to promote further understanding of the practice. They combined lectures, direct explanations, specific activities, and practical classroom examples to support preservice teachers' PCK. Examples of activities within this module can be found in appendix 3. Furthermore, to connect their understandings with their future practice, students analysed, reflect on and modified their initial lesson plans to adjust them to the new knowledge acquired (appendix 3).

Module 3: this module supposed an extension of the previous one. It had the same structure (combining practical and theoretical classes) and it used the same kind of resources (science notebooks, lectures, etc.). Students also continued with their lesson plan review assessment.

In order to cover the maximum of contents considered in the catalan science standards, this module concerned to modelling experiences related to plant life cycles and plant morphology/anatomy related to its function (structure/function). In this case, preservice students' didn't complete a whole lesson plan, but were engaged in some key activities belonging to different science units for elementary schools. As in the previous module, theoretical classes were used to reflect on these activities and to give support and tools to incorporate those instructional strategies in a classroom. Table 4 contains a summary of main activities done during this module and examples of activities can be found in appendix 3.

A1	Performing and analysing activities to explore/make explicit students' mental models on seed germination and plant-nutrition.
	As in module 2, preservice teachers performed an activity to explore their initial mental model. Such activity was similar to one performed with primary students. Preservice teachers compared their answers with those coming from primary students. Through lectures, they were also introduced to characteristics of naïve ideas in seed germination and plant growth (nutrition, respiration, etc.).
A2	Observation of seeds. Comparison of seeds. Use of binocular microscopes.
	Undergraduate students were required to collect seeds. Techniques to collect seeds with students in a field trip were introduced. Seeds were observed, with and without binocular microscopes. At this point, students were introduced on the use of microscopes and to the use of T-charts as a support tool for conducting comparisons. Preservice students were also required to perform an experiment to realise the relation between seed morphology and its function. This activity was used to discuss about the kind of problems that can be investigated with primary students and in relation with plant life cycles: what is being actually done in schools; what should be done in accordance to MCI, etc. A wide rage of problems was suggested to students.
A3	Conduct experiments related to plant nutrition. Comment other possible experiments.
	Preservice teachers performed different experiments related to movement of nutrients within a plant. As in previous sessions, the professor became a model for preservice teachers providing example on how to guide the experiments and how to scaffold primary students.
A4	Analyse and conduct experiments to realise the relations between rood morphology and its function. Introduce the potential of constructing models in science classrooms.
	Preservice teachers analysed different experiences made with primary students in order to think about rood morphology related to its functions. These activities were also used to introduce the interest/potential of building small-scale models with scholars.
A5	Design, perform and report a seed germination// plant growth experiment.
	In order to apply the knowledge acquired preservice students were given four pumpkin seeds and were required to formulate an investigable question and then, design, conduct and report an experiment to answer it. They were required to report their experiment as a poster and they were done scaffoldings to do it.

Table 4. Summary of main activities done during module 3.

Based on what they had been working during the whole semester, the last sessions of the 1st semester-course were used as recapitulation and to raise awareness of the acquired learning. Students had to deliver the modified lesson plans. Lesson plans, have been used as data sources of this dissertation (see section 4.4).

As it can be seen in table 2, modules 4, 5 and 6 (just for case B), were taught in the second semester. As a block, those modules pretended to go in depth on some of the pedagogical aspects introduced in the 1rst semester course. Modules 4 and 5 combined practical and non-practical classes. In this case, non-practical classes were used as a means to put into practice what was being discussed in theoretical classes. Thus, those sessions were used to design new lesson plans, critique already made activities, analyse students intuitive ideas, promote discussions about lectures, etc. Activities and examples given in these modules tried to cover all the scientific contents considered in the catalan standards for primary schools that were not covered in previous modules.

Module 4: module 4 focused on students' intuitive ideas, related to conceptual change. The module aimed to reflect on how scientific knowledge is acquired according to psychological approaches on conceptual change; how to promote conceptual change (related on what they had been experiencing in previous modules and in accordance with the theoretical in section 2.1.2) within an MCI framework; and which are the main characteristics of children's intuitive ideas on science contents and how to use them as starting points.

Module 5: this part of the course enabled to put together and give complete global sense to most of the knowledge early acquired. The aim of the module was double: to introduce (in case A) and go in depth (case B) on teaching-learning pathways for MCI (according with schemes described in section 2.2. of this dissertation) and to give further specific strategies for each of the different purposed steps.

In case A and as a main practical work within this module, students created a new lesson plan applying all the knowledge acquired within the two semester courses. This lesson plans have been used as data sources for this research (see section 4.4). In case B students adapted the lesson plan done in the 1st semester course in order to teach them in a real elementary classroom. Specific intructions for this assignments can be found in appendix 4.

Aside from creating/adapting lesson plans, main activities in modules 5 and 6 included (some examples can be found in appendix 3):

A1	Given different activities within a specific topic, undergraduate students hat to select and order them to construct a coherent lesson plan. This activity was done at the beginning of the course in order to explore prior knowledge of preservice teachers related to learning cycles and sequencing lesson plans. Later on, the same activity was recovered and reviewed as to promote awareness of the evolution of the learning process.
A2	Design, perform and report an animal behaviour experiment. As with the seed germination/plant growth experiments, students applied knowledge acquired within theoretical-practical classes to design-conduct and report experiments related to animal behaviour. Preservice teachers work with crickets, common animals in catalan science classrooms. The introduction of this activity was used to address issues such as: Furthermore, within the development of this activity students could deepen in scientific skills such as observation, measurement, hypothesis formation, testing… relating all these aspects to the theory and pedagogical tools that were presented in these and previous modules.
A3	Given a specific content, design and perform an activity to explore the initial model of a group of primary school students. Analyse the outcomes of the activity.

	In order to apply the new knowledge about science intuitive ideas, students hat to design an activity to explore initial models of a specific content. They did the activity to a group of primary school students and then, they analysed the results. This activity was related to theoretical classes on intuitive knowledge and evaluation. Students were guided on what to analyse (related to target models) and how to analyse. Students were given specific instruments to explore intuitive knowledge (initial models) and analyse it (i.e. V Gowin, concept cartoons, sharing conversations, etc.)
A4	Introduction to the use of digital tools to teach science.
	Preservice students were introduced to the use of "Ecodad", a common digital resource available in most science classrooms of catalan primary schools. They were introduce on how to use this specific resource and they reflect on the possibilities to use it in a classroom. They were given examples of uses.
A5	Initial questionnaires revision
	In order to raise awareness of the acquired learning, preservice students reflected on initial questionnaires (performed at the beginning of the 1st module) and changed their answers according their new learning.

Table 5. Summary of main activities done during module 5.

Module 6: As already mentioned, module 6 was only present in CASE B. Within this module, students hat the opportunity to put into practice, in a primary school, some of the activities planned in the first instruction period. Later on, they reflected on their intervention. This work has been used as data source for this research (see section 4.4).

A final overview and reflection concluded the course.

4.3.3. Researchers' role during investigation.

Through the investigation, the role of the author of this dissertation was dual: as an external observer and providing direct instruction in the first phase of data collection. The rest of professors who participated in the research, were involved in a collaborative manner in defining the problem; identifying the strategies/actions to be implemented; teaching according MCI; and collecting data. They also helped in the interpretation of data and in the application of findings (particularly with changes suggested for the development of the project in its 2nd phase -CASE B-). Thus, and as elsewhere said, there was an element of action research with a view to understand better and improve the professional practice.

4.4. Instruments for data collection

Results presented in this dissertation come from the analysis of 71 lesson plans. Specifically, results come from the comparison of initial (prior to instruction) and modified/new lesson plan designs/reflections (performed during and after MCI instruction). Complementary data sources including questionnaires, class exercises, students' science notebooks, extensive field notes of lessons, planning documents and personal reflections, were also collected for a better understanding and interpretation of the results.

Data were gathered at various time points during the courses as can be seen in figure 14 and as it is explained below.

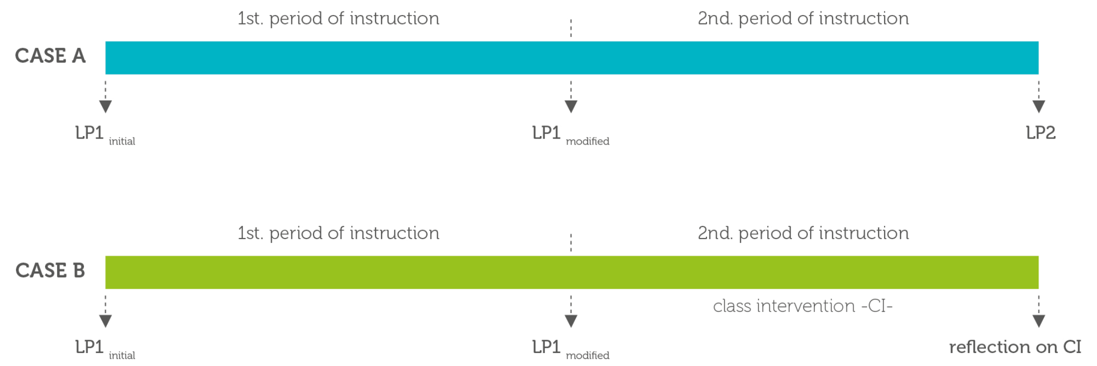


Figure 14. Study data sources timeline.

CASE A: for case A, a total of 40 lesson plans were analysed. These lesson plans correspond to:

- An initial group of 14 lesson plans that were done prior to instruction (LP1 initial in figure 14);
- The group of 14 lesson plans corresponding to the modification of this initial lesson plan, collected at the end of the first period of instruction (LP1modified in figure 14);
- A new group of 12 lesson plans made during the 2nd period of instruction and collected at the end of the two instruction periods (LP2 in figure 14).

CASE B: for this case, a total of 31 lesson plans were analysed. Groups of 10 LP1initial and LP1modified were collected as in case B. For the second period of instruction, data sources contain significant differences. In this case, and as already explained in section 4.3.2., a class intervention was promoted and reflections on this class interventions were used as data sources (reflection in CI figure 14).

Overall, lesson plans and reflections on class interventions were used to analyse the instructional strategies preservice teachers used in their lesson designs, evaluate their knowledge about MCI and provide a measure of the change occurred through instruction. Detailed information is specified below:

Initial lesson plans (LP1initial in figure 14) were done, in both cases, prior to any kind of instruction in order to capture preservice teachers initial understandings. To make them, students had to work into small groups, resulting into 14 different lessons in CASE A and 10 different lessons in CASE B. Instructors provided different topics from which preservice teachers could choose (i.e. buoyancy, olfactory sense, sound, evolution, etc.) and they were asked to make a lesson plan to teach it in a 6th grade class (11-12 years).

In CASE A, as the given topics were really open, preservice teachers were asked to restrict the specific aspects to work with. They were required to select specific target models and to unpack them into appropriate contents/key aspects to teach to primary students. Preservice teachers also had to decide which methodology, specific activities, sequence… they would use. Finally, they were required to reflect, in the development of the lesson plans, how would they act, as teachers in every specific activity they plan (i.e. what would they say to students, which material would they use, etc.). They did not have any further information, nor constriction.

In CASE B, topics, target and subtarget/models were provided by professors. In this case, students had to plan instructional activities that address the given target models. As in CASE A, preservice students were required to give maximum detail about join activity structure within each activity (i.e. describing which questions planned to pose; how would they act, etc.). Differences between case A and case B assignments are summarized in table 6.

During the first period of instruction (summer semester course 11-12, for CASE A and summer semester 12-13, for CASE B) these first lesson plans were submitted to student analysis, reflection and modification in order to adapt them to the new knowledge acquired through the instruction received. Preservice students were given specific instructions and reflective questions to adapt their lesson plans. Students were required to give rationales for those changes. The complete assignment for LP1modified can be found in Appendix 2.

In CASE A a new second group of 12 lesson plans were used as data source (LP2 in figure 14). As in the first period of instruction, students hat to work into small groups and instructors provided the contents from which preservice teachers could choose. Lesson plans were done through the period of instruction incorporating those elements being worked.

At the starting of the project it became apparent the need for preservice teachers to have more contact with real primary students. As already discussed in section 4.3, this was conceived as an action research project and thus, this aspect was consistently incorporated for case B in the second period of data collection. Preservice students chose some of the activities planned in LP1modified and taught them to a 6^{th} grade elementary class. Afterwards, they wrote a summary reflection in which they responded to prompts about the activities and their teaching performance. This reflective assignment was used as data source (reflection of CI in figure 14).

		Assignments	Topic	Target/sub target models	Activities	Activities' sequencing	Join activity structure
CASE A	1st period instruction	**Initial lesson plan (LP1initial)**	Given by porfessors	Chosen by students	Chosen by students	Chosen by students	Chosen by students
CASE A	1st period instruction	**Review of initial lesson plan (LP1 review)**	Given by porfessors	Chosen by students	Chosen by students	Chosen by students	Chosen by students
CASE A	2nd period instruction	**2nd lesson plan (LP2)**	Given by porfessors	Chosen by students	Chosen by students	Chosen by students	Chosen by students
CASE B	1st period instruction	**Initial lesson plan (LP1initial)**	Given by porfessors	Given by porfessors	Chosen by students	Chosen by students	Chosen by students
CASE B	1st period instruction	**Review of initial lesson plan (LP1 review)**	Given by porfessors	Given by porfessors	Chosen by students	Chosen by students	Chosen by students
CASE B	2nd period instruction	**Class Intervention (reflection on CI)**	Given by porfessors	Given by porfessors	Chosen by students	Chosen by students	Chosen by students

Table 6. Differences between case A and case B assignments (used as data sources).

Other artefacts: Other artefacts such as questionnaires, class assignments, students' science notebooks, exercises on exams, and field notes were also used in order to: characterize students; contrast information; and to better understand and interpret the obtained results.

4.5. Procedures, units and instruments for data analysis

This section describes the procedures, units and instruments created within the interpretative phase of this research. It also describes the strategies used to ensure the validity and transferability of both, the analysis procedures and the results.

4.5.1. Procedures for data analysis

Data analysis supposed a continuous, dynamic and repetitive process guided by the objectives of this research. The overall process was broken down into the following steps:

1. **Data preparation:** data from different sources was compiled and organized in order to facilitate subsequent processing of the gathered information. The quality of the material was reviewed and codes were created to identify documents (initial and final lesson plans, etc.).

2. **Establishment of analysis dimensions:** based on the objectives of this research and on main items within a MCI framework, 4 different dimensions of analysis were established:
    (1) Nature of science (NOS) underlying lesson plans
    (2) Performance in the identification of target models
    (3) Activities' sequencing
    (4) Planned join activity structure

The general idea of this fourth dimensional analysis was to gather information on preservice-teachers' general understanding on MCI and its "game rules"; and their capability to decide what to teach and how to teach a specific topic within this framework.

Overall, this approach intended to gain evidences of preservice teachers' PCK evolution through undergraduate courses on MCI and identify possible common traits that allow answering the research questions posed in section 3.

As explained in section 4.5.2, special emphasis was put on the analysis of the planned join activity structure. Given the own limitations of an investigation of this type, the rest of dimensions were explored in less detail and were used to complement and better interpret data gathered from the analysis of the planned join activity structure.

3. **Establishment of analysis units:** the above identified analysis levels required the identification of four kinds of analysis units in order to gather in depth information about preservice-teachers' comprehension of the MCI framework and their ability to plan according it. Three of them are first-rage units (lesson-plans; sessions; joint activity segments) while the other one (configurations of joint activity segments) it is considered a second-rage one.

These analysis units have their origin in the conceptual and methodological model for the analysis of some of the mechanisms of educational influence that take place in the context of joint activity (Coll, et al., 1992). Nevertheless, they have been adapted to our reality considering, for example, that in our case we do not analyse what occurs (what it is commonly analysed with this model) but which kind of interactions are being planned by preservice teachers "a priori".

(1) lesson-plans: constitute the basic unit of data-recording, analysis and interpretation. A teaching sequence reproduces a complete small process of teaching and learning. Therefore, it allows placing the different analysis dimensions, categories, indicators… searching patterns and trends, interpreting results as a hole and reflecting the importance of the temporal dimension in the analysis.

(2) sessions: every lesson plan is composed by different sessions. Within these sessions restart and continue the processes of learning and teaching. It is in this framework were the join-activity takes place and, thus, the place to plan the specific mechanisms of educational influence "a priori". Within lesson plans, preservice-students identified sessions, and we maintained this sessions as a reference.

(3) planned join-activity segments: they constitute the analysis unit situated at the lower level of the hierarchy. Within sessions, they are the segments where preservice teachers plan a similar joint activity structure. They represent the specific ways in which undergraduate students think joint activity should be organized in order to promote learning construction. As already said elsewhere (see sections 2.1.4 and 2.2 for further details), is in the scope of the joint activity that students and educators display around the contents and learning tasks, that the mechanisms of educational influence take place. Hence, identifying and analyzing how preservice teachers plan joint activity becomes indispensable in order to find indicators on how preservice teachers conceive the processes of progressive construction of shared meanings and transfer of control within the MCI framework.

(4) Configurations of planned joint activity segments: making a parallelism with join-activity segments that appear within a class-observation (Rochera et al., 1999), they are defined as groups of planned joint activity segments that appear in certain order and that are frequently repeated throughout a teaching sequence.

As it can be seen in figure 15 these units occupy different hierarchical levels, so that those situated in the upper level include those in the lower ones. Furthermore, all these analysis units vary both in extension and degree of detail. At a macro level, we find lesson plans; at a micro, joint activity segments. This characteristics and layout facilitates the establishment of connexions between analysis, integrating and interpreting results as a hole (Coll, et al., 1995).

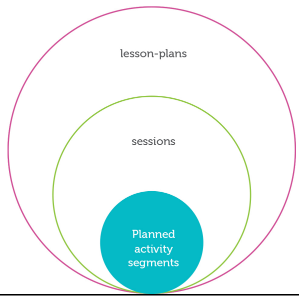


Figure 15. Analysis units hierarchical levels.

The identification of this units of analysis is the result of a contrast between theory and data involving the use of prospective-retrospective procedures. Is therefore, a laborious and complex process with direct implications in the identification of analysis cathegories, as explained in section 4.5.2.

4. **Exploratory analysis of the data:** once the analysis levels and units of analysis were determined, multiple detailed re-readings of lesson plans were used to identify "common traits" among data. This permitted to generate an initial system of analysis categories and subcategories as well as their operational criteria. To do so, four criteria for categorization were applied (Quecedo & Castaño, 2003):

    - Objectivity: the meaning of the categories should be expressed clearly and concisely in order to avoid double interpretations.
    - Membership: categories must be relevant in relation to the objectives of the study and should fit with the content being analysed.
    - Category adhesiveness: it has to be possible to locate each unit of meaning within one of the defined categories.
    - Classificatory sole principle: categories should be performed following a unique sorting criterion.

    When necessary, instruments for data analysis within a specific level of analysis were designed. Such devices are fully described in section 4.5.2.

5. **Initial testing of the categories' scheme:** the initial operational criteria were tested in a sample of data in order to evaluate the clarity and consistency of the operational criteria. When needed, adjustments and revisions were done until a sufficient consistency was achieved.

6. **Data analysis:** when sufficient consistency among categories was obtained, the whole data basis was analysed. As this analysis was performed while other data continued being collected, adjustments and revisions continued being done, when necessary (e.g. when new categories emerged).

Once data analysis was completed:

7. **In order to answer the first question of our research:** a comparison between data coming from initial and subsequent lesson plans was established, looking for relations among categories, evidences of change, acquisition of specific strategies, common tendencies… that visualized progressions on MCI performance along time.

8. **In order to answer the second question of our research:** results derived from steps 7 were confronted with an exploration of the students' starting point (i.e. analysis of the initial lesson plans and questionnaires) to establish patterns that enable to make predictions about possible difficulties, grade of students' performance, etc., and thus, adjust possible interventions in undergraduate courses.

4.5.2. Instruments for data analysis

Based on the MCI framework described in section 2.2, and as already mentioned in section 4.5.1, this research performs a four dimensional analysis based on:

(1) Nature of science (NOS) underlying lesson plans
(2) Performance in the identification of target models
(3) Activities' sequencing
(4) Planned join activity structure

The first three dimensions provide a general perspective of the data contained in lesson plans (macro analysis of data). Instruments selected to analyse this dimensions only seek to give an approximate characterization of preservice teachers' knowledge/ideas/understandings/performance on NOS, identification of target models and activities' sequencing. The last dimension (planned join activity structure) is more specific than the others and implies a microanalysis of the data contained within planned join activity segments.

Overall, the choice of these dimensions responds to:

a. The need to identify the correlation among NOS and the evolution of the instructional practices reflected on lesson plans in order to asses: its possible role as limiting factor to the acquisition of new teaching-instructional frameworks such as MCI; and/or the benefits of MCI in the evolution of NOS.
b. The need to identify preservice teachers' possible difficulties when selecting appropriate target models to teach and/or when trying to plan activities/adjusted aids to help students to construct this knowledge.
c. The need to evaluate preservice teachers' capacity of sequencing activities within a lesson plan in accordance with MCI and how this capacity evolves through specific instruction on MCI.
d. The need to understand how preservice students conceive join-activity; which mechanisms of educational influence they consider to construct shared meanings and assure a gradual realise of responsibility; how this aspects evolve along preservice instructional courses.
e. The need to identify common difficulties as well as specific aid-tools.

With the general aim to give and in-depth view of preservice students' PCK evolution and to answer the questions that guide this research (see section 3).

In general terms, the creation of instruments for data analysis followed an inductive-deductive approach. Although initial codes were initially theory-driven, they were submitted to successive data-driven reviews, until achieving a final instrument for analysis. As explained in section 4.5.3, inter-rater reliability was assessed in order to ensure the rigour of categories and operational criteria.

In the following pages, specific rationales for each selected dimension are given. Analytical instruments developed in order analyse each dimension are also presented as well categories within each dimension and operational criteria used to validate them.

(1) NOS underlying lesson plans.

Section 2.1. underlines modeling practices as fundamental scientific processes that encompass the investigative nature of science as well as the products of investigation (i.e. models can be used to predict and explain phenomena). Furthermore, sections 2.2 and 2.3. stress the potential of MCI for helping preservice teachers understand more about science content, science practice and discourses, and NOS.

Overall, the bijective relationship between NOS and MCI appears to be evident: on one hand, well-developed NOS views allow to better address the development of MCI practices. On the other hand, a way to enhance this NOS views is to engage preservice teachers in MCI practices.

The aim of dimension is, precisely, to map this relationship over the undergraduate course period. The magnitude of the present research-work impedes an in-depth analysis of preservice teachers' NOS views. However, and despite being aware of these limitations, it has been considered interesting to give a general view of NOS underlying lesson plans, considering that this insight will help to interpret results at a global scale and regarding to questions settled in section 3.

It is unquestionable that, when they first engage university courses, preservice teachers already possess a common sense host of ideas about what is science and about doing science. These ideas have been culturally constructed over years (by the exposure to media images of science and scientists, through their everyday experience with the products of scientific knowledge, through science experiences in classroom settings, from the kinds of explanations that emerge in everyday talk, etc.) and they are not necessary consistent with core commitments associated with current scientific practices.

On the other hand, it is also evident that any core commitment associated with scientific practices (even when it is not coherent with current real practices) has implications for science education. The recognition of scientific knowledge's sociocultural embeddedness, for example, means that learning science involves being initiated into scientific ways of knowing, making science ideas and practices meaningful at an individual level. At the same time, it supposes science educators mediating scientific knowledge for learners, helping them to make personal sense of the ways in which knowledge claims are generated and validated.

Different studies have attempted to establish the relationship between teachers' conceptions of NOS and their instructional practices in their classrooms. Findings in these studies show that teachers' knowledge on NOS has an explicit and direct translation into classroom practice. The more NOS is understand, the more they are informed about science and the scientific enterprise and thus, the more they are empowered to perform educational practices –such as MCI- coherent with an image of science (Abd-El-Khalick, et al., 1998; Bell, et al., 2000; Bartholomew, H., et al., 2004).

But, which is this "agreed expert NOS" preservice teachers need to understand? Among scholars, there is not consensus on a concise description of NOS (Driver, et al., 1996). NOS representations are as dynamic, diverse and complex as the knowledge and enterprise of science itself. It is not on the scope of this research to enter in such debate. However, it is important to clarify the NOS ideas that configure the "map" of reference to categorize preservice teachers' views. In this sense, the descriptions of NOS aspects shown in table 7 (described in Schwartz, et al., 2004), were used as a reference as it was considered that:

(a) They were congruent with authentic science inquiry and,
(b) Their implications for science education were also coherent with an MCI framework.

Aspect	Description
Tentativeness	Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. All other aspects of NOS provide rationale for the tentativeness of scientific knowledge.
Empirical basis	Scientific knowledge is based on and/or derived from observations of the natural world.
Subjectivity	Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experiences dictate what and how scientists conduct their work.
Creativity	Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.
Observations and inference	Science is based on both observation and inference. Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations. Perspectives of current science and the scientist guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations.
Sociocultural embeddedness	Science is a human endeavor and is influenced by the society and culture in which it is practiced. The values of the culture determine what and how science is conducted, interpreted, accepted, and utilized.
Laws and theories	Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Hypotheses in science may lead to either theories or laws with the accumulation of substantial supporting evidence and acceptance in the scientific community. Theories and laws do not progress into one and another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.

Table 7. NOS aspects and definitions (Schwartz, et al., 2004) used to characterize preservice teachers' NOS views.

In the analysed lesson plans, NOS was not explicitly addressed. Preservice students were not required to introduce NOS aspects obviously and overtly in the activities or objectives presented. Nevertheless, it was assumed that preservice teachers' lesson plans reflected their thinking about science and, therefore and in order to infer the relationship between preservice student's conception of NOS and their evolution on MCI practices (and vice versa), NOS underlying lesson plans was analysed.

Aspects of NOS were inferred from less prominent parts of data sources (isolated statements/practices inserted in an activity, activities consistent with a particular view of science, etc.) and, from them, a global vision of NOS was assigned to each lesson plan. Examples of aspects considered are:

- Inclusion of testable questions
- Aims of activities (hands-on; collect data/evidence; trying things "to see what happens"…)
- Procedures designed to collect data/obtain evidences
- Relations between phases (e.g. the way explanation and evidence are coordinated -claims are being supported by arguments based on collected data-evidence?-)
- Function of hypothesis (as "guesses about outcomes" or as parts from a larger explanatory frameworks)
- Presence/absence of model creation-use-test-revision; ways to promote each phase

In order to characterize broadly the trends derived from the analysis of isolated factors in lesson plans three categories were defined as shown in table 8. If the inferred NOS views in lesson plans were in line with the standard aspects described by Schwartz and colleagues (Schwartz et al., 2004), it was considered informed. On the contrary, if the view was not in accordance, it was termed naïve. When the inferred NOS contained some of the aspects considered by the authors, it was considered partially-informed.

Categories	Operational criteria
Informed	NOS view inferred from implicit aspects in lesson plans is completely in line with the NOS descriptions set in Schwartz et al., 2004, as set in table 7. The core features within these lesson plans were models and their explanatory power. Activities were completely coherent with the MCI framework described in section 2.4. The creation-use-evaluation-revision of models was the central aspect of activities and was performed coherently with real-scientific activity (of course, adapted to an school environment).
Partially-informed	NOS view inferred from implicit aspects in lesson plans successfully incorporate some aspects of scientific activity and intended to incorporate some others so as to give a NOS view partially in accordance with NOS aspects listed by Schwartz and colleagues (Schwartz et al., 2004). Lesson plans within this category successfully include and at least try to include some aspects of scientific endeavour (investigable questions, collecting data-evidence, model creation, testing, revision, use…). Nevertheless, the overall result failed to do it in coherence with NOS view set in table 6 because either/or: • Activities posed in lesson plans aimed to collect data-evidence but they do it as a direct observation of a phenomena in order to "show what happens" (not to construct new knowledge testing initial models…). • They considered the existence of a simplistic and standardized "scientific method". • Explanations were conceived as descriptions of phenomena. • Explanations were seen as simplistic relations between observable features or "taken-for granted" features and take the form of empirical generalizations • They did not promote or failed to promote scientific discussions to, for example, compare models, share data and think about their validity/relation/meaning…
Naïve	NOS view inferred from implicit aspects in lesson plans is in complete disaccord with the NOS descriptions as set in table 7 (Schwartz et al., 2004). Lesson plans within this category either: • Did not include any kind of scientific activity (they did not pose investigable questions, they may purpose hand-on activities but without collecting data-evidence, they share results but without promoting scientific discussions to compare models…), or • When they intended to include any kind of scientific activity, they **always** failed to do it.

Table 8. Categories and corresponding operational criteria used to characterize preservice students' NOS.

(2) Performance in the identification of target models.

One of the things preservice teachers need to learn to become good professionals is to decide which topics need to be covered, which of them must be covered in depth, which can be covered more superficially, etc. As explained in detail in section 2.2 (see figure 8), within the MCI framework underlying this research, this involves the identification of target models, build on scientific core ideas.

In order to give an idea of preservice teachers' awareness and ability to identify target models and to plan and teach lessons building on core ideas contained in these target models, within this dimension, two categories of analysis were identified:

1. Their ability to select target models according science core ideas.
2. Their ability to further develop the selected target models within lesson-plans.

Subcategories and operational criteria are summarized in table 9.

Categories	Subcategories	Operational criteria	Code
1. Ability to choose	Spontaneous good-selected	Target models arise from preservice students and are selected according to science core ideas.	1
	On demand	Target models/subtarget models to develop along lesson plans are given by the professor and are selected according to science core concepts.	0
	Spontaneous ill-selected	Target models arise from preservice students. They are isolated, anecdotal facts that do not bear in mind science core ideas.	-1
2. Ability to develop	Appropriate	Subtarget models-ideas developed within activities are in accordance with the selected target models.	1
	Inappropriate	Subtarget models-ideas developed within activities are in accordance with the selected target models. When target models have been correctly selected, there's no coherence between them and the ideas/subtarget models developed within/through activities.	0

Table 9. Categories, subcategories and operational criteria used to inform about preservice teachers' ability to select and plan activities according to target models.

Each category and subcategory was identified with a 0/1/-1 number, resulting a grid that represents all the possible situations (see table 10).

Ability to choose	Ability to develop	
0	0	Target models selected by the professor. Not coherently further developed.
0	1	Target models selected by the professor. Coherently further developed.
-1	0	Target models selected by students inappropriately and thus, not further developed.
1	0	Target models correctly selected by students but inappropriately further developed.
1	1	Target models correctly selected by students and appropriately further developed.

Table 10. Codes used to qualify preservice teachers' ability to select and further develop target models. Note that situation (-1 1) cannot occur (when target models are not selected correctly, they can not be further developed).

(3) Activities' sequencing.

To avoid the use of episodic and fragmented instructional activities it is important that preservice teachers learn to build articulated sequences of instructional activities that foster in-depth understanding of complex natural phenomenon (Ramsey, 1993).

One of the most widely recognized and adopted model for teaching guided-inquiry-based science in schools is the 5E Learning Cycle (Bybee et al., 2006). First created by Robert Karplus in the late 1950s and early 1960s, the 5E Learning Cycle has been regarded as an effective hands-on, minds-on, inquiry-based scientific pedagogy with strong constructivist foundations, for enhancing understanding (Bybee et al., 2006; Stamp & O'Brien, 2005). The 5E Learning Cycle consists of five phases: engagement, exploration, explanation, elaboration, and evaluation (Bybee et al., 2006; Eisenkraft, 2003) that can be summarized as shown in the first column of table 11.

5E cycle		***Model-centred instruction***	
Phases	***Summary***	***Phases***	***Summary***
Engagement	Access and exposure to the learners' prior knowledge. Engagement to new content promoting curiosity.	**Exploration**	Acces and exposure of learners' initial mental model.
Exploration	Provide students with a common base of activities within which current concepts (i.e. misconceptions), skills and processes are identified and conceptual change is facilitated.	**Model evolution**	Provide students with cyclical processes of hypothesis generation, empirical or rational testing and model modification or rejection to promote model evolution through conceptual change (learning to inquiry+inquiry to learn).
Explanation	Provide students with opportunities to demonstrate their conceptual understanding, process skills or behaviors.		
Elaboration	Provide new experiences to challenge and extend students' concept understanding and skills. Apply students' understandings of concepts by conducting additional activities.	**Application**	Provide new experiences to challenge and extend students' models and skills. Apply students' models by conducting additional activities.
Evaluation	Encourage students to assess their understandings and	**Evaluation**	Encourage students to test models in light of evidences and empirical data.

Table 11. Correspondence between the 5E Learning cycle and the Model-centred, and with the aim of exploring the ability of preservice teachers to provide sequenced learning experiences coherent with MCI, a new analysis tool was developed modifying and adjusting this cycle to models and modeling practices.

The "model of modeling diagram" (figure 6, section 2.2) proposed by Justi & Gilbert (Justi & Gilbert, 2002) and the learning-teaching pathways described by Clement (Clement, 2000) (see figure 8 section 2.2.) were taken as a reference to create a new diagram (called "ideal lesson plan diagram") for activity sequence analysis (figure 16, below).

As shown in figure 16, the "Ideal lesson plan diagram" maintains the steps outlined by Clement (Clement, 2000) and outlines the dialogic relationship between models and data/evidence proposed in the model of modeling diagram (Justi & Gilbert, 2002).

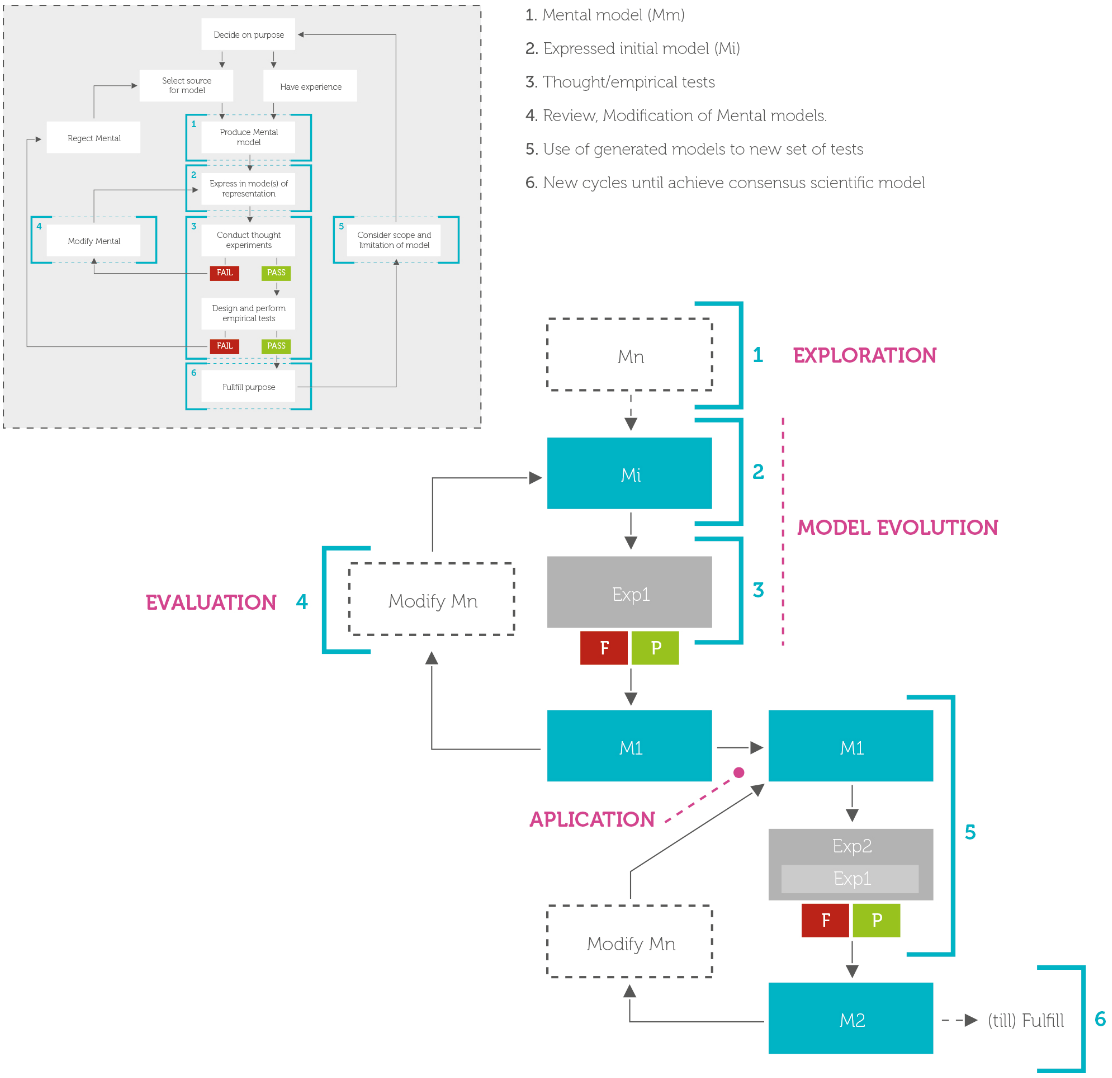


Figure 16. "Ideal lesson plan diagram". Outlined phases correspond to those in Justi &Gilbert's "model of modeling diagram" (dashed box). "Model of modeling" diagram is explained in detail in section 2.2. Note that 5 is represented as a new merged ideal scheme. Simplification of the scheme responds to best suitability to steps revised by students in their initial lesson plan.

Using the "ideal lesson plan diagram" as a reference, a system of cathegories and subcathegories was established as follows:

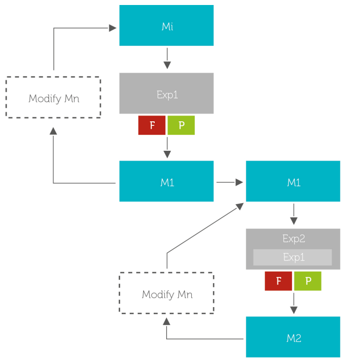
Categories	Subcategories
1. Constructive	1.1. Model-centred with application phase
	1.2. Model-centred without application phase
	1.3. Model-centred without application phase; maintenance of non suitable activities
2. Failed-constructive	2.1. Failed-model centred
	2.2. Non-model centred
3. Transmissive	3.1. Hands-on/minds-off with scientific activity
	3.2. Hands-on/minds-off without scientific activity
	3.3. Manipulative-transmissive
	3.4. Pure-transmissive

Table 12. Categories and subcategories used to qualify preservice teachers' ability to design learnig cycles according to MCI.

For each subcategory, a diagram was created and operational criteria were defined as follows:

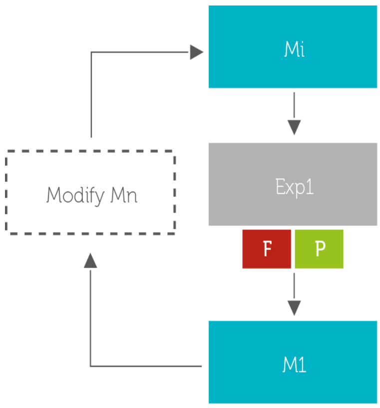
1. Constructive

1.1. Model centred with aplication phase



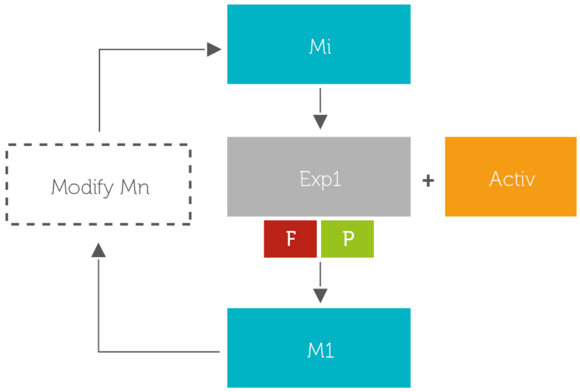
Initial mental models are explored and considered for further planning. Initial mental models are explored in accordance with key science principles/core concepts. Activities aim to collect data and evidence to revise prior models and/or construct new ones. Activities to apply the model are planned.

1.2. Model centred without aplication phase



Initial mental models are explored and considered for further planning. Initial mental models are explored in accordance with key science principles/core concepts. Activities aim to collect data and evidence to revise prior models and/or construct new ones. Activities to apply the model are not planned.

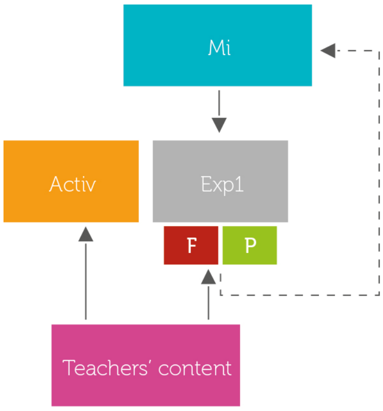
1.3. Model-centred without application phase; maintenance of non-suitable activities.



Initial mental models are explored and considered for further planning. Initial mental models are explored in accordance with key science principles/core ideas. Activities aim to collect data and evidence to revise prior models and/or construct new ones. Activities to apply the model may also be planned.

2. Failed-constructive

2.1. Failed model-centred

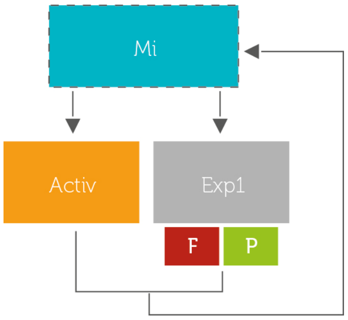


Lesson plan intends to develop the learning cycle for model centred instruction but fails to do it because (either/or):

a. The inability to plan activities from initial model exploration.
b. The inability to use data/evidence to review initial models

Lesson plan can include activities not linked to the model under construction-revision.

2.2. Non-model-centred

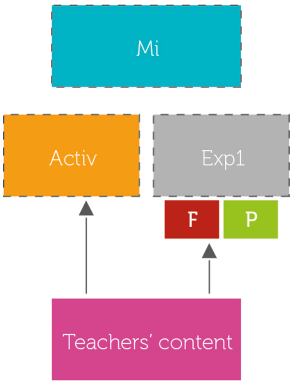


Lesson plan considers exploring student's prior knowledge but not in accordance to core concepts/principles. Not all the activities involve aspects of scientific activity (i.e. obtaining data through experimentation), although it may be knowledge and, when appropriate an application of new knowledge to similar problems.

In general terms, lesson plan accomplishes a complete learning cycle but fails to do it in coherence with model centred instruction.

3. Transmissive

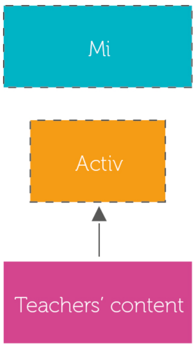
3.1. Hands-on/minds-off with scientific activity



Initial mental models are explored in an inconsistent way (prior knowledge is explored in a generic way not in relation to principles/core concepts/core concepts) and they are not used for further planning.

The lesson plan includes "hands-on" activities used for verification or discovery of a collection of isolated concepts not in relation with science core ideas. These hands-on activities also include teacher/expert presenting information. There are some activities with scientific activity.

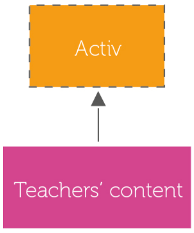
3.2. Hands-on/minds-off without scientific activity



Initial mental models are explored in an inconsistent way (prior knowledge is explored in a generic way not in relation to principles/big ideas) and they are not used for further planning.

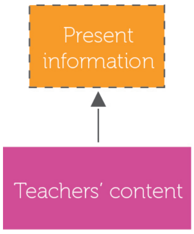
The lesson plan includes "hands-on" activities used for verification or discovery of a collection of isolated concepts not in relation with science core ideas. These hands-on activities also include teacher/expert presenting information.

3.3. Manipulative-transmissive



Initial mental models are not considered. The lesson plan includes "hands-on" activities used for verification or discovery of a collection of isolated concepts not in relation with science core ideas. These hands-on activities also include teacher/expert presenting information.

3.4. Pure-transmissive



Initial mental models are not considered. Activities involve teacher/expert presenting information not filtered by the lens of principles/core concepts.

Using this system of cathegories and subcathegories, llesson plan analysis was performed as detailed below:

1. Identification and delimitation of cognitive or manipulative actions proposed to the pupils beyond the criteria used by students in the delimitation of activities.

2. Characterization of these actions according to the elements identified by the "Ideal lesson plan diagram" (figure 16) and construction of the logical structure diagram underlying each MCI lesson through confrontation with the "Ideal lesson plan diagram".

3. Comparison of the obtained structures with the established categorical system.

(4) Planned joint activity structure.

As outlined in sections 2.1.3 and 2.4, the psychological theoretical framework adopted by MCI is the constructivist view of school teaching and learning (Coll, 2001). This conception recognizes that the process of knowledge construction is both individual and social in nature. Consequently, it considers as key elements so as for school learning to take place, the internal processes given within joint activity. From this perspective, the interactions between teacher and students and among students provide the context in which mechanisms of educational influence can operate (Colomina et al., 2001; Onrubia, et al., 2001).

Based on the above statements, the aim of this analysis dimension is to identify, describe and analyze -within lesson plans- how preservice teachers expect joint-activity to be. The interest lies in finding out how/which mechanisms of educational influence (related to the construction of shared meanings and fading of responsibility) are foreseen and how they change through the college MCI period.

Specifically, this dimension seeks to explore which mechanisms of educational influence are considered when planning, their suitability within an MCI framework of learning-instruction; their evolution over the college courses/when class interventions occur (lesson-plan reflection, case B), etc. to identify common traits and recognize possible difficulties that preservice teachers encounter when trying to help students to construct science knowledge and when helping to do so within a new learning-teaching framework (MCI).

Given the limited attention in the literature for analysis of lesson plans within an MCI framework, an adequate instrument to analyze mechanisms of educational influence within lesson plans was not available. However, there is a broad range of studies that have addressed this issue in real classroom settings (see Salvador, et al., 2008 for a summary of main approaches and results of a number of research studies based on educational influence mechanisms). All these studies use the methodological model for the analysis of mechanisms of educational influence proposed by Coll (Coll et al., 1995), valuing its usefulness for identifing joint-activity structure and mechanisms of education influence.

The present study builds on this methodological model and develops a new tool to fit specific requirements for the analysis and evaluation of expected mechanisms of educational influence reflected within lesson plans. Below, detailed descriptions of the process of analysis, categories and operational criteria are given.

- Identification of programed activity segments

As it has been justly said, this research bases its analysis on the methodological model for the analysis of mechanisms of educational influence proposed by Coll and colleagues (Coll et al., 1995). However, this methodology bases its analysis on the identification of joint-activity segments that, due to the nature of our data, are not always possible to identify.

Joint-activity segments (Coll et al., 1995) represent a first level of analysis to explain what really happens in a class and in relation to the interactivity-triangle. Nevertheless, in this research, data comes from preservice students' planifications/reflections on class intervention (see section 4.4) and, therefore, data do not reflect what would really happen in a class, but:

- in the case of students' plans: which actions are considered important (for preservice teachers) to take into account when planning and in order to ensure a gradual construction of shared meanings and a gradual process of transfer of responsibility.
- in the case of reflections on class intervention: which actions were performed and/or which of them are seen as key actions in the achievent of interventions' goals.

Although preservice teachers were required to describe in detail what they would do/what they have done, it is obvious that the detail given in lesson plans/reflections it is not comparable to an "in situ" observation (e.g. it cannot reflect teachers' spontaneous answers to students' reactions). For this reason, instead of using joint-activity segments, a new unit of analysis was defined: the programed activity segments (PAS).

In this research, PAS represent lower levels of analysis that correspond to minimum identificable segments were preservice teachers:

- plan (or reflect on, in case of class-intervention reflections, case B, final report) specific actions to achieve a certain instructional goal and around a specific content.
- forsee/identify some of the students' reactions/answers/difficulties regarding a specific task/content.

Therefore, it can be said that PAS define, "a priori" or "a posteriori" , the way in which preservice teachers conceive general traits of joint-activity. Within each PAS preservice teachers scketch, in a greater or lesser extent:

a. the structure pf social participation (definining what is going to do the teacher/alumni; why; with whom… and considering a general traits to articulate comunicative interaction).
b. the structure of the academic task (explaining the logic of the task around which joint activity is organized; defining steps and their order… as well as some of the actions, associated with the process of knowledge construction or task resolution, that participants are expected to perform/have performed)

The criteria used to identify and define (PAS) within sessions delimited by students in lesson plans was the "aim accomplisched by join-activity". Whenever there was a substantial and detectable change in the intentionality of the described join-activity, it was considered a change of PAS.

In order to accurately delimitate the beginning and final of each PAS, successive readings were carried out. A first group of lesson-plans was analysed and segmentation performed. After this initial segmentation, the identification of categories was a process of back and forth between data and the theoretical model. Common traits between segments were identified and a first system of categories and operational criteria was established. New lesson plans were analysed using the initial set of categories. In order to adjust them to the new data obtained from this analysis, the initial system of categories was revised. Similar successive improvements were done until achieving a final mutually exclusive system of categories, as shown in table 13. As it can be seen, 7 different PAS categories were identified. Each PAS category was given a code and a color. This code-color has been used when visualization of the global joint-activity structure, as explained later on. It is worthwhile to notice that any category was created regarding evaluation. As undergraduate courses did not specifically address this issue, it was not considered for analysis.

	Code	PAS Category	Operational Criteria
1	Frt	Facilitate the representation of the task	This PAS always appears at the beginning of sessions. Actions contemplated in this PAS are mainly held by the teacher who seeks: - Making connections between past and present learning experiences - Anticipating activities and focus students' thinking on the learning outcomes of current activities so that students become mentally engaged in the instructional objectives, concept, process, or skill to be learned.
2	Apk	Activating prior knowledge	PAS containing actions/strategies aimed to drawing out/make transparent students' mental models to adjust their teaching accordingly. This kind of PAS usually appears at the beginning of lesson-plans and/or when willing to explore mental models regarding a specific science idea that is later on developed. PAS "activating prior knowledge" involve teacher posing questions and/or specific problems/tasks and students answering and/or performing the desired task.
3	Pi	Providing information	PAS where: - Actions are mainly held on by an expert (teacher, person from a museum, etc.) who provides new information to students regarding a specific content and either: on its own initiative or on demand of students. - Students obtain information regarding a specific content searching it in different media or

			posing questions to an expert.
4	Pae	Planning of assignment elements	PAS where an expert (teacher, person from a museum, etc.) and the students share actions to ensure the performance of an assignment/task, related to a specific content. Pea PAS end when students start to do the assignment. Internal structure of these PAS can be either: - Actions are mainly held on by an expert (teacher, person from a museum, etc.) who gives instructions to perform a certain assignment/task. - Teacher and students perform actions in order to consensuate the way to perform a certain assignment/task. - Teacher delegates responsibilities (and scaffolds or not) to students who decide how to perform a certain assignment/task.
5	We	Work execution	These PAS appear as a consequence of Pae PAS and, therefore, appear after them. It involves actions performed by students as consequence of indications in Pae PAS and teachers' scaffoldings so as to ensure that students' can perform their actions.
6	EC	Elaboration-conclusion	PAS containing teachers' scaffolding actions that aim students to organize-elaborate knowledge in order to reach conclusions and modify internal models. EC PAS appear usually at the end of sessions or at the end of a sequence including a Pae PAS and a We PAS.
7	M	Metacognitive	This kind of PAS can appear at any moment within lesson plans. They include teachers' actions that seek to prompt students' metacognitive behaviors. Actions include specific scaffoldings to: reflect on the validity of a certain procedure; its suitability for a certain purpose; reflecting on models, validity of data, etc.

Table 13. Categories and operational criteria used to define and delimitate programed activity segments (PAS).

- Categorization of specific actions within programmed-activity segments.

Once PAS were established, actions within each segment were identified and categorized. Actions within each PAS were idntyfied using the criteria of "actions' intentionallity".

In general terms, the procedure to do so, was similar as with PAS categorization: based on literature available (Lemke, 1997; Clement, 2000; Chin, 2007; Van Zee & Minstrell, 1997), an initial intuitive system of categories was performed and, then, it was successively revised and refined through the analysis of lesson-plans and until achieving a final system of non-exclusive categories (see tables 14 to 20). As in the categorization of PAS, each action was identified with a code that was used when building joint activity maps.

- Actions within "Facilitate the representation of the task" PAS:

Code	Action Categories	Operational Criteria
1.a.	Framing	The teacher gives information and/or poses questions to anticipate and frame a problem, issue, topic… Students' are supposed to pay attention and answer the required questions.
1.b.	Anchoring	The teacher anchors new concepts on other experiences/knowledge known and shared by students. Students' are supposed to pay attention and answer the required questions.
1.c.	Recaps	The teacher orchestrates a summary of what has been said/learned in previous sessions either as a monologue or aiming students to participate.

Table 14. Actions and operational criteria within "Facilitate the representation of the task" PAS.

- Actions within "Activating prior knowledge" PAS:

To reflect richness of actions within "Activating prior knowledge" PAS two subcategories were done: the first one, corresponding to expected actions performed within joint-activity and, the second one, with expected actions performed by the teacher, but not in the context of joint-activity.

A. Actions within joint-activity		
Code	**Action Categories**	**Operational Criteria**
2.A.a.	General brainstorming	Teacher requires students to tell/write all they know about a topic, without framing student's responses.
2.A.b.	Specific knowledge asking	Teacher formulates one or more specific questions to explore a desired content/topic and in relation to key ideas from target models. Students' answer the question individually.
2.A.c	Posing a problem/scenario/seatwork assignment	Teacher poses a problem/scenario and/or describes a specific seatwork assignment to explore students' internal models. Students' perform individually or into small groups the required task.

2.A.d.	Hypothesis question	Teacher formulates a question that aims students to activate prior knowledge to make a hypothesis.
2.A.e.	Recap	The teacher orchestrates a summary of what has been said as a monologue or aiming students to participate.

B. Specific teachers' actions		
Code	**Action Categories**	**Operational Criteria**
2.B.a.	Analyzing	Teacher analyses student's exposed models and uses results from this analysis to plan further activities.

Table 15. Actions and operational criteria within "Activating prior knowledge" PAS.

- Actions within "Providing information" PAS:

Code	Action Categories	Operational Criteria
3.a.	Teacher exposition	This action is based on Lemke's category with the same name. It indicates actions were an expert (teacher, person of a museum…) is expected to present information as a monologue (presenting a new content, to respond to student's question…). Through this exposition students' are supposed to be listening, taking notes, and/or interrupting to ask for clarification, when necessary.
3.b.	Teachers' questioning dialogue	This action is also based on Lemke's categorical system, corresponding to the "triadic dialogue". In this case, the teacher/expert initiates a series of questions on the subject-matter topic and students answer them. In this case students are only required to reproduce answers, not fostering their thinking through questions (see "socratic questioning").
3.c.	Students' questioning dialogue	Activity structure based on Lemke's categorical system. The structure is equivalent to teacher's questioning dialogue but, in this case, different students initiate the questions on the subject-matter topic and the teacher/expert answers them.
3.d.	Students' information searching	Activity structure where students' are aimed to search information from books, media, etc. Teacher may pose questions to guide this research.
3.e.	Socratic questioning	Category based on Chin, C. (2007). The teacher/expert uses a series of questions to prompt and guide students' thinking instead of telling the students a mass of information via direct teacher exposition. The difference between this category and the teachers' questioning dialogue relies in the fact that, in this case, teacher introduces new knowledge and fosters' students' thinking via questions.

Table 16. Actions and operational criteria within "Providing information" PAS.

- Actions within "Planning of assignment elements" PAS:

Code	Action Categories	Operational Criteria
4.a.	Giving directions	This action is similar to "teachers' exposition". An expert (teacher, person of a museum…) is expected to give information as a monologue on how to perform a specific assignment. Through this exposition students' are supposed to be listening, taking notes, and/or interrupting to ask for clarification, when necessary.
4.b.	Indirect Giving directions	This action is also similar to "Teachers' questioning dialogue". The teacher/expert initiates a series of questions and, through the answers, students' outline instructions to perform a specific assignment.
4.c.	Students' giving directions	Structure of actions that students' perform in order to decide how to perform a task. Minimum guidance of teacher is given.
4.d.	Split-up	A complex task is broken into easier, more "doable" steps to facilitate student achievement.
4.e.	Reformulating	Teacher uses a different way to explain what he has already said.
4.f.	Modelling	Strategies/ interventions that aim to demonstrate/give example of/propose a way to develop a specific task.
4.g.	Noticing	Actions to emphasise the relevance of certain aspects (i.e. a concept, skill or strategy)
4.h.	Focusing	Teacher focuses on a specific gap (i.e. a concept, skill or strategy) that students need pay special attention.

Table 17. Actions and operational criteria within "Planning of assignment elements" PAS.

- Actions within "Work execution" PAS:

Code	Action Categories	Operational Criteria
5.a.	Non hands-on	Students' work individually or into small groups to perform non hands-on activities in relation to the content. Teacher helps them.
5.b.	Hands-on	Students' work individually or into small groups to perform hands-on activities that do not imply scientific activity in relation to the content. Teacher helps them.
5.c.	Obtaining data-evidence	Students' work individually or into small groups to perform scientific activity to obtain empirical data/evidences in relation to the content. Teacher helps them.

5.d	Organizing data-evidence	Students are required to organize data (i.e. using tables) to further elaborate and interpret them.
5.e.	Monitoring	Teacher controls and provides information regarding student's assignment performance.

Table 18. Actions and operational criteria within "Work-execution" PAS.

- Actions within "Elaboration-conclusion" PAS:

Two different subcategories have been defined within this PAS. The first one correspond to general actions performed within join activiy while, the second one correspond to actions in reference to specific science content.

A. General actions		
Code	**Action Categories**	**Operational Criteria**
6.A.a.	Sharing	Teacher requires students' to share results obtained individually or into small-groups within a "work execution" PAS in order to ensure that knowledge construction is a social process.
6.A.b.	Teachers' questioning dialogue	This action is equivalent to 3.b category. The teacher/expert initiates a series of questions aiming students' to draw conclusions with minimum guidance.
6.A.c.	Socratic questioning	This action is equivalent to 3.e category. The teacher/expert uses a series of questions to prompt and guide students' thinking to reach conclusions.
6.A.d.	Cross-discussion	This category is based on Lemke (1997). Lemke describes cross-discussion as dialogue directly between students, with the teacher playing only a moderating role.
6.A.e.	Recasts	Teacher's reformulation of the student's utterance aiming to minimize errors.
6.A.f.	Reflective toss	This category is based on Van Zee & Minstrell (1997). The teacher catches the meaning of what a student is saying and throws the responsibility for thinking back to the student/class.
6.A.g.	Recapitulation	As in 2.A.e., the teacher orchestrates a summary of what has been said as a monologue or aiming students to participate, organizing when necessary, information.
6.A.h.	Fill-in-the blanks questioning	Teacher/expert requires students' to raise conclusions providing close answers (fill-in-the blank sentences/paragraphs) were students have to provide the missing word/words.

B. Specific science-content		
Code	**Action Categories**	**Operational Criteria**
6.B.a.	Elaborate data/evidence	Teacher prompts students to interpret data elaborating (i.e. representing data as a graph, diagram, etc.)
6.B.b.	Referring to data/evidence	Teacher prompts students to construct evidence-based arguments.
6.B.c	Discrepant events	Activity structure based on Clement's (2000). Teacher promotes forms of "participative dissonance". Teacher provides information allowing the student to discover a conflict with his or her own current model.
6.B.d	What if… scenarios	Activity structure based on Clement's (2000). Teacher aims students' to speculate on what would happen if one or more parameters associated with the initial model change.

Table 19. Actions and operational criteria within "Elaboration-conclusion" PAS.

- Actions within "Metacognition" PAS:

Actions within "Metacognition" PAS were divided into three different subcategories corresponding to:

A. Declarative metacognitive knowledge: containing actions to enhance students' knowledge about their learning processes and the actions they need to perform in order to learn.
B. Procedural metacognitive knowledge: containing actions to reflect on the methodologies that can be used to solve problems/perform assignments and to reflect on their validity.
C. Conditional metacognitive knowledge: containing actions to enhance students' ability to use declarative and procedural knowledge in appropriate settings/situations

A. Declarative metacognitive knowledge		
Code	**Action Categories**	**Operational Criteria**
7.A.a.	Revision of previous models	Teacher prompts students to revise previous models
7.A.b.	Reflecting on models	Teacher prompts students to reflect on models: their characteristics; utility, etc.
7.A.c.	Recapitulation	Similar to Recapitulations in categories 2.A.e. and 6.A.g. teacher orchestrates a summary of the steps performed by students to reach a conclusions and gain new knowledge, either as a monologue or aiming students to participate.

B. Procedural metacognitive knowledge

Code	Action Categories	Operational Criteria
7.B.a.	Thinking on the validity of data-evidence	Teacher prompts students to reflect on the validity of the obtained data-evidence.
7.B.b.	Thinking on the validity of a certain procedure/methodology	Teacher prompts students to reflect on the validity of a certain procedure.

C. Conditional metacognitive knowledge		
Code	**Action Categories**	**Operational Criteria**
7.C.a.	Thinking on the suitability of a certain procedure	Teacher prompts students to reflect on the suitability of a certain methodological/construction knowledge procedure.

Table 20. Actions and operational criteria within "Metacognition" PAS.

- Visualization of the global joint activity structure

In order to visualize the global joint-activity structure as planned by preservice students, joint activity maps for each lesson-plan were done. Joint activity maps are graphic forms that represent the structure of joint activity and its evolution through - in our specific case- the planned/expected process of teaching and learning.

	PAS 1	PAS 2	PAS 3	PAS 4
Session 1	Apk	PAE	WE	
	2.A.d.	4a	5c	
Session 2	Apk	PAE	WE	EC
	2.A.d.	4a	5c	6.A.b. 6.B.b
Session 3	Apk	PAE	WE	EC
	2.A.d.	4a	5c	6.A.b. 6.B.b
Session 4	Apk	PAE	WE	EC
	2.A.d.	4a	5c	6.A.b.

Figure 17. Example of a join activity map showing the structure of join-activity planed by students in a specific lesson plan.

As it can be seen in the example above (figure 17), running vertically along the map, there are the different sessions into which a lesson-plan is divided. Within a same session and running horizontally, there two lectures:

- A first level indicating PAS within sessions, temporarily ordered.
- A second level indicating actions planned within each PAS.

In order to facilitate lecture and interpretation, each PAS has been identified with a color and a code as indicated in table 13. Under each PAS, each action has been indicated with their code (tables 14-20). Furthermore, an action was planned but the way it was described assessed deficiencies, it has been considered as ill-posed and it has been indicated using the appropriate code but highlighting it with red.

Overall, the quantitative and qualitative analysis of the sequencing of PAS, the changes detected within their internal structure (actions within PAS), the analysis of their evolution through lesson plans (data collected at different times of college courses), etc. has allowed find interpretable indicators that gives better understandings of:

- Preservice teachers' conceptions of PAS within science-classroom settings and their evolution through their training on MCI.
- Preservice teachers' actions/difficulties when planning adjusted aids.
- Preservice teachers' actions/difficulties to ensure a gradual transfer of responsibility from the teacher to the student.

All these results and conclusions are presented and discussed, respectively, in chapters 5 and 6 of this report. Furthermore, implications of results are presented in chapter 7.

4.5.3. Reliability, validity and transferability of procedures and results.

In order to attain rigor in the already described framework of qualitative research, different strategies, based on criteria established by Guba & Lincon (Guba & Lincon, 1981, 1982, 1989), have been implemented.

- **Use of previous theoretical background to create categories and for data interpretation.** Different theoretical frameworks have been used in two key moments of the analysis procedure: when creating categories and for data interpretation. In the first case, and whenever possible, emerging categories/subcategories have been compared with those defined in other researches or with those expected considering our theoretical framework. On the other hand, theoretical frameworks (see section 2) have been also reviewed for data description and interpretation.

- **Triangulation.** In all cases, investigator triangulation (Denzin, 1970; Lincoln, Y.S. & Guba, E.G., 2000) has been used in order to escape some of the biases that are implied in this kind of research. Investigator triangulation has been used in defining categories, coding of lesson plans and questionnaires, and eventually, in the identification of patterns in the data. Observations notes and other classrooms artefacts also have been used to triangulate findings.

Taking into account not only data procedures and analysis but also the validity and transferability of the whole research procedure, this dissertation also tried to:

- Describe with maximum details the decisions taken into account during the research process and the perspectives in which they are based on.
- Describe the cases and the selection process.
- Achieve congruence between processes for data analysis and research questions.
- Promote constant interaction between data and theoretical framework. Building a solid foundation was promoted through constant checking and rechecking. Ideas emerging from data were reconfirmed in new data. This, in turn, gave rise to new ideas that were, again, verified in data already collected moving always from macro-micro perspective.

5. Results

The purpose of this chapter is to present the key results obtained in this investigation and related to research questions settled in chapter 3. Those results are later on discussed in chapter 6 and implications, limitations and proposals of further research are later on considered in chapters 7 and 8.

The chapter is organized into 4 different sections. Section 5.1 examines results from the analysis of NOS underlying lesson plans. Section 5.2., presents results regarding the analysis of preservice teachers' performance in the identification of target models. Section 5.3. shows results from the analysis of activities' sequencing and, finally, section 5.4. displays results derived from the analysis of the planned join activity structure.

5.1. Nature of science (NOS) underlying lesson plans

The analysis of NOS view inferred from implicit aspects in lesson plans reveals naïve-partially informed NOS views in all cases. Initial, reviewed and final lesson plans tried to incorporate, in all cases, some but not all aspects considered by Schwartz et al. (2004). Furthermore, in some cases, students failed to incorporate them properly. NOS views inferred from final lesson plans improved significantly regarding to those inferred from lesson plans made prior to instruction. The key to this improvement lies in the fact that preservice teachers were able to successfully incorporate, some of the aspects considered in table 8 according to what they have been learning through instruction. Table 21 summarizes major findings from this analysis.

	LP1i			**LP1f**			**LP2**		
	Naïve	Partially-informed	Informed	Naïve	Partially-informed	Informed	Naïve	Partially informed	Informed
CASE A	71%	29%	0%	43%	57%	0%	0%	100%	0%
CASE B	10%	90%	0%	10%	90%	0%	-	-	-

Table 21. NOS views inferred from lesson plans.

In CASE A, all initial lesson plans (LP1i) tried to incorporate some aspects of scientific activity (i.e. posing hypothesis; data collection…) but 71% always failed to do it in coherence with ideas considered by Schartz et al. (table 7). These lesson plans showed a simplistic and certain view of scientific reasoning and contained many transmisive/hands-on activities, without scientific activity.

NOS views inferred from CASE A reviewed lesson plans, were naïve in 43% of cases. However, in final lesson plans (LP2; made during the second period of instruction), all of them were partially informed (table 21).

In CASE B, NOS views inferred from initial and reviewed lesson plans were all but one partially informed. The lesson plan categorized as "naïve" did not change significantly after revision.

In both CASES A and B, lesson plans with partially-informed NOS views contained activities that aimed students to collect data-evidence. However, these activities failed to encourage students to coordinate theory/ideas with partially conflicting data. In most cases, data-evidence was obtained as direct observations to demonstrate a "taken-for-granted" phenomena. In other cases, students were encouraged to draw obvious inquiry conclusions from simple experiments.

Simplistic and standardized science views could be also inferred beyond activities. The examples presented below[1] are shorthand illustrations of the sort of data gathered within lesson plans and through the questionnaires performed at the beginning and at the end of the first period of instruction.

Example 1: CASE B 1213.03.02i

"- *Mètode científic.*

- Es planteja un problema i a partir d'aquí es fan prediccions, hipòtesis, s'experimenta es valoren els resultats i s'extreuen conclusions."

CASE A 1112.03.13i

"*A partir de l'experimentació podran plantejar hipòtesis que els ajudaran a trobar respostes a les seves preguntes.* "

Example 2: CASE A 1112.03.04i

"A partir de les idees que hauran aportat a l'activitat anterior la mestra distribuirà els alumnes en parelles o grups de 3 i els proposarà anar a l'aula d'ordinadors per contrastar-les amb informació del contingut. Posteriorment cada grup d'estudiants hauran d'explicar el què han trobat i les conclusions que n'han tret de la pregunta inicial.
La mestra deixarà clar el mètode que utilitzen els científics tot dient-los que els errors són útils per avançar en la recerca. Els ha de treure la por a l'error. La mestra els facilitarà l'ajuda necessària però deixarà que els alumnes siguin els propis protagonistes i que facin ells la recerca."

Example 3:

Alumni 1 (initial)

"Primer els hi sorgeix un dubte sobre algun fet, a continuació fan prediccions i hipòtesis sobre els motius que fan que aquell fet es produeixi. Tot seguit experimenten sobre aquell fet i per últim comparen els resultats amb les prediccions i hipòtesis i en treuen unes conclusions."

Alumni 2 (initial)

"Depenen de la branca de la ciència que s'estudiï s'ampliarà el coneixement d'una manera o una altra, és a dir uns faran reaccions químiques, d'altres estudiaran el cos humà, n'hi ha que observaran l'espai exterior.

Però tots tenen un tret en comú, ja que en major o menor grau la ciència s'amplia a partir de l'observació."

---

[1] Examples (in this and other sections) are shown literally. Expresion and gramatical misconceptions correspond to the original.

Alumni 3 (reviewed)

"Els científics investiguen partint d'una pregunta, un fet o una observació, perquè tenen la necessitat de comprendre. La investigació científica genera dades, fets i evidències. Dins d'aquest marc, juguen un paper clau les preguntes i la comunicació amb la resta de la comunitat científica. Una part de la investigació necessita de dissenys experimentals, per poder observar un fenomen concret, analitzar i recollir les dades, per intentar establir unes conclusions o argumentacions. Normalment, un factor clau en el desenvolupament experimental són les possibles hipòtesis. Depenent de l'orientació de les mateixes, la investigació pot seguir diferents camins, alguns dels quals quedaran aparcats per a properes experimentacions.

La finalitat de les investigacions científiques és crear noves idees i models teòrics argumentats. La ciència explica models teòrics temporals, i la comunitat científica n'és conscient. Els científics s'han d'adaptar a l'actualització d'aquests models, per tant, podem dir que han de reconstruir constantment les seves idees (models), perquè aquests canvien, no són per sempre."

Example 1, presents fragments corresponding to the section where preservice teachers' were required to describe general pedagogical principles on which they based their LP. Example 2 illustrates weak understandings on NOSinferred from lesson plans descriptions. Example 3 presents answers to the question "How do you think scientists construct their knowledge?" posed in initial and reviewd questionnaires.

Altogether, these data provide insight into preservice students' thinking about NOS and helped to discriminate more or less informed NOS profiles.

- **Summary of main ideas:**

  - **NOS views inferred from lesson plans and contrasted with questionnaires are naïve or, at best, partially informed.**

  - **NOS views improved through instruction. This improvement was due to preservice teachers' capacity to incorporate some aspects worked during the instructional period.**

5.2. Performance in the identification of target models

Identifying and unpacking target models (i.e., identify learning goals and subconcepts/subskills that feed into these target learning goals) is an essential starting point for teaching and improving teaching, in this case, through MCI. This section presents results regarding teachers' performance in the identification and further development of target models. Consequences regarding to this findings are discussed in relation with other data of this study in section 6.

Data analysis about preservice teachers' performance in the identification of target models reveals two basic ideas:

- In general terms, preservice teachers have difficulties to identify and articulate appropriate target/subtarget models by themselves.

- When target/subtarget models are given by the professor, preservice teachers have the ability to find activities to develop them within lesson plans.

Below, different examples illustrate and further develop these general conclusions.

As explained in section 4.4. and summarized in table 6, in CASE A, target models always arise from preservice students. Data resulting from the analysis of these lesson plans reveals that all preservice science teachers had huge great difficulties to select appropriate target/subtarget models. Only 3 of the analysed lesson plans in CASE A contained target models with scientific ideas that were partially in accordance with science core concepts. No significant differences were found between initial and reviewed lesson plans performed during the first period of instruction and lesson plans performed during the second period of instruction.

As already mentioned and shown with examples 1, 2, 3 and 4, instead of target/subtarget models based on science core concepts, preservice teachers selected a list of "disconnected science facts to be learned".

Example 1: (CASE A 1112.03.03i)

a. *" Cada part de la llengua detecta gustos diferents, com per exemple: a la punta de la llengua notes el gust dolç, els costats reconeixes el gust salat i àcid i amb el fons reconeixes el gust amarg.*
b. *No totes les persones detecten el mateix gust en una substància específica.*
c. *Els aliments poden tenir diversos sabors a la vegada.*
d. *Amb una mica de sal els aliments els trobem més gustosos.*
e. *Cada ésser humà té desenvolupat la intensitat de l'olfacte diferent.*
f. *Els sabors amargs et fan fer cares rares.*
g. *Els sabors àcids ens fan venir esgarrifances i, a vegades, fa que et surtin les llàgrimes.*
h. *Per notar el sabor de les coses, la llengua ha d'estar mullada de saliva."*

In this case, the topic given to students was "senses", with the underlying science core idea (not given to students "a priori") that can be summarized as: "senses provide information about the world and supply it to our brain, which is responsible to coordinate orders to give an answer to this information." Preservice students in this group decided to frame the topic focusing their work on the taste sense.

As it can be seen, ideas selected correspond to "isolated facts" that show that undergraduate students do not have in mind the above mentioned core idea. They focus on flavours not in "taste" as a "sense" (a physiological capacity to provide information from the outside world).

Furthermore, if we look at them more closely, we see that:

- Some of them are quite "anecdotic/irrelevant" (b., f., g.);
- Some of them correspond to typical content that can be found in science-activity books (a; d; h);
- Some of them are quite "confusing" (b; c)
- One of them does not even correspond to the selected topic (e).

Examples 2 and 3 also represent this typical selection of "isolated science facts", not in relation to target models.

Example 2: (CASE A 1112.03.03i)

"a. Els ocells neixen d'un ou.

b. Els ocells necessiten un mascle i una femella per a reproduir-se.

c. Per tal de mantenir l'espècie és imprescindible la fecundació.

d. Dins l'ou hi transcorren diverses fases, a partir de les quals es va forman la cria d'ocell."

Example 3: (CASE A 1112.03.05i and 1112.03.05f)

"a. El mimetisme és un fenomen que permet a un organisme adaptar-se al seu entorn per tal d'enganyar als sentits dels animals.
b. El camaleó té la capacitat de canviar el color de la pell gràcies a les diverses cèl·lules cromatòfores amb pigments diferents."

In example 2, the topic given to students was "embryonic development of a chick". As it can bee seen, ideas selected correspond to "general facts". Only the last one (d) "addresses" the given topic. Nevertheless, the statement is too generic, do not bearing in mind any science core idea. Furthermore, ideas (a and b) are, in general terms, too evident for 10-11 years old children (lesson plans were addressed, on requirement, to a 6 grade class). Somehow, it might be interesting to refresh these ideas at the beginning of such a lesson plan, but not to fix them as core ideas. Finally, idea c evidences, clearly, the weakness of preservice teachers' content knowledge: fertilization initiates the development of a new organism. Neither it ensures the survival of a specie; nor is the unique strategy for producing offspring.

In example 3, the given topic to students was "colour in living organisms", as a "physical adaptation which help living things survive". In this case, undergraduate students focused their lesson plan in the study of the chameleon. Once more, selected ideas are presented as isolated facts. Idea a shows, once more, weakness of content knowledge: mimicry makes an specie to resemble its surroundings, making it difficult to detect and, thus, increasing its survival chances. The aim is not cheating animals senses. On the contrary, idea b appears to be what could be considered "anecdotic knowledge", coming from books, not in relation with core science ideas appropriate for six grade pupils.

Finally, example 4 shows how preservice teachers sometimes put emphasis on formalisms. In cases like the one in the example, target models were presented as "objectives". The emphasis was put on the way to write them as learned in other university courses. Nevertheless, selected objectives were, once more, a list of disconnected facts, mostly too generic and not conceived in terms of scientific core concepts."

Example 4: (CASE A 1213.04.04)

"a. Conèixer la realitat de la dispersió de les llavors.

b. Desenvolupar habilitats per descobrir els diferents mecanismes de dispersion.

c. Aprendre les diferents aerodinàmiques d'algunes llavors concretes.

d. Entendre quin paper juguen els animals en la dispersió de les llavors."

When preservice science teachers had the oportunity to review lesson plans, they did not always modify the selected ideas. Furthermore, and as seen in exemple 5, when reviewed, they did not change them significantly.

Example 5: (CASE A1112.03.01i)

"a. Tipus de vol en els ocells: aquells que s'impulsen, i aquells que necessiten d'altura per planejar.

b. Incidència de l'aire en el vol dels ocells, forma de les seves ales i corrents d'aire calent.

c. Cavitats d'aire i ossos buits per dins, eines del vol dels ocells.

d. Causes climatològiques que afecten el comportament dels ocells."

(1112.03.01f)

"a. Tipus de vol en els ocells: aquells que s'impulsen, i aquells que necessiten d'altura per planejar.

b. Principi de Bernouilli (forma de les ales i la incidència de l'aire).

c. Cavitats d'aire i ossos buits per dins, eines del vol dels ocells."

Although activities were better planned in terms of scientific activity (see sections 5.4. and chapter 6), results coming from the analysis of reviewed lesson plans and the second lesson plan (LP1 reviewed and LP2, figure 14), show the same weaknesses as those coming from initial lesson plans (LP1 initial, figure 14). Students continued identifying learning goals as isolated knowledge not related to science core concepts. Nevertheless it is worthwhile to mention that, when students reviewed their ideas, a small qualitative improvement could be found. In these cases, it was possible to infer blurred science core concepts behind the selected ideas.

Behind the selected ideas in the reviewed lesson plan shown above (1112.03.01reviewed), for example, there is somehow the idea that "living organisms have certain structures in order to do certain functions that enable them to survive." In this case, preservice teachers eliminated "idea d" and focused efforts in the study of those structural components that enable birds to fly. Although "idea a" was not modified, its orientation within activities changed in the mentioned direction. Equivalent changes were found in other lesson plans.

As mentioned at the beginning of this section, three of the initial lesson plans in CASE A selected scientific ideas quite in accordance with science core ideas (example 6). In all cases, these ideas improved after revision. Furthermore, preservice students selected suitable activities to develop them. Nevertheless, as shown in section 5.4 and discussed in chapter 6, the selection of appropriate activities did not ensure the ability to plan convenient tasks to ensure knowledge construction in a classroom setting and in accordance with MCI.

Example 6: (CASE A 1112.03.08i and 1112.03.08f –bold-)

a. ***"Quan ens reproduïm hi ha aspectes del pare o la mare que es repeteixen en els descendents, però no tots ni sempre de la mateixa manera.***
b. *Els fills s'assemblen als pares, però només en certs aspects.*
c. *Hi ha fets en què hi ha molta semblança entre pares i fills (per exemple el color dels ulls, embolicar la llengua, moure les orelles,* ***el color dels cabells...),*** *i en d'altres n'hi ha molt poca (són més aleatoris, com el caràcter* ***o la lletra****).*
d. *El color dels ulls, entre d'altres aspectes, no és aleatori, sinó que té a veure amb la genètica de la família."*

Although they may be not clearly expressed, ideas selected by preservice teachers in example 6 correspond to science core ideas such as: "parents are similar but not exactly the same as their offspring"; "some characters are inherited, others result from interactions with the environment."; "reproduction ensures the transmission of hereditary information between generations".

Finally, when target models were incorporated in lesson plans on demand (CASE B, see section 4.4.), preservice students hat the ability to select and design learning activities according to this target models. As it will be discussed in chapter 6 and in coherence wit other results from this study, this did not ensure ability to plan actions to perform such activities according the MCI framework.

Summary of main ideas:

- Without support, preservice science teachers struggle to identify relevant target/subtarget models.

- In the selection of target models to develop within lesson plans, preservice students:

a. tend to select isolated content to be learned that do not have in mind the scientific core ideas.
b. show weakness of specific content knowledge and knowledge about learners and how they learn.
c. rely on lab-books/text-books to select ideas/facts/content.
d. put emphasis on formalisms to write ideas to be learned.

- Facilitating target/subtarget models helps preservice teachers to select and design appropriate learning activities.

- The selection/design of appropriate learning activities does not ensure planning suitable scaffoldings to ensure students' knowledge construction in accordance with MCI.

5.3. Activities' sequencing

Building articulated sequences of instructional activities is essential to construct in-depth understanding of complex natural phenomenon as well as to promote scientific literacy. Learning cycles as shown in figure 16 and table 11, become robust inquiry-based instructional approaches that benefit from extensive research and that can assist preservice elementary teachers in developing coherent "conceptual storylines" through carefully sequenced activities.

This section presents results about preservice teachers' ability to provide sequenced learning experiences coherent with MCI. As explained in section 4.5.2., results from this analysis help to provide a general perspective of lesson plans in order to better interpret results derived from the microanalysis of data (planned join activity structure, section 5.4.). Therefore, discussions of major findings in this section are found, in relation with other data, in section 6.

		CASE A			CASE B	
Categories	Subcategories	LP1i	LP1f	LP2	LP1i	LP1f
1. Constructive	1.1. model-centred with application phase	0	0	1	0	0
	1.2. model-centred without application phase	0	0	0	0	0
	1.3. model-centred without application phase; maintenance of non suitable activities	0	0	0	0	0
2. Failed-constructive	2.1. failed-model centred	0	4	3	5	9
	2.2. non-model centred	0	0	8	0	0
3. Transmissive	3.1. hands-on/minds-off with scientific activity	13	9	0	5	1
	3.2. hands-on/minds-off without scientific activity	0	0	0	0	0
	3.3. manipulative-transmissive	1	1	0	0	0
	3.4. pure-transmissive	0	0	0	0	0

Table 22. Characterisation of activities' sequencing in CASE A and CASE B lesson plans.

As explained in detail in section 5.4 and discussed in chapter 6, lesson plans were (especially those made the beginning of the course), very heterogeneous. The categorical system shown in table 12, allowed us to determine the kind of sequence underlying each lesson plan. Table 22 summarizes these results.

As it can be seen, CASE A lesson plans performed at the beginning of the undergraduate course (LP1i) were, in all cases, far distant from the ideal lesson plan diagram (figure 16). In general terms, this lesson plans were based on unclear objectives, not in relation with science core ideas. Furthermore, students did not consider alumni mental models in their lesson plans or, when considered, they were explored in a vague way. Moreover, when explored in such a way, mental models were not considered for further planning. Activities in these lesson plans were far removed from real scientific activity and they did not expect students to collect data and evidence to revise prior models (schematized as lack of feedback to initial model) and construct new ones. Most units also included activities not in accordance with science key ideas. These lesson plans were classified as "hands-on/minds-off with scientific activity" and, in one case, as "manipulative-transmissive".

The half of the initial CASE B lesson plans were also characterized as "hands-on/minds-off with scientific activity" lesson plans. The rest of them, were considered "failed-model centred". It is important to remember that, in all these lesson plans, target models were incorporated on demand. In cases were lesson plans were characterized as "failed-model centred" preservice students selected activities to collect data-evidence according to the given core ideas. Furthermore, they planned initial activities to explore students' initial models. However, most lesson plans hat deficiencies in the way they planned to collect data; not all the selected activities were linked to the model under construction and, in all cases, they failed to present coherent activities to revise prior models (lack of feedback to initial model).

When comparing initial lesson-plans with revised lesson plans (CASE A and CASE B) and lesson plans performed during the second period of instruction (LP2 CASE A), clear evidences of certain improvements are found. In general terms, through instruction, lesson plans moved from transmissive learning cycles to "fail-constructive" learning cycles. However, the existence of common pitfalls did not allow them to resemble the model of modeling diagram (figure 16).

In CASE A, nine reviewed lesson plans (LP1f) were still considered "hands-on/minds-off with scientific activity". Furthermore, the lesson plan considered as "manipulative-transmissive" also remained at the same category.

In all these cases, lesson plans incoroporated changes related to an improvement in data/evidence collection and the planning of initial prior-knowledge exploration activities. However, all these lesson plans still presented most of the struggles as in initial lesson plans. The rest of CASE A reviewed lesson plans (4) were considered "failed-model centred". These lesson plans hat similar characteristics as those in initial CASE B lesson plans.

Eight CASE A lesson plans performed during the second period of instruction (LP2), were considered "non-model centred". Just one of them was considered "model-centreed with application phase" and, the rest of them were considered "failed model-centred".

In general terms, all these lesson plans continued improving the way they plan data/evidence collection activities, as well as the planning of initial prior-knowledge exploration activities. However, they still hat problems when trying to identify target models (in the case of "non-model centred" lesson plans) and when trying to ensure feedback to initial models (in "failed model-centred" lesson plans). In most cases, activities without scientific activity were still planned.

In CASE B reviewed lesson plans, preservice students also easily incorporate changes related to an improvement in data/evidence collection as well as designing elicitation activities of the initial model. However, feedback to initial model was difficult to incorporate in all cases and, when incorporated, it was not done in a consistent way. Therefore, all but one lesson plans were considered "failed model-centred" and, the other one, was still characterised as "hand-on/minds off with scientific activity".

Summary of main ideas:

- Most lesson plans performed at the beginning of the undergraduate course (LP1i) were, in all cases, far distant from the ideal lesson plan diagram (figure 16). These lesson plans respond, mainly, to a "hands-on/minds-off" approach.

- The half of CASE B initial lesson plans were categorised as "failed model-centred". The introduction of target models on demand facilitated the selection of activities but did not ensure the ability to plan coherent activities to revise initial models.

- When comparing initial lesson-plans with reviewed lesson plans (CASE A and CASE B) and lesson plans performed during the second period of instruction (LP2 CASE A), clear evidences of certain improvements are found. Through instruction, lesson plans move from transmissive learning cycles to constructive cycles more in coherence with the "ideal lesson plan diagram". However, common pitfalls occur in most cases in relation to:

a. **exploring prior knowledge not in accordance with science big ideas.**
b. **absence of real feedback between the outcome of data analysis and the initial model.**

Which supposes in all but one case "fail-constructive" learning cycles.

5.4. Planned Join Activity structure

This section presents results from characteristics of preservice teachers' planned join activity structure. Findings derived from the analysis of planned join activity structure highlight:

- How preservice students structure join activity over lesson plans and in relation to mechanisms of transfer of responsibility.
- Patterns of planned tasks within each PAS.
- The location of mechanisms of transfer of responsibility in each PAS.
- Matches and mismatches of these planned actions/tasks regarding MCI.
- Similarities and differences between CASE A and CASE B lesson plans done at the same point of instruction.
- Evolution of performance through time and regarding to instruction.

In order to facilitate the visualisation of results and a further interpretation of them:

a. A first general overview is given. Maps of programmed activity segments for all CASE A lesson plans and for LP1initial and LP1reviewed in CASE B are presented. A common map of programmed activity segments for plans on class intervention is also exposed. Procedures used to build maps of programmed activity segments can be found in section4.5.2. General tendencies are exposed.

b. An in-depth description of findings within each PAS category is made. To do so, different charts present the relative frequencies of each specific action through time. Relative frequencies (being referred as ß) have been calculated as follows:

$$\beta = \frac{(\text{nº of times an action occurs})}{(\text{total amount of PAS within a specific period of data collection})}$$

Computations have been performed using the relative frequencies in order to allow sample sets of different sizes to be compared (CASE A LP1i contain a total amount of 80 PAS, LP1f contain 88 PAS, and LP2 contain a total amount of 111 PAS; while CASE B LP1i contain 57 PAS; and LP1f contain, all together, 68 PAS). Major trends within each CASE and comparing CASES are commented.

c. A brief summary of major outcomes concludes each section.

Results are discussed in an interrelated manner in chapter 6. Implications and limitations of the study are exposed in chapters 7 and 8.

5.4.1. Planned join activity structure: general overview.

Figures 18, 19, 20, 21 and 22 contain maps of programmed activity segments for all CASE A lesson plans and for LP1initial and LP1reviewed in CASE B. General commentaries on these maps follow below. Maps of programmed activity segments performed during the second period of instruction in CASE B (corresponding to plans performed to apply the acquired knowledge in a real classroom situation) are also exposed further on.

1112.03.01i

	PAS1	PAS2	PAS3
Session 1	Apk 2.A.a.	EC 6.A.d. 6.A.a. 6.A.g.	
Session 2	Apk 2.A.b.	EC 6.A.g.	
Session 3	PI 3.c		
Session 4	PAE 4.a	WE 5.c	EC 6.A.b
Session 5	PAE 4.a	WE 5.a	EC 6.A.b

1112.03.02i

	PAS1	PAS2	PAS3
Session 1	Apk 2.A.a	EC 6.A.a.	
Session 2	PAE 4.a	WE 5.c	EC 6.A.b.
Session 3	PAE 4.a	WE 5.a	EC 6.A.b.

1112.03.03i

	PAS1	PAS2	PAS3	PAS4	PAS5
Session 1	Frt 1.a.	Apk 2.A.b 2.A.e.			
Session 2	Apk 2.A.b.	PI 3.d.	PAE 4.a.	WE 5.b.	EC 6.A.a. 6.a.c.
Session 3	Apk 2.A.c.	PI 3.d.	EC 6.A.g. 6.a.c. 7.A.a		
Session 4	PAE 4.a	WE 5a	EC 6.A.g.		

1112.03.04i

	PAS1	PAS2	PAS3	PAS4	PAS5	PAS6
Session 1	Apk 2.A.a. 2.A.e.		PI 3.a.			
Session 2	PI 3.d.	EC 6.A.a.				
Session 3	PI 3.d.	EC 6.A.b.				
Session 4	PAE 4.a.	WE 5.c.	PI 3.a.			
Session 5	PAE 4.a	WE 5.c.	PI 3.a.	PAE 4.a	WE 5.c.	PI 3.a.
Session 6	PAE 4.a.	WE 5.c.				

1112.03.05i

	PAS1	PAS2	PAS3	PAS4
Session 1	Apk 2.A.a			
Session 2	PI 3.d.			
Session 3	PI 3.d.			
Session 4	EC 6.A.a.			
Session 5	Frt 1.c. 1.a.	PI 3.a.	Apk 2.A.d	PAE 4.c.
Session 6	WE 5.b			
Session 7	Apk 2.A.d	WE 5.c 5.d 5.e	M 7.A.a.	EC 6.A.d.
Session 8	EC 6.A.d.	M 7.A.a.		

1112.03.08i

	PAS1	PAS2	PAS3
Session 1	Apk 2.A.a.		
Session 2	PAE 4.a.	WE 5.c. 5.d.	
Session 3	EC 6.A.c.		
Session 4	PAE 4.a.	WE 5.c. 5.d.	EC 6.A.c.
Session 5	PAE 4.a.	WE 5.a. 5.e.	

1112.03.09i

	PAS1	PAS2	PAS3	PAS4	PAS5	PAS6	PAS7
Session 1	Apk 2.A.c.						
Session 2	PAE 4.a.	WE 5.a.	EC 6.A.b.	PAE 4.a.	WE 5.c.	EC 6.A.b.	PI 3.c.
Session 3	PAE 4.a.	WE 5.b					
Session (3n)	PAE 4.a.	WE 5.c.					
Session 4	PAE 4.a.	WE 5.c.	PI 3.c.	EC 6.A.b.			
Session 5	PI 3.d.						
Session 6	EC 6.A.a.						
Session 7	PAE 4.a.	WE 5.a.	EC 6.A.a.				

1112.03.10i

	PAS1	PAS2	PAS3	PAS4	PAS5	PAS6	PAS7	PAS8
Session 1	PAE 4a	WE 5b	PAE 4a	WE 5b	EC 6.A.b.			
Session 2	PAE 4a	WE 5b	EC 6.A.a.					
Session 3	Apk 2.A.a.							
Session 4	Frt 1.a.	Apk 2.A.b.	PI 3.a.	PAE 4a	WE 5.c.	EC 6.A.d.	PAE 4a	WE 5a
Session 5	Apk 2.A.b.	PAE 4a	WE 5.c.	EC 6.A.d.				

1112.03.11i

	PAS1	PAS2
Session 1	Frt 1.b.	Apk 2.A.b.
Session 2	PI 3.d.	EC 6.A.a. 6.A.b.
Session 3	PAE 4c	
Session 4	WE 5.c.	PI 3.b.
Session (5n)	PAE 4c	WE 5.c. 5.e.
Session 6	EC 6.A.c.	

1112.03.12i

	PAS1	PAS2	PAS3	PAS4	PAS5	PAS6
Session 1	Apk 2.A.a.	PAE 4c				
Session 2	PAE 4c					
Session 3	Frt 1.c.	PI 3b 3.a.	PAE 4a 4f	WE 5.b.	PAE 4a	WE 5.a.
Session (4n)	WE 5.c.	EC 6.A.a				
Session 5	PI 3d					
Session 6	PI 3b					
Session 7	WE 5.c.					
Session 8	EC 6.a.d					

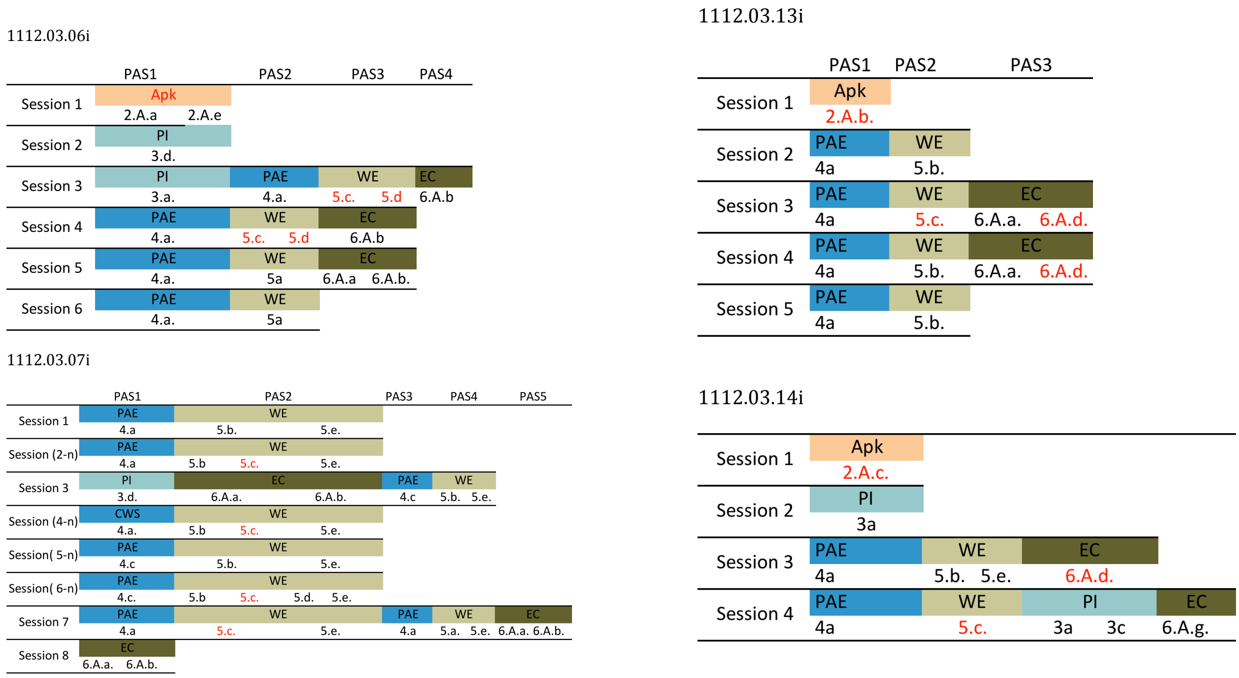
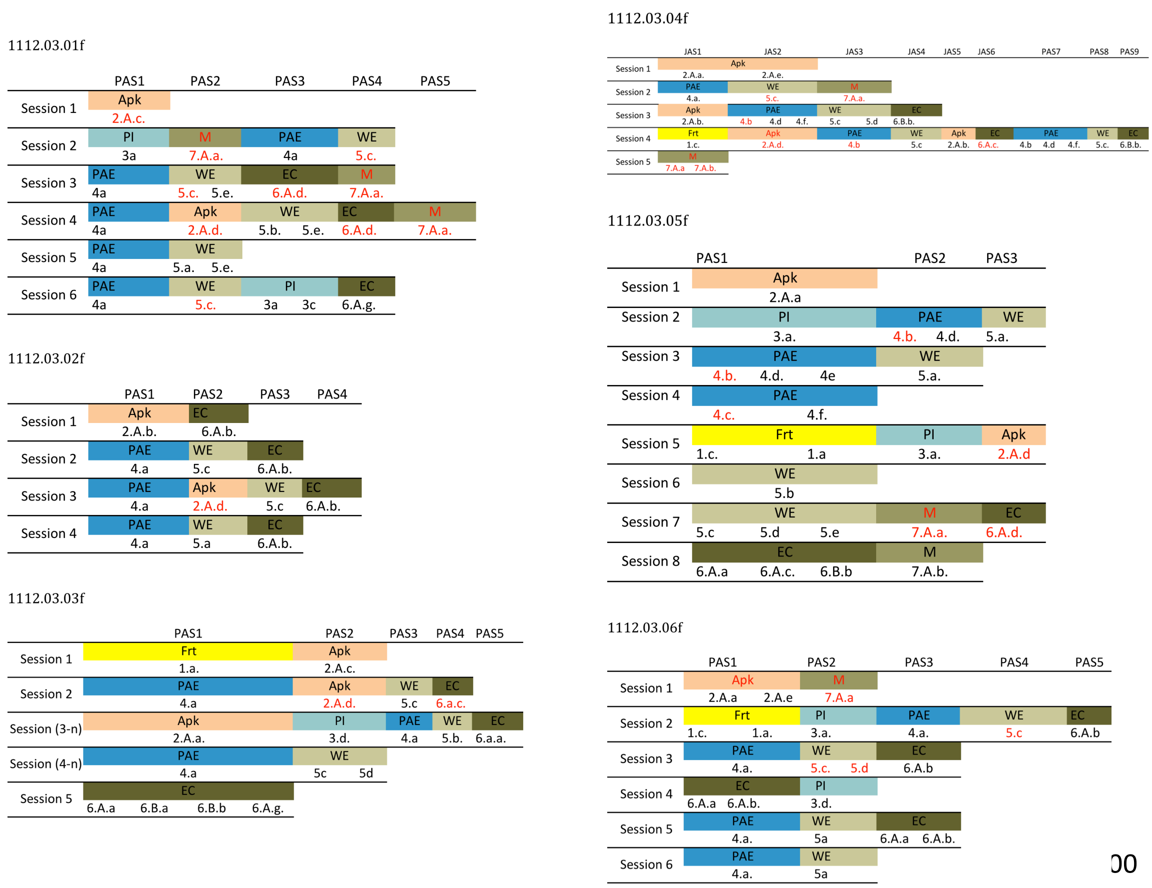


Figure 18. Maps 1112.03.01i to 1112.03.14i corresponding to initial lesson plans, performed before instruction, in CASE A.



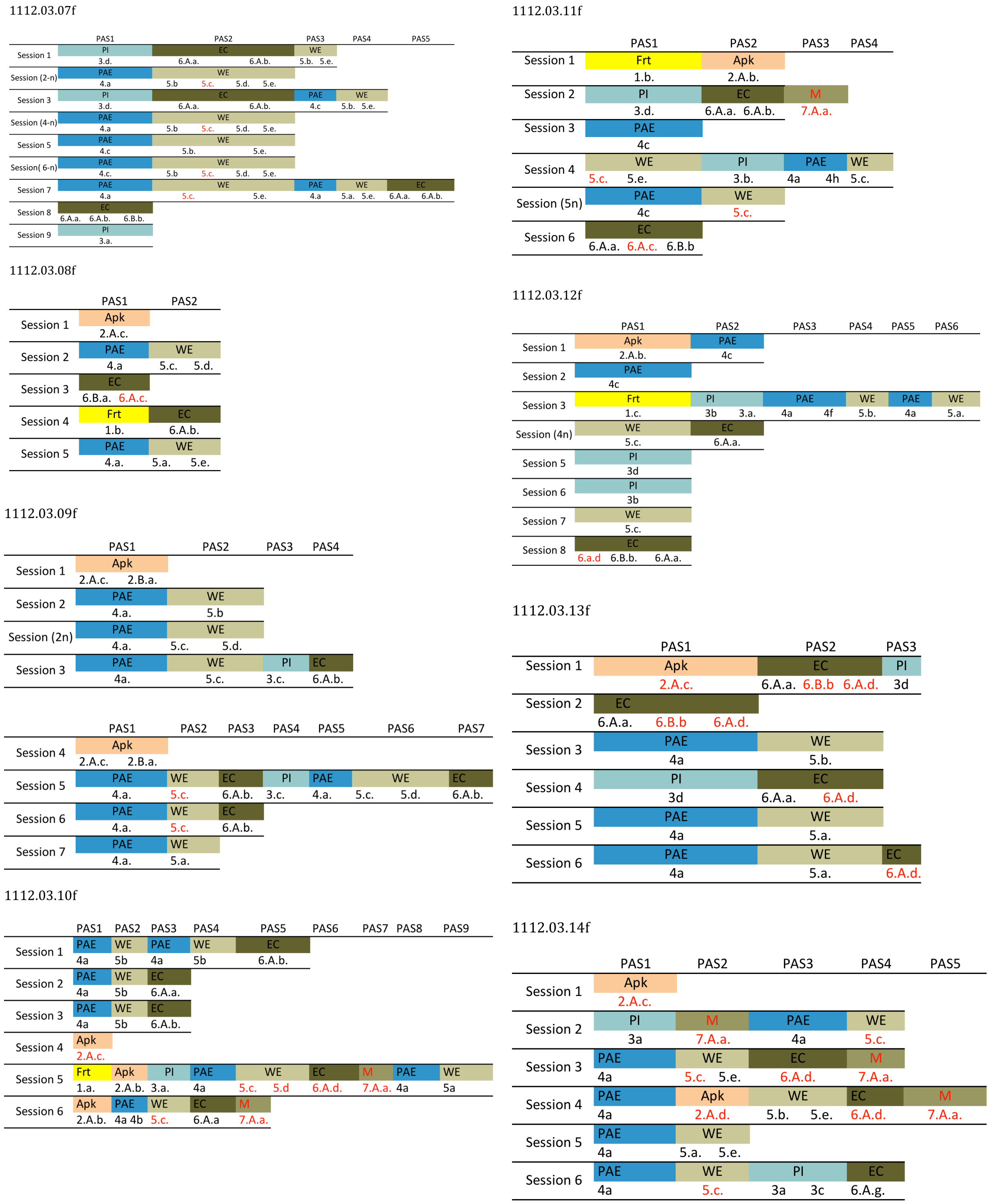
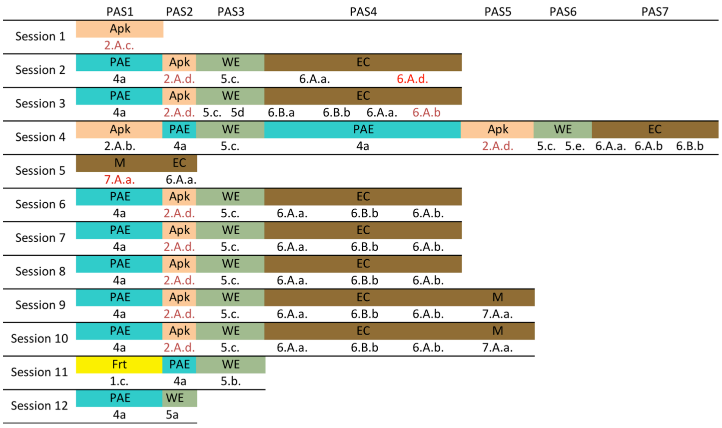
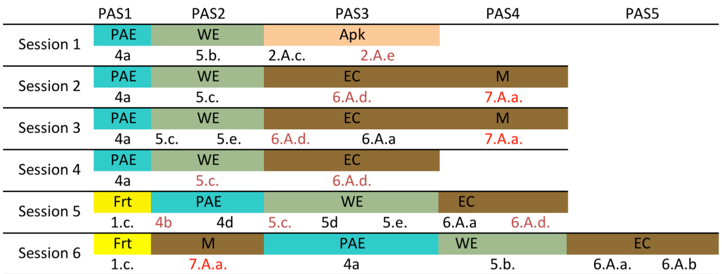


Figure 19. Maps 1112.03.01f to 1112.03.14f corresponding to modified lesson plans, CASE A.

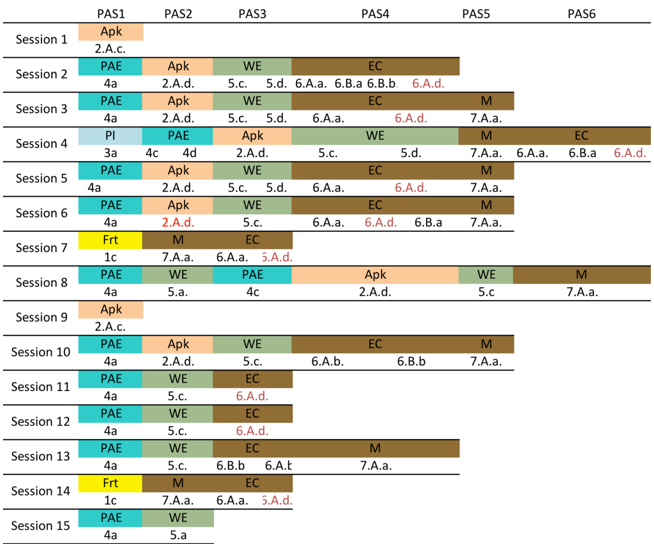
1213.04.01



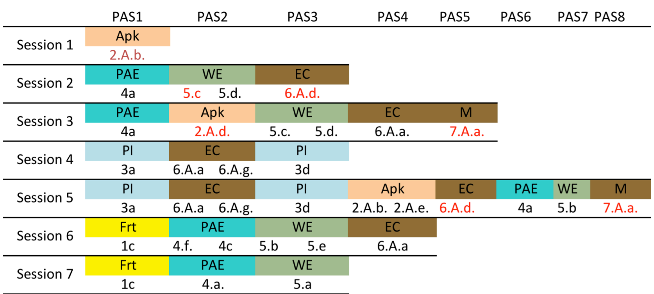
1213.04.02



1213.04.03



1213.05.04



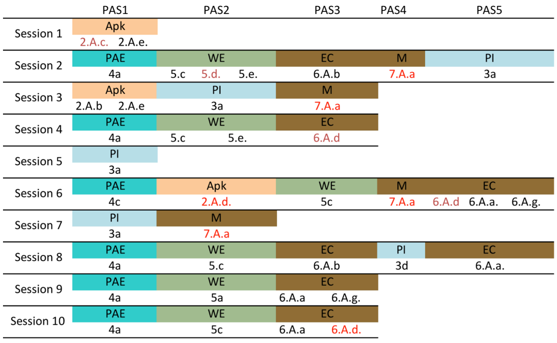
1213.04.05

	PAS1	PAS2	PAS3	PAS4	PAS5	PAS6
Session 1	Apk 2.A.c.					
Session 2	PAE 4a	WE 5.c	EC 6.A.a 6.A.b.	PAE 4a	WE 5.c	
Session 3	Apk 2.A.c.	Frt 1c	EC 6.A.d	PAE 4a	WE 5.c	EC 6.A.d
Session 4	Apk 2.A.c.	PI 3a	PAE 4a	WE 5.a	EC 6.A.g	
Session 5	PAE 4a	WE 5.a	EC 6.A.a 6.A.g			
Session 6	PAE 4a	WE 5.c	EC 6.A.b	PAE 4a	WE 5.c	EC 6.A.b 6.A.a
Session 7	PAE 4a	WE 5.c	EC 6.A.b			
Session 8	M 7.A.a.					
Session 9n	PAE 4a	WE 5.a 5e	PAE 4c	WE 5.b	EC 6.A.a	

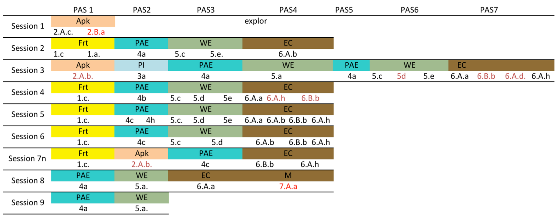
1213.04.06

	PAS1	PAS2	PAS3	PAS4	PAS5
Session 1	Apk 2.A.c.				
Session 2	Frt 1c	PI 3a	PAE 4a	WE 5.a	
Session 3	PAE 4a	WE 5.b	PI 3a	PAE 4a	WE 5c
Session 4	PAE 4a	WE 5.c	EC 6.A.d. 6.A.a. 6.A.g	M 7.B.b	
Session 5	PAE 4a	WE 5.c	EC 6.A.d.		
Session 6	M 7.A.a	EC 6.A.a. 6.A.g	PAE 4a	WE 5a	
Session 7	PAE 4a	WE 5a			

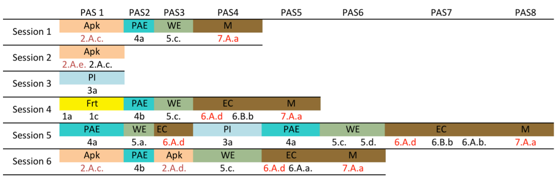
1213.04.07



1213.04.08



1213.04.09



1213.05.10

	PAS1	PAS2	PAS3	PAS4	PAS5
Session 1	Frt	PI	PAE	WE	EC
	1a	3a	4a	5.c.	6.A.a
Session 2	Apk				
	2.A.b. 2.A.e				
Session 3	PI	PAE	WE	EC	
	3a	4a	5.a.	6.A.a 6.A.g	
Session 4	PAE	WE	EC		
	4a	5.c. 5.d.	6.A.d		
Session 5	PAE	WE			
	4a	5.c. 5.d			
Session 6	PAE	WE	EC		
	4a	5.c.	6.A.d. 6.A.a		
Session 7	PAE	WE	M		
	4a	5.a.	7.A.a		
Session 8	PAE	Apk	WE	EC	
	4a	2.A.d.	5.c 5.d.	6.A.a	

1213.04.11

	PAS1	PAS2	PAS3	PAS4	PAS5	PAS6
Session 1	Apk					
	2.A.c. 2.B.a 2.A.e					
Session 2	PAE	WE	EC	PAE	WE	
	4a	5.c.	6.A.g	4a	5.c.	
Session 3	PAE	WE	EC	PI	PAE	WE
	4a	5.a.	6.A.c	3a	4a	5.c.
Session 4	PAE	WE	EC			
	4a	5.c.	6.A.d			
Session 5	PAE	WE	EC			
	4a	5.c.	6.A.d			
Session 6	PAE	WE	EC			
	4a	5.c.	6.A.d			
Session 7	PAE	WE	EC			
	4a	5.c.	6.A.d			
Session 8	PAE	WE				
	4a	5.a 5e				

1213.04.12

	PAS1	PAS2	PAS3	PAS4	PAS5	PAS6	PAS7
Session 1	Apk	explor					
	2.A.b. 2.B.a						
Session 2	Frt	Apk	PI	EC	PI		
	1c	2.A.b. 2.A.e	3.d.	6.A.a 6.A.g	3.a.		
Session 3	Frt	PAE	WE	EC	PAE	WE	EC
	1c	4a	5.c. 5.d	6.A.a 6.A.g	4a 4.g.	5.c.	6.A.c 6.B.b. 6.A.g.
Session 4	Frt	PAE	WE	Apk	WE	EC	M
	1c	4a	5c	2.A.d 2.A.e.	5.c.	6.A.d 6.B.b. 6.A.a	7.A.a
Session 5	Apk						
	2.A.b.						
Session 6	PI	M	PAE	WE			
	3.a.	7.B.c	4a	5.a.			
Session 7	Frt	PAE	WE	EC			
	1c	4c	5c	6.A.d 6.A.c 6.B.b			
Session 8	PAE	WE	EC				
	4a	5c 5e	6.A.a 6.A.d				
Session 9	Frt	Apk	PAE	WE	EC		
	1c	2.A.d.	4c/4b	5c	6.A.d 6.B.b		
Session 10	Frt	Apk	M				
	1c	2.A.c. 2.Ab 2.B.a	7.A.a				
Session 11	PAE	WE					
	4a	5.b.					
Session 12	PAE	WE	M				
	4a	5.b.	7.A.a				
Session 13	PAE	WE	EC	PI			
	4a	5.a.	6.A.a	3.a.			
Session 14	PAE	WE	EC	PI			
	4a	5c	6.A.a	3.a.			

Figure 20. Maps 1213.04.01 to 1213.04.14 corresponding to lesson plans performed during the second period of instruction, CASE A.

1213.03.01i

	PAS1	PAS2	PAS3	PAS4	PAS5
Session 1	PAE	WE	EC		
	4a	5.c.	6.A.a 6.A.b		
Session 2	PAE	WE	EC	PAE	WE
	4a	5.c.	6.A.a 6.A.b	4a	5.a.
Session 3	PI	PAE	WE		
	3a	4a	5.b.		
Session 4	Apk	PAE	WE	EC	
	2.A.b.	4a	5.c. 5.d 5.e.	6.A.a 6.A.b 6.B.b.	
Session 5	M				
	7.A.a				

1213.03.02i

	PAS 1	PAS2	PAS3
Session 1	Apk		
	2.A.b.		
Session 2	PAE	WE	EC
	4a	5c	6.A.a. 6.A.b
Session 3	M		
	7.A.a		
Session 4	PAE	WE	EC
	4a	5a	6.A.b

1213.03.03i

	PAS 1	PAS2	PAS3	PAS4
Session 1	Apk			
	2.A.a.			
Session 2	PAE	WE	EC	
	4a	5c	6.A.a. 6.A.d	
Session 3	PAE	WE	EC	
	4a	5c 5.d	6.A.a. 6.B.b. 6.A.b	
Session 4	PAE	WE	EC	
	4a	5c 5.d	6.A.a. 6.B.b. 6.A.d	
Session 5	PAE	WE	EC	PI
	4a	5a	6.A.c.	3a

1213.03.04i

	PAS 1	PAS 2	PAS 3	PAS 4	PAS 5
Session 1	PI	Apk			
	3a	2.A.d.			
Session 2	Apk				
	2.A.d.				
Session 3	WE	M	EC		
	5c	7.A.a	6.A.d		
Session 4	PAE	WE	PAE	WE	EC
	4a	5c	4c	5c	6.A.c
Session 5	PAE	WE	EC	PAE	WE
	4c	5c	6.A.b	4a	5a
Session 6	PAE	WE	EC		
	4a	5c	6.A.d		

1213.03.05i

	PAS 1	PAS 2	PAS 3	PAS 4	PAS 5	PAS 6	PAS 7
Session 1	Apk						
	2.A.b.						
Session 2	PAE	WE	EC	Apk	PI	PAE	WE
	4a	5c	6.A.b	2.A.b.	3a	4a	5a
Session 3	PAE	WE	EC				
	4a	5c	6.A.b				
Session 4	Frt	PAE	WE	EC			
	1a	4a	5c	6.A.d			
Session 5	PAE	WE	EC				
	4a	5c	6.A.d				
Session 6	PAE	WE	EC				
	4a	5c	6.A.d				
Session 7	EC	PAE	WE				
	6.A.g	4a	5a				

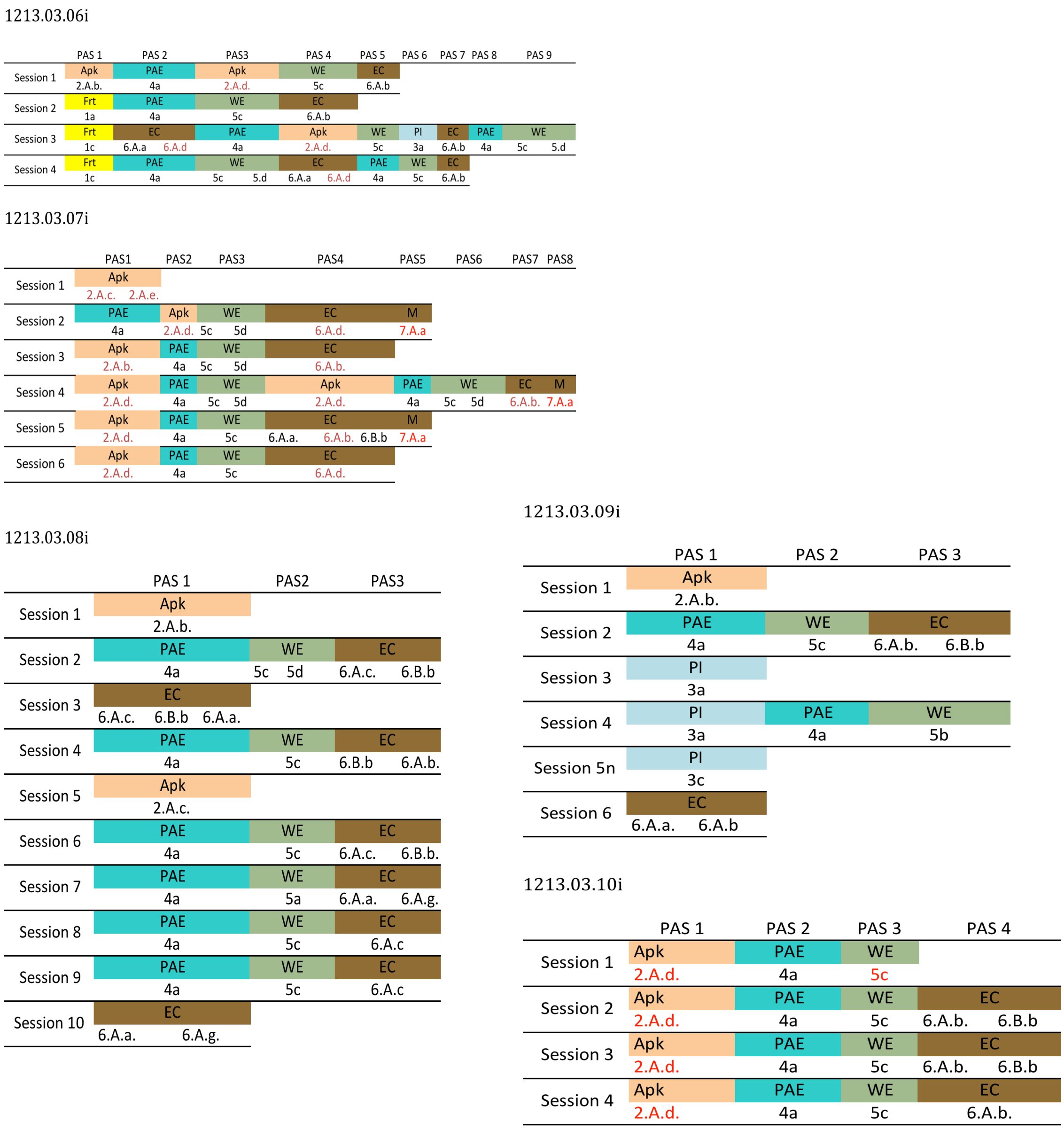


Figure 21. Maps 1213.03.01i to 1213.03.10i corresponding to initial lesson plans, performed before instruction, in CASE B.

1213.03.01f

	PAS1	PAS2	PAS3	PAS4	PAS5	PAS6
Session 1	PAE 4a	WE 5.c. 5.d	EC 6.A.a 6.A.b	Apk 2.A.c.		
Session 2	PAE 4a	WE 5.c.	EC 6.A.a 6.A.b	M 7.A.a		
Session 3	Frt 1c	Apk 2.A.b.	PAE 4a	WE 5.a.	EC 6.A.a 6.A.c	M 7.A.a
Session 4	Apk 2.A.b.	PAE 4a 5.c.	WE 5.d 5.e.	EC 6.A.a 6.A.b 6.B.a 6.B.b.		
Session 5	M 7.A.a					
Session 6	PAE 4a	WE 5.a.				

1213.03.02f

	PAS 1	PAS2	PAS3	PAS4	PAS5	PAS6	PAS7
Session 1	Apk 2.A.b.						
Session 2	PAE 4a	WE 5c	EC 6.A.a. 6.A.b				
Session 3	PAE 4a 4f	WE 5a	EC 6.A.d.	PAE 4a	WE 5b	EC 6.A.b	PI 3a
Session 4	M 7.A.a	PAE 4a	WE 5b				
Session 5	PAE 4a	WE 5a	EC 6.A.b				

1213.03.03f

Session 1	Apk 2.A.a.			
Session 2	PAE 4a	WE 5c	EC 6.A.a. 6.B.b. 6.A.b	
Session 3	PAE 4a	Apk 2.A.d.	WE 5c 5.d	EC 6.A.a. 6.B.a. 6.B.b. 6.A.d
Session 4	Apk 2.A.d.	PAE 4a	WE 5c 5.d	EC 6.A.a. 6.B.a. 6.B.b. 6.A.b
Session 5	PAE 4a	WE 5a		

1213.03.04f

	PAS 1	PAS 2	PAS 3	PAS 4	PAS 5	PAS6
Session 1	Apk 2.A.c.					
Session 2	Apk 2.A.e.					
Session 3	WE 5c	EC 6.A.d	M 7.A.a			
Session 4	Apk 2.A.b.	PAE 4c	WE 5c	EC 6.A.c		
Session 5	Apk 2.A.d.	PAE 4a	WE 5c	EC 6.A.b	PAE 4a	WE 5a
Session 6	Apk 2.A.b.	PAE 4a	WE 5c	EC 6.A.d		
Session 7	PAE 4a	WE 5a				
Session 8	PAE 4a	WE 5a				

1213.03.05f

	PAS 1	PAS 2	PAS 3	PAS 4	PAS 5	PAS 6	PAS 7
Session 1	Apk 2.A.b.						
Session 2	PAE 4a	WE 5c	EC 6.A.b	Apk 2.A.b.	PI 3a	PAE 4a	WE 5a
Session 3	Apk 2.A.d.	PAE 4a	WE 5c	EC 6.B.b. 6.A.b			
Session 4	Frt 1a	PAE 4a	Apk 2.A.d.	WE 5c	EC 6.B.b. 6.A.b		
Session 5	PAE 4a	WE 5c	EC 6.A.d				
Session 6	PAE 4a	WE 5c	EC 6.B.b. 6.A.b				
Session 7	EC 6.A.g						
Session 8	PAE 4a	WE 5b					

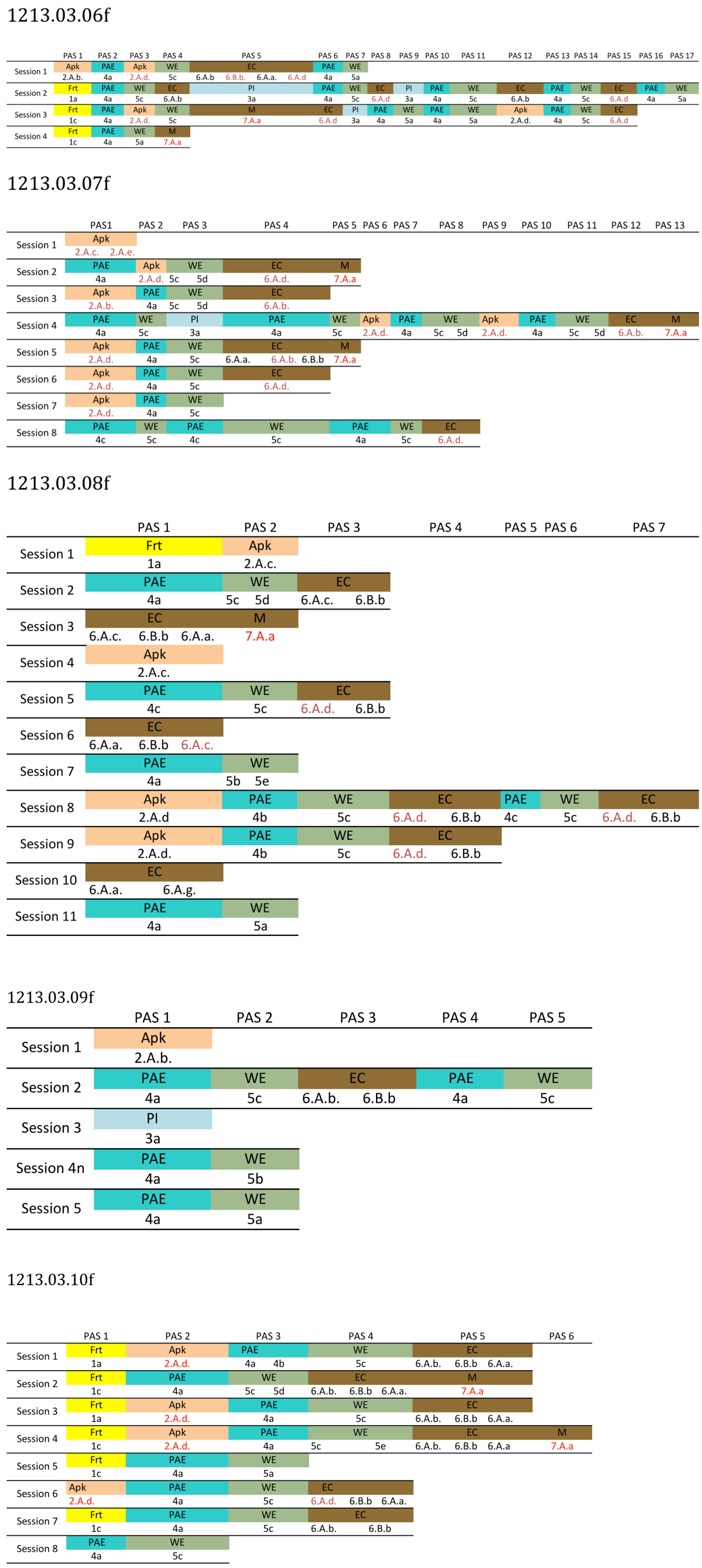


Figure 22. Maps 1213.03.01f to 1213.03.10f corresponding to initial lesson plans, performed before instruction, in CASE B.

If we look globally at maps of programmed activity segments we can see that, in general terms, lesson plans programmed at the beginning of both instructional periods (maps 1112.03.01i to 1112.03.14i in figure 18 and 1213.03.01i to 1213.03.10i in figure 20) are the shortest ones.

		nº of sessions (total amount)	
		CASE A	CASE B
3rd	LP1i	80	57
	LP1f	88	68
4th	LP2	111	-

Table 23. Comparative table showing the total amount of planned sessions within LP1 initial and reviewed (CASE A and B) and LP2 (CASE A).

As we can see in table 23, CASE A initial lesson plans (maps 1112.03.01i to 1112.03.14i, figure 18) suppose a global amount of 80 sessions while reviewed lesson plans (maps 1112.03.01f to 1112.03.14f, figure 19) suppose 88 sessions. Lesson plans performed during the second period of instruction (maps 1213.04.01 to 1213.04.12, figure 20) have, all together, 111 sessions.

In CASE B, initial lesson plans (maps 1213.03.01i to 1213.03.10i, figure 21) suppose a global amount of 57 sessions while, reviewed ones contain 68 (maps 1213.03.01f to 1213.03.10f, figure 22). Due to constraints of the activity, plans performed to apply the acquired knowledge in a real classroom situation always contain only two sessions: one to explore initial models of students and analyse them and another one to perform the activities. Therefore, due to its specificities, this period of instruction cannot be, in this case, compared with the other ones.

Unless in maps of programmed activity segments performed during the second period of instruction in CASE B (4rth year, course 13-14, figure 23, below), there is no regular pattern/common structure in all of them. This is specially so in both cases, in initial lesson plans (maps 1112.03.01i to 1112.03.14i and 1213.03.01i to 1213.03.10i, figures 18 and 21 respectively).

In lesson plans performed after introducing the learning cycle was introduced (at the beginning of the second period of instruction, CASE A and during the first period of instruction CASE B) it is possible to identify some regularities (figures 21 and 22). In general terms, these lesson plans include an initial Apk PAS, flowed with different sessions with predominance of WE PAS that suppose actions to obtain data-evidences (5c actions) and final sessions with WE PAS that include, mostly, hands-on (5b) or non-hands-on (5a) actions. As it is explained in detail later on, these final sessions with less 5c actions correspond to what preservice teachers identify as sessions to "structure and apply" knowledge. Other common traits regarding lesson plans are exposed in relation to each PAS in the following sections. However, despite these small regularities, lesson plans remain very different from each other.

As already mentioned, activities/actions planned to apply the acquired knowledge in a real classroom situation were subject to restrictions of the activity. Figure 23, shows the resulting map of programmed activity segments. Note that these maps represent what teachers programmed to do before class-intervention. Data obtained from their reflections was insufficient to create maps of join-activity during class-intervention.

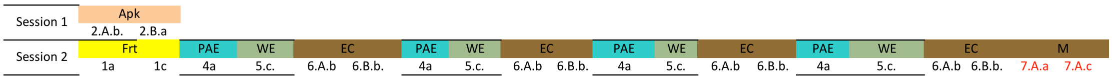


Figure 23. Map of programmed activity segments found in all plans corresponding to the second period of instruction in CASE B (planning of class intervention).

In all cases, preservice teachers planned, on demand, two sessions: in the first session, on demand, students planned actions to activate students' knowledge. This activity was sent to school and performed by in-service teachers. Results were later on analysed by preservice teachers for further planning. Session 2 contains actions to do within classroom settings. As it can be seen in figure 23, all plans contain a first segment to facilitate the representation of the task followed by different sequencies of PAE+WE+EC programmed activty segments. Preservice students planned to conclude their class intervention with a Metacognitive PAS.

Planned tasks within each PAS are discussed in the sections below. However, it is worthwile to mention that as planed, all tasks but the one within "Metacognitive PAS" were, in all cases, well-posed. Data obtained from preservice students' reflection on intervention did not allow, in most cases, to analyse what really happened during classroom performance.

Summary of main ideas:

- Lesson plans increase their extension and "complexity" through instruction. In both cases, initial lesson plans have fewer sessions and less PAS within sessions than final lesson plans.

- In general terms, initial lesson plans do not follow/have any common structure. In both cases all of them are quite different from each other.

- When learning cycles are introduced, little regularity can be found.

- Maps of programmed activity segments found in all plans corresponding to the second period of instruction in CASE B (planning of class intervention) have always the same structure due to restrictions of the activity.

5.4.2. Planned join activity structure: facilitate the representation of the task PAS.

Frt PAS always can be found at the beginning of lessons and/or at the beginning of sessions. They aim to (see table 14 for detailed description of actions categories and operational criteria):

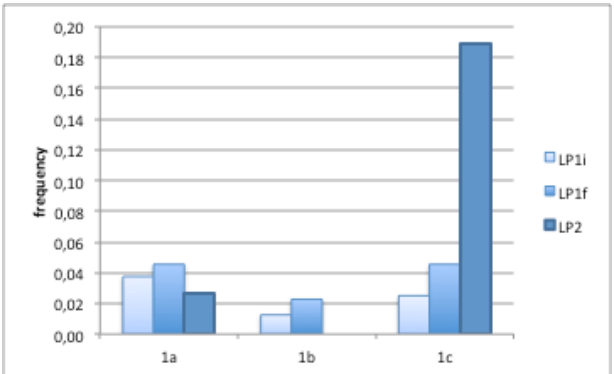
1a. anticipate what is going to happen within a lesson plan/session (the teacher presents the content, objectives…).

1b. make connections between already known knowledge and the new content.

1c. review what has been done in previous sessions.

Frt PAS are not usually considered within initial lesson plans. They presence increases through instruction although it remains, in general terms and compared with other PAS, very low. In CASE A we only find Frt PAS in 5 from 14 initial lesson plans (LP1i, figure 18); 8 from 14 lesson plan reviews (LP1f, figure 19) and 10 from 12 lesson plans performed during the second period of instruction (LP2, figure 20). In CASE B it is possible to find Frt PAS in 2 from 10 initial lesson plans (LP1i, figure 21) and 5 from 10 reviewed lesson plans (LP1f, figure 22). All lesson plans performed for class intervention contain an initial Frt PAS in the second session (figure 23).

CASE A **CASE B**



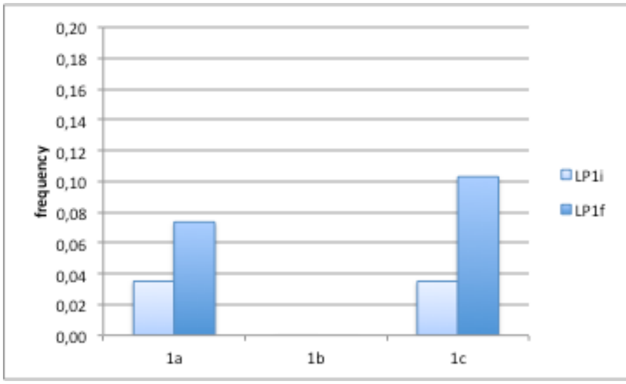


Chart 1. Chart 2. Relative frequency of actions in Frt PAS. 1a corresponds to "Framing" action category; 1b corresponds to "Anchoring" and 1c to "Recapts" (table 14). LP1i corresponds to lesson plans performed before instruction. LP1f corresponds to reviewed lesson plans, performed during the first period of instruction. LP2 corresponds to lesson plans performed during the second period of instruction (figure 14).

Charts 1 and 2 show a clear increase of Frt PAS through instruction. In CASE A, this is mainly due to the inclusion of actions to review what has been done in previous sessions (1c). Furthermore, it is important to notice that such growth is detrimental to 1a and 1b actions. In CASE B, growth in Frt PAS implies the incorporation of 1c and 1a actions. In CASE B, actions to make connections between already known knowledge and the new content (1b) are not considered in any case.

As described in lesson plans, actions within Frt PAS are mainly held on by the teacher, who is expected to introduce the topic and/or orchestrate a review of previous knowledge as a monologue or posing questions to students. Students are expected to have either a passive role or to answer teachers' questions. In all described cases, control remains on teachers' hands.

Actions within Frt PAS are always described in a general way. Qualitatively, their description does not change though instruction. Preservice teachers describe briefly what they would say (as a monologue) or which actions should be performed (i.e. asking students) without describing them in detail (i.e. sort of questions, how to manage discussions, etc.). Examples below illustrate common situations.

Example 1: (CASE A 1112.03.05i and f)

Preservice students anticipate a classroom situation where teachers orchestrates a review, asking questions to students to facilitate connections between old/new knowledge. Preservice students do not specify the kind of questions they would pose or other actions they would make. They state that this review seeks to ensure that students understand previous knowledge and to "refresh" them.

"El mestre entra a classe i desprès de les oportunes salutacions, comença la sessió repassant alguns dels conceptes més rellevants de la classe anterior mitjançant preguntes relacionades amb la informació que van treballar els diferents grups d'experts. Fa un sondeig ràpid per comprovar si els conceptes estan clars i, sinó, refrescar-los.

A continuació, els hi fa la següent proposta: *Ara ens convertirem en científics. Els científics quan investiguen es fan preguntes sobre allò que podria passar abans de fer el seu experiment. Nosaltres també ho haurem de fer per poder portar a terme la nostra investigació".*

In this case, Frt PAS were considered in both, initial and reviewed lesson plans. In the first paragraph, preservice teachers plan a "recap" (1c, table 14). They do not give details about the questions, nor what is going to be evaluated or how they are going to "refresh" misconceptions. In the second paragraph, they plan a framing action.

Example 2: (CASE A 1112.03.04f)

Preservice students imagine a classroom situation were they enter to the class and say: "*Com vam veure a la sessió anterior amb els avions hi ha ocells que s'aguanten molta estona en l'aire sense batre les ales*".

This Frt PAS was introduced in the reviewed lesson plan of the first period of instruction. Preservice teachers imagine a "recap" (1c, table 14) as a monologue where they remember to the students the conclusions from the previous session. After that, they explain the next experience.

Example 3: (CASE A 1112.04.02)

"La mestra fa que els alumnes facin memòria sobre el tema que s'està treballant mitjançant preguntes i utilitzant els comentaris dels alumnes per fer reflexionar a tota la classe. El mestre o la mestra demanarà als alumnes i a les alumnes què recorden sobre les diferents activitats que s'han anat fent"

This example corresponds to a lesson plan done during second period of instruction. Once more, students plan a "recap" (1c, table 14). In this case it seems more negotiated with the students. Nevertheless, preservice students do not specify questions, special aspects to put emphasis on, etc. They just state that they will "orchestrate a recap" and that they would use "questions and students' commentaries to do it".

Example 4: (CASE B 1213.03.06i and1213.03.06i)

"Obrirem la sessió repassant els conceptes massa i volum treballats en la sessió 2."

Example 4 is even more general then the previous one. Preservice students state that they would orchestrate a recap but do not give details on how to do it. The description remains the same in the reviewed lesson plan.

Example 5: (CASE B 1213.03.04f)

"La mestra explica que ara han d'estudiar com es propaga la llum i per conèixer com succeeix hauran de realitzar un experiment. "

This last example illustrates the incorporation of an "anchoring" (1a, table 14) action in reviewed lesson plans, CASE B. The description of the action is, once more, brief, and performed as a monologue.

Summary of main ideas:

- Frt PAS are not usually considered within initial lesson plans. They presence increases through instruction although, in general terms and compared with other PAS, it remains very low.

- Frt PAS always can be found at the beginning of lessons and/or at the beginning of sessions.

- Actions within Frt Pas are always described in a general way. Actions are mainly held on by the teacher as a monologue or posing questions to students.

5.4.3. Planned join activity structure: activating prior knowledge PAS.

Just one initial and reviewed lesson plans do not contain any activity aimed to activate prior knowledge (1112.03.07i and 1112.03.07f, CASE A, first period of instruction, figures 18 and 19). All other lesson plans in CASE A and B contain Apk PAS.

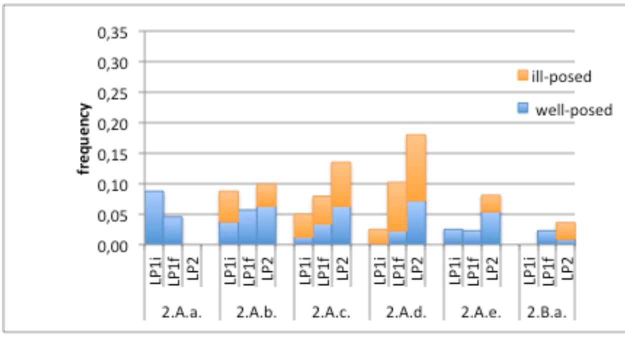
Within Apk PAS we can distinguish two kinds of PAS segments:

(a) Apk PAS situated at the beginning of lesson plans and/or when a new idea is going to be introduced. Its aim to explore and make explicit initial internal models in relation to the ideas that are going to be developed within lesson plans.

(b) Apk PAS situated at any point within a lesson plan, but always before a WE PAS, that contain "Hypothesis question" actions.

Findings from the analysis of both types of PAS segments are represented in charts 3 and 4 and displayed below.

CASE A **CASE B**



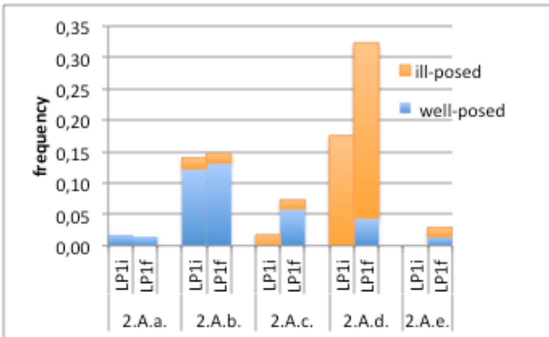


Chart 3. Chart 4. Relative frequency of actions in Apk PAS. 2.A.a corresponds to "General Brainstorming" action category; 2.A.b. corresponds to "Specific knowledge asking"; 2.A.c. to "Posing a problem/scenario/seatwork"; 2.A.d. corresponds to "Hypotesis question"; 2.A.d. to "recapitulation" and 2.B.a. corresponds to "Analysing" action category (table 15). LP1i corresponds to lesson plans performed before instruction. LP1f corresponds to reviewed lesson plans, performed during the first period of instruction. LP2 corresponds to lesson plans performed during the second period of instruction (figure 14).

(a) Apk PAS aimed to explore and make explicit initial internal models:

Apk PAS aimed to explore and make explicit initial internal models appear, mostly, at the beginning of all lesson plans in both, CASE A and CASE B. In one case (1112.03.10i, figure 18) this kind of Apk PAS it is not situated at the beginning of the lesson plan but at the 3th session. The same preservice students state that *"Iniciarem la unitat amb un fet motivador"* which means that activities posed in first sessions aim to motivate and situate alumni, not starting to work with new content until the 3th session. That also happens in the reviewed lesson plan (1112.03.10f, figure 19). In some lesson plans Apk PAS aimed to explore and make explicit initial internal models appear also appear later on, at any point of the sequence, when a new idea is going to be developed and preservice teachers plan to explore students' prior knowledge regarding it.

Actions within this subgroup of Apk PAS include, mainly: 2.A.a. actions (General Brainstorming, table 15); 2.A.b actions (specific knowledge asking, table 15) and 2.A.c. actions (posing a problem/scenario/seatwork; table 15). Associated with them but in minor proportion there are also described 2.A.e (recapitulation, table 15) and 2.B.a actions (analysing, table 15).

Charts 3 and 4 reveal several trends when analysing what happens through instruction and comparing CASE A and CASE B. Different examples are exposed to illustrate findings.

In CASE A Apk PAS from initial lesson plans (LP1i, figure 18) aimed to explore internal models contain, mainly, 2.A.a. actions. They usually that take the form of general questions like in example 1 ("what do we know about….?") or a general brainstorming, like in example 2.

Example 1: (CASE A 1112.03.10i)

- *"Què sabem sobre què és el gust i què és l'olfacte?*
- *Què volem saber sobre el gust i l'olfacte?*
- *Què és realment el gust i l'olfacte?"* (Note that this question it is not appropriate for an activity that aims to explore initial knowledge…)

Example 2: (CASE A 1112.03.02i)

"Descripció de l'activitat:

Plantejament de la pregunta inicial als alumnes:

- *Per què no tots els éssers vius poden viure en tots els territoris del món?*

Primer hauran de respondre la pregunta de forma individual i, posteriorment, en grup. Finalment es posarà en comú les respostes."

In this case preservice students pose a general reproductive question that does not examine any specific core idea.

In smaller proportion, this Apk PAS also contain 2.A.b and 2.A.c. actions. In some cases, a combination of 2.A.a and 2.A.b. actions appears (after a general brainstorming teachers focuses on one aspect which is further developed and asks a specific question regarding to it) –example 3-. Furthermore, when they contain 2.A.b. actions, these actions are, in most cases, ill-posed (3 of 6 in 2.A.b actions and 3 of 4 in 2.A.c. actions) as they do not explore properly main ideas related with the content developed within lesson plan.

Example 3: (CASE A 1112.03.02i)

"La mestra començarà la sessió fent una única pregunta clau que condicionarà tota l'activitat: què hi ha dins d'un ou? En grups de 4 o 5 persones, debatran les possibles respostes i les plasmaran en un paper, podent fer dibuixos o explicacions... Després, ho posaran en comú. (Després) A cada grup se'ls proporcionarà una fitxa amb diferents preguntes que faran de fil conductor i d'activitat introductòria, sobre els diferents coneixements que tenen sobre la reproducció dels ovípars.

a) *Perquè les aus neixen de l'ou?*

b) *Tots els ous acaben sent ocells? Justifiqueu la resposta*

c) *Què creus que és el rovell i la clara de l'ou?"*

This example corresponds to a lesson plan that aims to work core ideas in relation to embryonic development of a chick. Preservice students plan to pose an initial ill-posed general question ("What is there inside an egg?) and expect a general brainstorming from students. After that, they pose other questions supposedly more concrete. Nevertheless, these questions do not address core concepts of the given topic. In the reviewed lesson plan, both 2.A.a and 2.A.b actions are changed for a 2.A.c. action where students are expected to draw what do they think it happens inside an egg, during chick development.

In CASE A reviewed lesson plans (LP1f, figure 19), Apk PAS situated at the beginning of lesson plans contain the half of 2.A.a actions and nearly the double of 2.A.c. actions. They also include less 2.A.b. actions but all of them are correctly posed (exemple 4). In general terms, 2.A.c actions are better posed than in initial lesson plans although most of them are still ill-posed (4 of 7) –example 5-.

Example 4: (CASE A 1112.03.03f)

"La mestra començarà la sessió fent una única pregunta clau que condicionarà tota l'activitat: Com creus que es desenvolupa un pollet dins d'un ou?

A nivell individual, crearan unes vinyetes on descriguin el desenvolupament del poll dins l'ou. Després, ho posaran en comú."

Example 5: (CASE A 1112.03.03f)

"El docent repartirà a cada nen/a la fitxa de l'activitat 1. Aquesta consistirà en el següent: a la fitxa hi haurà quatre imatges sobre el camuflatge. A partir de cada imatge, l'infant haurà d'explicar de forma escrita, amb un dibuix... el què passa a cada fotografia."

The topic underlying this lesson plan was the role of colour in living organisms. Preservice students framed the topic in camouflage. As it can be seen, this exploratory activity aims students to describe what do they see, not to think about the role of camouflage in living organisms.

As it can be seen in Chart 3, in CASE A lesson plans performed during the second period of instruction (LP2, figure 20), there are not 2.A.a. However 2.A.b and, above all, 2.A.c actions, continue to rise, although more than a half planned actions are still ill-posed.

In all, initial, reviewed and lesson plans performed during the second period of instruction, Apk situated at the beginning of lesson plans can contain recapitulation actions (2.A.e., table 15). As it can be seen in example 6, these actions are generally described. In the example below, preservice students explain that they will use "good questions" to help students to share results but they do not specify which ones.

Example 6: (CASE A 1213.04.02)

"Un cop s'hagi fet el treball individual **(-preservice students explain what to do-)** *s'hauran de posar en comú les idees que s'han exposat abans* **(-preservice students explain how to organize students-)***. S'ajudarà als alumnes mitjançant bones preguntes a identificar allò que tenen en comú i allò que és diferent en tots els dibuixos."*

In reviewed (LP1f) and final lesson plans (LP2), 2.B.a actions can be also found (table 15). In LP1f, there are two cases were a 2.B.a action appears. In these cases preservice teachers use an instrument ("xarxa sistèmica") introduced during the course to analyse results from the exploratory activity.

Example 7: (CASE A 1112.03.01f)

"Aquesta primera activitat servirà per conèixer quines són les idees prèvies que porta l'alumnat a l'aula, i ho farem mitjançant una xarxa sistèmica per poder ordenar i classificar les idees comunes. Posteriorment, observarem cap a on volem portar aquestes idees per tal que els alumnes puguin modificar els seus models inicials capa a altres de més científics"

In contrasting CASE A lesson plans with those in CASE B, it is possible to say that, in general terms, both cases follow the same tendencies. Throughout instruction, there is a clear increase of 2.A.b and 2.A.c. actions accompained by a decrease of 2.A.a.

actions. Nevertheless, unlike findings from CASE A, initial lesson plans in CASE B (LP1i, figure 21) contain much lower proportion of 2.A.a. actions (ß=0,09 CASE A; ß=0,02 CASE B, Charts 3 and 4). In contrast, the relative frequency of 2.A.b. actions is much higher (ß=0,09 CASE A and ß=0,014 CASE B, charts 3 and 4). Like in CASE A, not all actions were considered well-posed. Anyway, CASE B contained more well-posed actions than CASE A. As it is shown in example 8, in initial lesson plans, preservice teachers tend to pose questions in relation to the given core ideas.

Example 8: (CASE B 1213.03.05i)

"Preguntes a fer a l'alumnat:

- *Què creieu que és una ombra i com creieu que es produeix?*
- *Què es necessita per a fer una ombra?"*

2.A.e actions could also be found in reviewed lesson plans. However, they appeared in less frequency than in case A. As in CASE A, 2.A.e. actions were described without detail. 2.B.a actions were not found in any case.

As explained above, lesson plans performed before class intervention contained, on demand, Apk PAS. All of them contained 2.A.c actions and 2.B.a actions, on demand (example 9). All of them were well-posed, as they were supervised before giving them to students. In some cases, during class intervention 2.A.e. actions were performed (example 10). Tough, data obtained from reflections on class intervention did, not allow to know how many times it occurred.

Example 9: (CASE B 1314.04.06 planning on class intervention)

"Abans de començar la sessió els alumnes hauran contestat un qüestionari previ (Appendix 1) que els vàrem enviar a la mestra amb unes pautes per tal de saber quin era el seu nivell en relació a la flotabilitat i així dissenyar un tipus d'activitat o un altre a dur a terme."

Example 10: (CASE B 1314.04.04 reflection on class intervention)

"Vaig iniciar el taller fent referència a la fitxa que els havíem passat anteriorment per tal d'esbrinar quins eren els coneixements previs sobre el tema a tractar: llum i ombra."

Reflections on class interventions bring out preservice students' misconceptions regarding actions within Apk PAS (examples 11 to 14). Similar misconceptions were also detected in CASE A lesson plans (considered as ill-posed actions) –example 13 and 14-. Misconceptions include:

a. equating actions to explore initial models, not to a diagnostic evaluation, but to an evaluation that seeks to accredit the level of knowledge of students (example 11)
b. expecting "right answers" (according to scientific facts) from activities aimed to explore initial models (examples 12, and 13).
c. expecting only students' misconceptions (example 14 and 15). In example 14, consequences of such misconception can also be traced.

Example 11: (CASE B 1314.04.06 planning for class intervention) –emphasis added-

"Abans de començar la sessió els alumnes hauran contestat un qüestionari previ (Appendix 1) que els vàrem enviar a la mestra amb unes pautes ***per tal de saber quin era el seu nivell en relació a la flotabilitat*** *i així dissenyar un tipus d'activitat o un altre a dur a terme."*

Example 12: (CASE B 1314.04.04 planning for class intervention)

"Tornarem a fer referència a la fitxa que els vam passar. Parlarem sobre els tres nens/es que hi havia dibuixats (...) en el cas que hi hagués algun alumne que no entengués que es necessita un objecte, un focus i una pantalla els farem una demostració."

Example 13: (CASE A 1213.04.01)

"Un cop tinguem totes les idees en un full les debatrem i validarem o rebutjarem pensaments per conèixer una mica el tema."

Example 14: (CASE B 1314.04.06 reflection on class intervention)

"En la primera part les meves preguntes tenien una clara intenció de refrescar allò que els nens havien apuntat als qüestionaries que se'ls va passar. Treure una conclusió final o una idea conjunta dels motius o factors que influïen en la flotabilitat d'un objecte. La intenció era que aquesta idea consensuada fos errònia, ja que d'aquesta manera a través de l'activitat es podria descartar aquesta concepció."

"Les preguntes que es van realitzar en aquesta part varen ser molt semblants a les del qüestionari inicial però amb algun matís que induïa a una resposta errònia:

- *Si un objecte pesa mil quilos floratà o s'enfonsarà?*
- *Pot ser que un objecte que pesi com una goma d'esborrar no floti?*
- *Si un objecte és molt gran diríeu que flotarà?*
- *Penseu que un objecte pot flotar un dia i al cap d'una setmana el mateix objecte pot enfonsar-se?*

La majoria de nens i nenes van caure en els "paranys" d'aquestes preguntes, tot i que un parell d'ells contestaven bé amb raonaments certs buscant objectes de la vida real."

"Jo vaig dirigir molt tendenciosament el debat perquè no s'arribés a cap conclusió concreta, i que encara menys fos certa. Al concloure que no ho sabíem els vaig demanar com podríem fer per saber-ho amb els materials que disposàvem."

Example 15: (CASE B 1314.04.04 reflection on class intervention)

"Un dels infants, abans de començar a experimentar amb els tubs ja tenia molt clarque la llum viatja en línia recta i anava recalcant als seus companys que no calia que ho comprovessin perquè ell ja els hi deia que viatjava en línia recta. De totes maneres, jo vaig intentar en tots moments crear dubtes a aquest alumne per tal que manipulés i comprovés que era així, d'aquesta manera, a part de saber que la llum viatja en línia recta, ho va comprovar personalment."

Finally, reflections on class interventions also reflect the undergraduate students' difficulties on guiding construction of knowledge -during class intervention- regarding to this diagnostic exploration of initial models. As shown in example 16, in some cases, preservice teachers were able to use the results obtained from the analysis of initial models to foster students' construction of knowledge. I this cases, preservice students performed their activities regarding their plans (done prior to class intervention), but adjust their interventions in relation to students' answers. In other cases, however, preservice students were not able to use information gained from initial exploratory evaluation to adjust interventions (examples 17 and 18). Example 18 gives insight into preservice students' interesting reflection regarding to this difficulties.

Example 16: (CASE B 1314.04.02 reflection on class intervention)

In this lesson plan, preservice students state that their aim is to work these two ideas:

"- tant els sòlids com els líquids i els gasos estan formats per partícules."

- diferències entre les partícules dels diferents estats de la matèria."

After analysing students' answers to initial exploration activities, they state:

"*De bon principi els infants han trobat diferenciat el gas del líquid i el sòlid, per tant hem hagut de fer èmfasi en els sòlids i els líquids."*

And, although lesson plans reflect difficulties in reaching conclusions, they do so.

Example 17: (CASE B 1314.04.01 reflection on class intervention)

In this case, preservice teacher A starts the class intervention making explicit some findings from the analysis of initial models. As it can be seen, most students represent smell as tiny particles. Beside this statement, reflection on class intervention does not show that this idea was further used/developed.

"Els vaig comentat que molts d'ells havien dit que s'imaginaven l'olor com la pols i posteriorment els hi vaig demanar per què creien allò. Tots van contestar que l'olor no es veu i havien buscat un element petit per tal de poder fer una representació visual."

Later on the same preservice teacher asks:

"Què creieu que hi ha en aquesta aula? Creieu que ho podem caçar?"

and poses:

"Els alumnes em van dir que hi havia aire i que per aquest motiu podien respirar."

Although all pupils knew that air was arround them, preservice Student does not modify their initial plan and states (as if students did not have prior knowledge):

"No vaig donar cap resposta i els hi vaig dir que ho comprovessin ells mateixos."

"Amb aquesta experiència els infants van comprovar que, tot i no poder-lo veure, en aquella aula hi havia aire. Un cop els infants van ser conscients que l'aire ens envolta vam començar a experimentar amb les olors."

Example 18: (CASE B 1314.04.06 reflection on class intervention)

I this case, preservice student B reflects on results regarding buoyancy. Findings show that most students relate buoyancy to "air within objects".

"A l'hora de fer les prediccions sobre si els diferents objectes flotarien o no responien basant-se en experiències, però també donaven molta importància a si l'objecte tenia aire o no a dins."

Preservice teacher B performs the activities as planned. Activities address the fact that "buoyancy does not only deppend on the mass of an object". Preservice teacher B ignores results regarding to air. When relecting on trying to reach conclusions Preservice teacher B states:

"La majoria de vegades la predicció casava amb la realitat i a l'hora de raonar perquè havia passat una cosa o una altre tornaven a recórrer al pes i a l'aire de l'objecte."

Once more, preservice teacher B does not address such ideas. In final reflections on class intervention she states:

"Pel que fa a les respostes dels alumnes en alguns casos aquestes em feien dubtar. Com he esmentat una de les principals causes a les que atribuïen la flotabilitat era l'aire que els objectes tenien o no al seu interior. Aquesta creença em va ocasionar dubtes en relació a la meva intervenció; els havia d'ajudar a allunyar-se d'aquesta creença a la vegada que els aproximava a la idea que un objecte flota depenent de la relació entre el pes i el volum d'aquest? O simplement els havia d'introduir la nova informació sobre la flotabilitat? Aquests dubtes varen ser ocasionats arrel de la meva desconeixença en relació al tema. Finalment vaig optar per introduir-los mica a mica el concepte de densitat sense esmentar massa el tema de l'aire i, així evitar donar-los una informació de la qual no estava segura."

"Em va resultar difícil fer-los adonar que la flotabilitat d'un objecte té a veure amb la relació que existeix entre el pes i la massa d'aquest, perquè tenien molt interioritzat que la flotabilitat depèn de l'aire que hi ha dins l'objecte."

b) Apk PAS situated at any point within a lesson plan, but always before a WE PAS, that contain "Hypothesis question" actions.

As can be seen in charts 3 and 4, CASE B lesson plans contain, from the very beginning, much more 2.A.d. actions ("Hypothesis question", table 15) than lesson plans in CASE A (CASE A LP1i ß=0,03; CASE B LP1o ß=0,18). However both charts show a clear increase of 2.A.d. actions through instruction. The increase from initial (LP1i) to reviewed lesson plans (LP1f) in CASE B (0,14) is twice as much as in CASE A (0,07) and nearly equivalent to the increase from initial (LP1i) to plans performed during the second period of instruction (LP2) in CASE A (0,15). All plans performed before class intervention include "hypothesis question actions". Reflections on class interventions do not allow to know if they were really performed during class intervention. When performed, such actions took the form of "predictions" as students answer questions as a "gess", in all cases (example 19).

Example 19: (1314.04.05 reflection on class intervention)

"Abans de començar l'experiment vaig preguntar:

- *Què li passarà a la llum quan entri al tub recta? I el tub torçat?*

Most of the planned "Hypothesis question actions" in both, CASE A and CASE B lesson plans are considered "ill-posed". This ill-posed actions are widely described and they suppose, in all cases, making a guess of what would happen after doing an specific experiment/assignment without truly activating prior knowledge. Examples 20 and 21 illustrate these situations. With instruction, the relative frequency of well-posed "Hypothesis question actions" increases in both, CASE A and CASE B lesson plans. Nevertheless, in both cases still remain most of ill-posed actions.

Example 20: (CASE A 1112.03.14f)

"Abans de portar a terme l'experimentació els alumnes faran hipòtesis sobre què pot passar"

Example 21: (CASE A 1213.03.06i)

"Preguntarem als infants què pensen que passarà quan col·loqui una moneda, un suro i un raïm a la torre de líquids."

Summary of main ideas:

- It is possible to distinguish two kinds of Apk PAS:

(a) Apk PAS situated at the beginning of lesson plans and/or when a new idea is going to be introduced. Its aim to explore and make explicit initial internal models in relation to the ideas that are going to be developed within lesson plans. They contain "General Brainstorming"; "Specific knowledge asking", "posing a problem/scenario/seatwork"; "recapitulation" and "analysing" actions.

(b) Apk PAS situated at any point within a lesson plan, but always before a WE PAS, that contain "Hypothesis question" actions.

- Initial lesson plans in CASE B contain less "Brainstorming actions" and more "Specific knowledge asking actions" than in CASE A. Furthermore, "Specific knowledge asking actions" are better designed than in CASE A as preservice teachers tend to pose questions in relation to the given core ideas.

- CASE A and CASE B lesson plans follow the same tendencies. Throughout instruction, there is a clear increase of "Specific knowledge asking actions" and "posing a problem/scenario/seatwork actions" accompanied by a decrease of "Brainstorming actions".

- "Recapitulation actions" and "analysing actions" appear, with major frequency in CASE A and tend to increase through instruction.

- Reflections on class interventions give insight into preservice students' misconceptions regarding actions within Apk PAS. Misconceptions include: "expecting right answers"; "expecting only misconceptions" and "equating actions to explore initial models to an evaluation that seeks to accredit the level of knowledge of students".

- **Reflections on class interventions reflect preservice teachers' difficulties/success on guiding construction of knowledge (during class intervention) based on results from the exploration of initial models.**

- CASE B lesson plans contain, from the very beginning, much more "hypothesis question actions" than CASE A lesson plans. The relative frequency of this action category tends to increase through instruction in both cases.

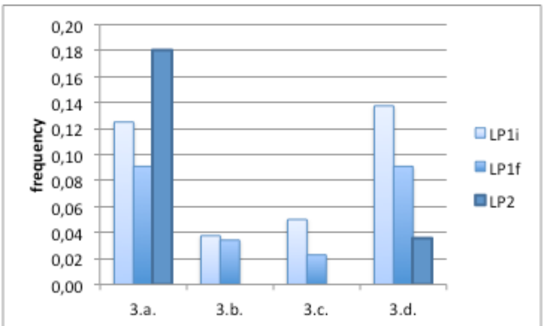
- Most "hypothesis question actions" are considered ill-posed as they are widely described and they suppose, in all cases, making a guess without exploring students' knowledge.

- With instruction, well-posed "hypothesis question actions" slightly increases in both; CASE A and CASE B lesson plans.

- All plans performed before class intervention include "hypothesis question actions". Reflections on class interventions do not allow knowing if they were really performed during class intervention. When performed, such actions took the form of "predictions".

5.4.4. Planned join activity structure: providing information PAS.

CASE A



CASE B

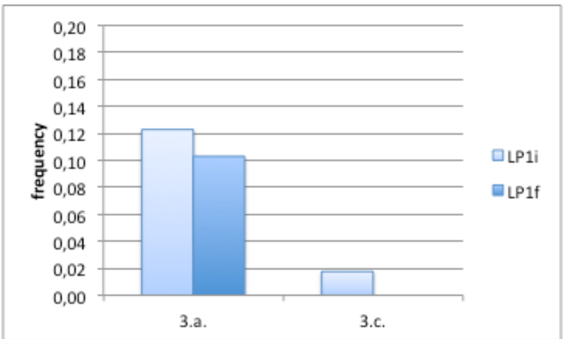


Chart 5. Chart 6. Relative frequency of actions in Pi PAS. 3.a corresponds to "Teacher exposition" action category; 3.b. corresponds to "Teachers' questioning dialogue"; 3.c. to "Students' questioning dialogue"; 3.d. corresponds to "Students' information searching" (table 16). LP1i corresponds to lesson plans performed before instruction. LP1f corresponds to reviewed lesson plans, performed during the first period of instruction. LP2 corresponds to lesson plans performed during the second period of instruction (figure 14).

CASE A lesson plans contain, in general terms, more "providing information PAS" than CASE B lesson plans. This can be seen by summing up all the relative frequencies of actions within the same period of instruction which naturally leads to the expected number of actions per PAS. In CASE A initial lesson plans (LP1i, figure 14) the expected number of action per PAS is 0,35 while, in CASE B initial lesson plans it is only 0,15. In CASE A reviewed lesson plans (LP1f, figure 14) the expected number of action per PAS is 0,24 while, in lesson plans performed at the same point of instruction in CASE B it is only 0,1. The expected number of action per PAS in CASE A lesson plans performed during the second period of instruction (LP2, figure 14) is 0,21 while, in plans performed before class intervention (CASE B), there are no PI PAS.

As seen in charts 5 and 6, actions within providing information PAS (and thus, PI PAS), decrease through instruction. An exception to this general tendency are "Teacher exposition actions" (3a actions) which increase in lesson plans performed during the second period of instruction (LP2) in CASE A. Specific details on these tendencies and examples are given below.

In CASE A, initial lesson plans (LP1i) PI PAS contain, mainly, 3.a. and 3.d. actions which suppose, respectively, that an expert presents information to alumni (as a monologue) and that alumni search information. Teachers' questioning dialogue (3.b) –example 5- and students' questioning dialogue (3.c.) –example 1, first part- also appear in a lesser extent. It has not been found, in any case, a socratic questioning dialogue (3e). In CASE B, PI PAS in initial lesson plans (LP1) only contain 3.a. and 3.c. actions.

In CASE A reviewed lesson plans (LP1f), it can be observed a noticeable decline of 3.a., 3.c, and 3.d actions within PI PAS (31%, 50% and 27% respectively). This decrease continues in LP2 lesson plans and responds to the elimination of most PI PAS and the transformation of activities containing PI PAS in other kind of activities (example 1). The same tendency can be found in CASE B where, 3c actions in initial lesson plans are eliminated and 3a actions are reduced.

Example 1: (CASE A 1112.03.01i and 1112.03.01f)

In LP1i, preservice students plan a field trip were students are expected to ask questions to an expert (3c). Preservice students note the sort of questions that may be asked by students:

"Alumnes: - *Perquè volen els ocells?*

Monitor: - *Uf! Quina pregunta més difícil. Anem per parts! El primer motiu és que els ocells tenen els ossos buits i en el seu interior hi ha aire en lloc de medul·la. Per aquest motiu l'esquelet d'un au voladora és lleuger i d'ossos prims.*

Alumnes: - *I només per aquest motiu ja volen? (...)"*

In LP1f, the same field trip is transformed into an activity were students obtain data-evidences:

"Com a primera activitat, els alumnes visitaran totes les aus que hi ha al Cim d'Àligues, per tal de conèixer-les. Tot seguit, els infants escolliran l'au que els ha agradat més i faran un dibuix explicatiu d'ella. Per tant, hauran d'observar detingudament totes les parts que la componen."

As mentioned, it is noticeable the increment of 3.a. actions in CASE A LP2. This increment responds partially, to the introduction of actions that aim to explain content about scientific procedures (examples 2 and 3).

Example 2: (CASE A 1213.04.09)

"Com a mestres en aquest punt hem d'agafar les regles de la investigació i ajudar, més directament als i les alumnes. Explicarem que per comprovar si és el pes o no la característica que determina la flotabilitat d'un material, hem d'aprendre a fer un disseny experimental amb control de variables." **and they continue explaining what is it and how to do it. They continue saying** *"Després d'ensenyar-los com es fa, teòricament passarem a la següent activitat per fer un experiment a partir d'un DECV (disseny experimental amb control de variables)"*

Example 3: (CASE A 1213.04.10)

"També el mestre/a podria explicar el concepte de pregunta investigable, que és aquella que es pot respondre per mitjà de l'experimentació"

In general terms, and in both CASES A and B PI PAS are conceived to introduce new information "a priori" (before doing any activity) regarding to a specific science concepts as a teachers'/expert monologue (exemple 4) or a teachers' questioning dialogue (exemple 5); searching information (exemple); whatching a vídeo (exemple 6); searching information (exemple 7) or asking questions to an expert (exemple 1).

Example 4: (CASE B 1213.03.01i)

"Explicarem als alumnes el sentit de l'olfacte funciona a partir d'uns sensors que detecten informació, estímuls del medi ambient. Els sentits tenen com a objectiu transmetre aquesta informació al cervell per tal que aquest pugui emmagatzemar-la i identificar en un futur de quina olor es tracta. Les persones tenim aquests sensors al nas, els quals ens permeten detectar les partícules de gas que ens envolten. Aquesta explicació la farà la mestra amb les paraules adients i adequades a l'edat i nivell dels alumnes. Deixant l'oportunitat als alumnes que demanin tots aquells dubtes corresponents."

Example 5: (CASE A 1112.03.12i)

"Per tant, l'activitat es comença demanant als alumnes:

- Algú sap o té una idea de com funciona una incubadora i per què serveix?- i un alumne respon: és una màquina en la qual la temperatura és molt alta, fa calor i els nens que neixen abans del previst els posen allà. (….)

- Molt bé, ara que ja sabem com funcionen les incubadores, també és molt important que el sabem mesurar. Amb quin instrument hem dit que el mesuraríem l'ou? ?- amb un peu de rei, i amb una cinta mètrica contesten els alumne. –Exacte - contesta la mestra, tot ensenyant els estris. Seguidament els explica que ell peu de rei és un aparell per mesurar longituds petites amb una precisió de centèsimes de mil·límetre.(…)"

Example 6: (CASE A 1213.04.05)

"Mostrarem un vídeo que parla sobre la percepció del dolor d'una manera molt gràfica.

Example 7: (CASE B 1213.03.09i)

*"***(el mestre)** *els explicarà que cadascun d'aquests equips haurà de cercar informació per tal d'esbrinar com detecten les olors cada classe d'animals."*

As mentioned, they are also produced to explain information about scientific procedures (examples 2 and 3). Finally, they are also created to explain scientific information "a posteriori" in relation to a previous hands-on/lab activity either as a teachers' monologue or searching information (examples 8, to 12).

Example 8: (CASE A 1112.03.03f)

After doing an experiment to collect data-evidence, preservice teachers state: *"Al final de la sessió els explicarà* **–referring to the teacher-** *que tot plegat és a causa de la superfície de l'ala i el corrent d'aire. Com més gran és la superfície de les ales, més s'aguanta al vol ja que la diferència entre corrents d'aire s'accentua."*

Example 9: (CASE A 1112.03.06f)

"(…), podran buscar a Internet més informacions sobre aquestes i per tant, ampliar, verificar, comprovar i consolidar les informacions obtingudes tant pel que fa referència a les sessions anteriors."

Example 10: (CASE A 1112.03.07f)

"El professor explicarà els principis bàsics de les lleis de Mendel a partir de les reflexions i els murals realitzats pels alumnes. És important que tots aquests principis es relacionin amb les pràctiques realitzades. D'aquesta manera, l'aprenentatge que realitzaran els alumnes serà significatiu. Els principis que s'hauran d'explicar són: principi de la uniformitat, principi de la segregació i principi de la

recombinació independent dels factors. Els esquemes que es poden realitzar per explicar aquestes principis s'haurien de realitzar, si és possible, a partir dels resultats obtinguts en el procés que han fet els alumnes."

Example 11: (CASE B 1213.03.02f) Preservice teachers plan an activity to perform a density column. Then they aim students to throw diferent objects to see what happens. After expecting students to perform the activity, they state: *"Explicarem que cada objecte té una densitat diferent, per tant, aquest es va enfonsant fins que troba un líquid que és més dens que ell i allà sura."*

Example 12: (CASE B 1213.03.02f)

"A partir d'aquesta activitat explicarem que el fet d'heretar caràcters funciona d'una manera semblant i els alumnes acabaran veien que hi ha caràcters que si que arriben a heretar-se i n'hi ha que no i que no sempre són els mateixos els que s'hereten. Per això per exemple hi ha germans amb els ulls de diferent color."

It is also important to note that, when 3d actions are planned teachers' scaffoldings to helps students to search information are not specified (examples 7 and 9). Just in one case, it is specified that teacher helps students questioning about the reliability of the information source (example 13).

Example 13: (CASE A 1112.03.11i)

"Els mateixos grups de quatre alumnes han de cercar informació a diferents fonts: Internet, biblioteca, preguntant amb els avis, pagesos del poble... per tal de conèixer més coses sobre el desenvolupament d'un pollet a dins d'un ou.

La mestra farà de guia, ajudant als alumnes a observar quines fonts són fiables i quines no, fent-los preguntes com: has mirat quin és l'autor? Creus que és fiable aquesta font d'informació? Per què?. D'aquesta manera els infants hauran de reflexionar, contrastar i relacionar diferents informacions."

Finally, just mention that although PAE PAS were not planned before class intervention, reflections on such interventions show that preservice teachers introduced them during class intervention. PAE PAS introduced during class intervetions imply, in all cases, 3.a. actions and refer, always, to science specific content. Furthermore, PAE PAS are, mainly, situated at the end of lesson plans and/or after performing an experiment. Just in one case, PAE PAS with 3a actions appear before an experiment. As it can be seen in examples 14 to 16 preservice teachers justify the introduction of these actions arguing that it was the way to ensure the comprehension of a specific content. Characteristics of reflection on class intervention assessments do not allow quantifying the relative frequency of appearance of these actions.

Example 14: (CASE B 1314.04.02 reflection on class intervention)

"D'altra banda, si les idees eren errònies i no les tenien clares como era el cas dels lligams entre partícules, els hi he fet una petita explicació fent sortir dos alumnes amb mi i fent la representació dels lligams en els líquids i en els sòlids."

Example 15: (CASE B 1314.04.05 reflection on class intervention)

"També vam presentar la maqueta que ajudaria entendre els alumnes l'ídea o fet que la llum viatja en línia recta." (...)

"Per ajudar a entendre els diferents conceptes treballats en el taller vàrem preparar una maqueta simbolitzava el focus de llum i els rajos que se'n desprenien fent servir una cartolina negre i llana de color vermell."

Example 16: (CASE B 1314.04.06 reflection on class intervention)

In a class intervention regarding buoyancy whose aim was to make students understand that buoyancy does not only depend on mass, preservice teacher A explanis that she hat difficulties to guide the final dialogue to reach conclusions, because students gave counterexamples to the consensus conclusion. Then, she states:

"Ho vaig solucionar fent un petit parèntesi tot explicant-los que un vaixell no és fet només de ferro, que a dins hi ha mobles de fusta, aire, persones, aigua i tot d'altres materials que feien que un vaixell no fos absolutament fet de ferro. No va semblar que els convencés gaire."

Summary of main ideas:

- CASE A lesson plans contain more "providing information PAS" than CASE B lesson plans.

- Actions within providing information PAS decrease through instruction in both CASE A and CASE B lesson plans. This decrease is due to the elimination of most PI PAS and the transformation of activities containing PI PAS in other kind of activities.

- An exception to this general tendency are "Teacher exposition actions" which increase in lesson plans performed during the second period of instruction in CASE A. This increment responds partially, to the introduction of actions that aim to explain content about scientific procedures.

- It has not been found, in any case, a socratic questioning dialogue (3e).

- In general terms, and in both CASES A and B PI PAS are conceived to:

a. introduce "a priori" new information regarding specific science content.

b. explain information about scientific procedures.

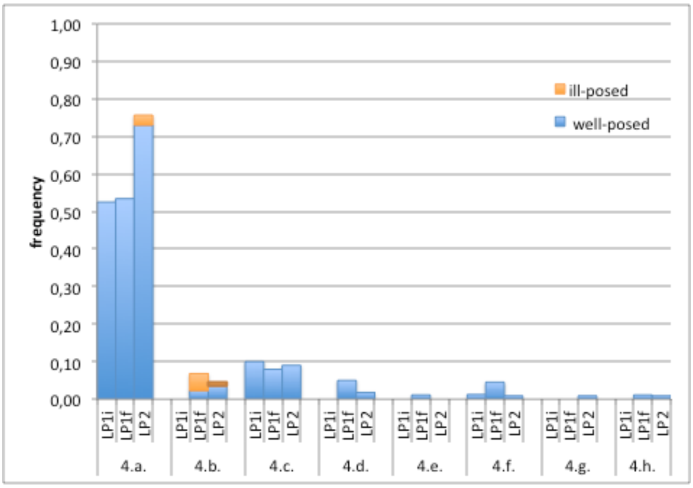
c. explain "a posteriori" the specific science content regarding a hands-on/lab activity.

- When "students' searching information" actions are planned teachers' scaffoldings to helps students to search information are not specified.

- Although PAE PAS were not planned before class intervention, reflection assessments show that preservice students introduced them. Actions within these PAE PAS refer always to "teacher exposition actions" aimed to explain "a posteriori" the specific science content.

5.4.5. Planned join activity structure: planning of assignments elements PAS.

CASE A **CASE B**



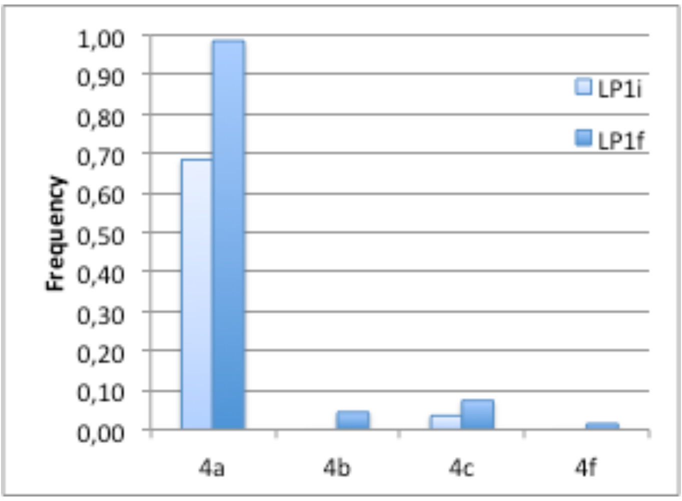


Chart 7. Chart 8. Relative frequency of actions in PAE PAS. 4.a corresponds to "Giving directions" action category; 4.b. corresponds to "Indirect giving directions"; 4.c. to "Students' giving directions"; 4.d. corresponds to "split-up" category actions; 4.e. corresponds to "Reformulating"; 4.f to "Modelling"; 4.g. corresponds to "Noticing" and 4.h. to "Focusing" action category (table 17). LP1i corresponds to lesson plans performed before instruction. LP1f corresponds to reviewed lesson plans, performed during the first period of instruction. LP2 corresponds to lesson plans performed during the second period of instruction (figure 14).

PAE PAS always precede work-execution PAS (WE PAS, section 5.4.6.) and occupy the major extension within lesson plans descriptions. In both, CASE A and CASE B lesson plans, PAE PAS suppose the bulk of the session description.

As seen in charts 7 and 8, predominant actions within PAE PAS imply, in all lesson plans teachers' direct exposition of assignments (4a) that, as it can be seen in charts 9 and 10, can be:

- Assignments to obtain data-evidence (small inquiries, lab instructions, instructions to observe a phenomena/animal behaviour…);
- Hands-on activities (i.e. constructing a bird feeder);
- Other kind of assignments (i.e. writing a report of what has been learnt).

In lesson plans performed before class intervention (CASE B) PAE PAS only contain 4a actions.

In all lesson plans, 4a actions take the form of detailed descriptions of what should be done. Furthermore, when they refer to hands-on activities and, mainly, activities to obtain data-evidence they appear as "cooking-recipes" (example 1).

Example 1: (CASE A 1112.03.01f)

"La mestra ha portat a l'aula diversitat d'ossos; hi ha de pollastre, pardal, guatlla, vedella i gall d'indi. A continuació, els ossos es passen per tots els alumnes per a què puguin observar com són de ben a prop, tocar-los i observar el seu tacte i veure el pes que poden arribar a tenir. Tot seguit, la mestra proposa als alumnes de pesar els ossos en les balances digitals, i anotar amb exactitud quin és el seu pes a la llibreta de ciències.

Un cop els alumnes han anotat el pes, la mestra haurà repartit recipients numerats amb aigua. D'aquesta manera, es tracta que els alumnes puguin observar el volum que ocupen els ossos dels diferents animals. Per mesurar el volum, els alumnes introduiran els ossos dins el recipient amb aigua (que està numerat). El volum inicial d'aigua serà de 100ml. Llavors, quan introdueixin els ossos, el nivell de l'aigua pujarà. Aquesta nova marca indicarà el volum de l'os introduït en ml. El càlcul s'ha de fer restant el nivell inicial al nou nivell un cop introduït l'os (cal destacar que ja hem fet observació de volums en unitats de programació anteriors).

Així doncs, els alumnes hauran de fer una activitat guiada relacionada amb el volum i el pes dels ossos, i com afecten aquests al vol dels ocells. Les activitats es faran en petits grup, i totes poden tenir diferents resultats. Aquest que presentem a continuació pot ser un exemple de taula a seguir per realitzar l'activitat:"

Within PAE PAS we can find, in a smaller proportion, other kinds of actions. In both CASE A and case B initial lesson plans (LP1), it is possible to find "Students' giving directions" actions (4.c) which suppose students deciding themselves what to do. As it can be seen in examples 2 and 3, within these 4.c actions, the role of the teacher is completely passive. "Modelling" actions (4.f.) also appear in CASE A initial lesson plans (LP1) although its relative frequency of appearance is only 0,01.

Example 2: (CASE B 1213.03.04i)

"Els alumnes tindran diferents materials; transparents, translúcids i opacs. A la classe hi haurà focus de llum i pantalles. Per parelles, hauran d'experimentar i descobrir en quina situació es creen ombres."

Example 3: (CASE B 1112.03.05i)

"Un cop escollides aquestes hipòtesis hauran de rumiar com desenvolupar-la, quins materials necessiten, quines activitats realitzaran per demostrar les seves idees, com enregistraran les dades, si faran fotografies o vídeos..."

The presence of action categories within PAE PAS increases through instruction, specially, in CASE A lesson plans. Reviewed lesson plans (CASE A and CASE B LP1f) and final lesson plans (CASE A LP2) contain more and more diverse actions than those in initial lesson plan.

In CASE A, the relative frequency of 4a actions increases progressively through instruction (relative frequency of 4a actions in LP1i=0,43 ; in LP1f ß=9,53 ; and in LP2 ß=0,73) while the relative frequency of 4c actions decreases a little bit (relative frequency of 4c actions in LP1i=0,10; in LP1f ß=0,08; and in LP2 ß=0,09). "Modelling" actions (4.f.) increase a little bit in reviewed lesson plans (relative frequency of 4f actions in LP1i=0,01; in LP1f ß=0,05); and decrease, again in LP2 (relative frequency of 4f actions in LP2=0,01). Furthermore, other actions such as "indirect giving orientations" actions (4.b.); ""split-up" actions (4.d.); "Reformulating" actions (4.e.); "Focusing" actions (4.h.) or "Noticing" actions (only in LP2) appear "the novo". However, the relative frequency of appearance of these "new" actions is really low in all cases.

In CASE B, both 4a and 4c actions increase through instruction (relative frequency of 4a actions in LP1i=0,68 while, in LP1f ß=0,99. Relative frequency of 4c actions in LP1i=0,04 while, in LP1f ß=0,07). The only actions that appear "the novo" in reviewed lesson plans are "indirect giving orientations" actions (relative frequency of 4b actions in LP1f=0,04) –example 4- and "Noticing" actions (relative frequency of 4f actions in LP1f=0,01). The relative frequency of appearance of these actions is, again, really low.

Example 4: (CASE B 1213.03.10f)

"En el segon apartat de l'activitat (…) introduir als infants diversos recursos per registrar dades i representar-les (taules, gràfics,...) i fer preguntes com ara: On posarem el termòmetre per mesurar la temperatura de la classe? El posarem les dues vegades que mesurarem la temperatura al mateix lloc?"

Scaffoldings in reviewed lesson plans are mainly found when describing steps to perform activities to obtain data-evidence. Specifically, most reviewed lesson plans incorporate an experimental design. This experimental strategy was taught during the course as a way to obtain data-evidence and interpret them. Students incorporate them in most reviewed lesson plans. They always take as a reference the table/steps given during the undergraduate course. In most cases, students incorporate the table they used during the course identifying the variables to perform the desired experiment and how to do it but they do not specify how they (as teachers) would help primary students to identify. In other cases, they do foresee actions such as in examples 5 and 6 (split-up), 7 (focusing), 8 (modelling) and 9 (reformulating):

Example 5: (CASE A 1112.03.05i and 1112.03.05f) In this case corresponding preservice students describe (in LP1i) that students plan an experiment themselves (4c action category) and state that it is not necessary to explain steps. In reviewed lesson plan they split-up an experimental design and they use different sessions to explain what is an hypothesis and make hypothesis, determine variables, etc. To do it, they use the example given during the course. They use the same sentence examples-scaffoldings, tables, etc.

1112.03.05i: *"Pel que fa al mètode científic que seguiran els alumnes en aquesta activitat, no és necessari que els expliqui de manera teòrica tots els passos que cal seguir durant l'experiment per arribar a una conclusió final. El mestre ha de tenir clar quins són aquests passos que han d'anar seguint i a través de preguntes s'anirà seguint el mètode científic. Al final, els alumnes hauran fet un experiment seguint els passos del mètode científic sense haver de fer una classe teòrica sobre el mètode científic on, probablement, més de la meitat d'alumnes no haurien entès res."*

While, in the reviewed lesson plan, in the same activity, they say; *"Creiem que proporcionar aquesta pregunta els ajudarà a tirar endavant el disseny. Hem de tenir en compte que són nens i, els mestres, els hem d'ajudar a organitzar els seus coneixements."* and they help students to plan an experimental design, set an investiable question, etc.

Example 6: (CASE A 1213.04.03)

"El mestre/a explicarà als nens i les nenes que per tal de realitzar un DECV de manera ordenada i controlada, cal que primer identifiquin (...). Aleshores, hauran de seleccionar una variable per tal de... (...) A més, hauran de definir què no podran modificar (...)"

Example 7: (CASE A 1112.03.05f)

"A continuació els alumnes aportaran les seves idees i la mestra els anirà conduint perquè centrin l'atenció en els aspectes de les ales dels ocells."

Example 8: (CASE A 1112.03.05f)

"Per ajudar-los a formular preguntes els donarem models de preguntes, com per exemple:

- *Què li passa a (variable dependent) quan modifiquen (variable independent)*
- *Com afecta a (variable independent) quan modifiquen (variable dependent)?*
- *Quan canvio (variable dependent), què li passa a (variable independent)?"*

Example 9: (CASE A 1112.03.05f)

"És possible que hi hagi alumnes que tinguin dificultats per comprendre què és una hipòtesi, per això, és convenient que el mestre/a estigui alerta i comprovi que tots comprenen el concepte. Si no és així, cal que els hi expliqui amb altres paraules (per exemple, què creieu que passarà si...). "

Finally, it is important to note that, in some cases, preservice teachers suppose situations that they would hardly occur in a real situation (examples 10 and 11):

Example 10: (CASE A 1112.03.04f)

"Com ho faríeu perquè aquesta tira de paper se sustentés a l'aire com un ocell?". Possiblement els nens se'ls acudiria llençar el paper a l'aire i bufar-lo per sota. Llavors la mestra podria preguntar-los: "Tenint en compte que és l'ala d'un ocell, creieu que podeu intentar-ho d'una altra manera sense llençar-la a l'aire?". Després d'experimentar amb la tira de paper una estona, els infants probablement s'hauran adonat que necessiten l'aire per aguantar d'alguna manera el paper (movent l'altra mà o bufant). La mestra els ha de guiar fent preguntes com ara: "Com ho faries per ser més precís a l'hora de dirigir l'aire? Et funciona més si dirigeixes l'aire cap a un lloc lluny o a prop? T'has fixat cap on dirigeixes l'aire: a sobre o a sota del paper?".

Example 11: (CASE A 1213.04.02)

"(...) proposarem a l'alumnat fer un disseny experimental amb control de variables. Però per aconseguir que ho entenguin, intentarem que siguin ells mateixos que facin el disseny.

El mestre o la mestra dirà:

- *"Bé, ara farem un experiment per veure quina relació hi ha entre el tacte i les sensacions que nosaltres sentim, per veure si realment, tal com hem dit abans, existeix una connexió entre el sentit i el sistema nerviós. La proposta la farem entre tots, i l'únic que us puc dir és que tenim aquestes plomes, les quals hem d'utilitzar. Recordeu que l'objectiu principal és veure quina relació hi ha entre el tacte i el sistema nerviós.*
- *A veure, de quina manera podríem utilitzar la ploma?* **(pluja d'idees arriben a la conclusió que volen ells: passar la ploma pel cos)**
- *Ara que ja tenim clar què fer amb la ploma, per on penseu que ens la podríem passar? Només per una zona en concret o per varies?*
- *Un cop tenim clar de quina manera utilitzar la ploma, anem a dissenyar el nostre disseny experimental amb control de variables. Primer de tot, què volem saber? (...)*
- *Seguidament la mestra pregunta a l'alumnat quin és l'aspecte que anirem canviant durant tot l'experiment (...)"*

Summary of main ideas:

- PAE PAS always precede work-execution PAS and occupy the major extension within lesson plans descriptions.

- Predominant actions within PAE PAS imply, in all lesson plans teachers' direct exposition of assignments (4a), which can be:

*** assignements to obtain data-evidence**
*** hands-on activities**
*** other kind of assignments**

- 4a actions appear detailed descriptions of what should be done (like "cooking-recipes").

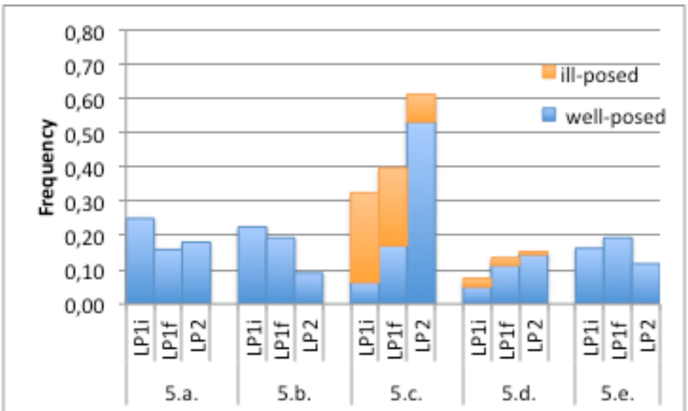
- Specially in CASE A, reviewed lesson plans and final lesson plans contain more and more diverse actions than those in initial lesson plan. These new actions appear in really low relative frequencies and are mainly found when describing steps to perform activities to obtain data-evidence.

- Instruments/examples used during the undergraduate course (i.e. tables to design an experimental design) are used to plan specific actions.

- Within actions preservice teachers suppose situations that they would hardly occur in real situations.

5.4.6. Planned join activity structure: work execution PAS

CASE A **CASE B**



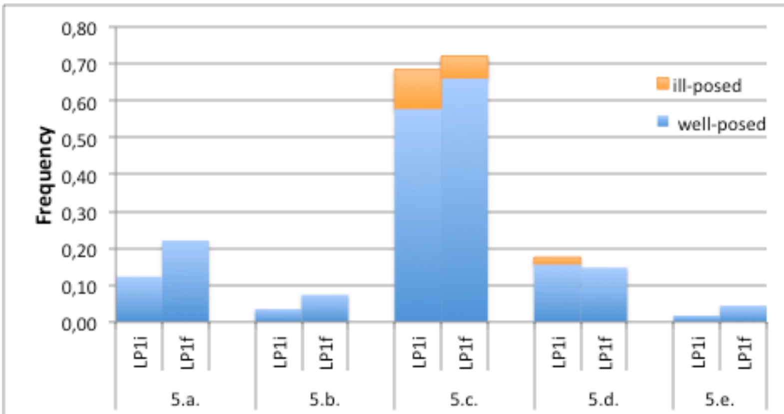


Chart 9. Chart 10. Relative frequency of actions in WE PAS. 5.a corresponds to "Non hand-on" action category; 5.b. corresponds to "Hands-on"; 5.c. to "Obtaining data-evidence"; 5.d. corresponds to "organizing data-evidence" and 5.e. corresponds to "monitoring" action category (table 18). LP1i corresponds to lesson plans performed before instruction. LP1f corresponds to reviewed lesson plans, performed during the first period of instruction. LP2 corresponds to lesson plans performed during the second period of instruction (figure 14).

Work execution PAS (We PAS) appear as a consequence of PAE PAS. In Planned join activity structure maps (figures 18 to 22) We PAS always follow PAE PAS. They include actions where students have an active role and suppose:

- non hands-on assignments (5.a. actions)
- "hands-on" assignments (5.b. actions)
- actions to obtain data-evidence (5.c. actions) that sometimes are accompanied by actions to organize data-evidence (5.d actions)

Occasionally, these actions appear together with 5.e. actions ("monitoring" action category) which suppose an active role of the teacher.

As shown in charts 9 and 10 actions to obtain data-evidence (5.c. actions) represent the bulk of actions within We PAS in all lesson plans. In lesson plans performed before class intervention (CASE B) We PAS it is only possible to find 5c actions associated to 4a actions.

In "reflection on class intervention" assessments, preservice teachers do not describe, in deep detail, how they performed the planned intervention. In their reflections they put emphasis on classroom timing and management. Regarding PAE and WE PAS preservice students always express satisfaction on performance and report minor changes (i.e. due to availability of material, restrictions regarding the space were they performed the activities, etc.) or small difficulties due to classroom management. In some cases, however, it is possible to see that some major changes occurred within classroom intervention (example 1).

Example 1: (CASE B 1314.04.02 reflection on class intervention)

"Hem realitzat les tasques que teníem preparades per tal de parlar sobre tema, però no han entès gaire, així que els he proposat realitzar com una mena de joc per entendre-ho millor."

The relative frequency of actions to obtain data-evidence in initial lesson plans (LP1i) is higher in CASE B than in CASE A (relative frequency of 5c actions in CASE B LP1i=0,69; relative frequency of 5c actions in CASE A LP1i=0,32). Furthermore, these actions are significantly better posed in CASE B initial lesson plans than in CASE A initial lesson plans: while relative frequency of well-posed 5c actions in CASE B is 0,58 its relative frequency in CASE A LP1i is only 0,06. Ill-posed 5c actions suppose experiments poorly/not adequately designed (i.e. in example 1 students do not recognize a DECV) and/or that do not address the big ideas underlying lesson plans (examples 2 and 3).

Example 2: (CASE A 1213.04.11)

"En aquesta activitat la mestra proposarà als alumnes que construeixin dos avions de paper amb dos fulls Din A-4, que tindran el mateix pes (vegeu annex 1 i 2). A continuació demanarà als alumnes que per grups, llancin els dos avions de paper unes deu vegades cada un i anotin en una llibreta quina distància recorre cadascun. És important que remarqui que haurien d'intentar llençar l'avió aproximadament amb la mateixa força."

Example 3: (CASE B 1213.03.01i) preservice teachers state that the aim of this activity is: *"Objectiu de l'activitat: amb aquesta activitat es pretén que els alumnes s'adonin que les olors són partícules molt petites en forma de gas."*

However, as described, the activity does not address such aim:

"En grups de quatre alumnes, els donarem una full guia en el qual hi haurà un itinerari marcat i un seguit de preguntes que hauran de respondre. Aquest itinerari seguirà un ordre diferent per cada grup per tal que no coincideixi tot el grup classe en un mateix espai. D'aquesta manera, tots els alumnes podran explorar tots els espais proposats per després poder posar en comú les informacions recollides i extreure'n conclusions.

Un cop fets els grups i assignats els itineraris, els alumnes faran una volta pels diferents espais de l'escola (menjador, lavabo, gimnàs, consergeria, biblioteca, pati, etc.) i s'aturaran en aquells on percebin una olor que destaqui en aquella zona. Un cop s'aturin, hauran de respondre les preguntes del full guia sobre cada olor que percebin (un per grup)."

In each school-area students have to say where does the smell come from, how does it come to the nose and if they have to get close to the place were it comes from to smell it.

In both CASE A and CASE B, the relative frequency of actions to obtain data evidence (5c) increases over time. The relative frequency of well-posed 5c actions also increases over time. Along with this increase, the relative frequency of 5.d. actions (using charts, tables, etc. to organize data-evidence, example 4) in CASE A also increases. On the contrary, it slightly decreases in CASE B. Specific data from these tendencies is visualized in table 24.

		LP1i	LP1f	LP2
Relative frequency of 5c actions	CASE A	0,32	0,4	0,61
	CASE B	0,69	0,72	-
Relative frequency of 5d actions	CASE A	0,08	0,13	0,15
	CASE B	0,18	0,15	-

Table 24. Tendencies of relative frequencies of 5c and 5d actions through instruction.

Example 4: (CASE B 1213.03.07i)

"A mesura que van fent les comprovacions ho aniran anotant a la taula de resultats amb un color diferent perquè sigui més visual."

As mentioned at the beginning of this section, We PAS also contain 5.a. actions (non hands-on assignments) and 5.b. actions ("hands-on" assignments). Looking at what happens through instruction, we see different tendencies in CASE A and CASE B lesson plans.

The relative frequency of 5a and 5b actions is lower in CASE B initial lesson plans. In CASE B lesson plans, the relative frequency of both actions tends to increase over time. In CASE A the relative frequency of 5b actions also increases over time. However, the relative frequency of 5.a. actions decreases in reviewed lesson plans (LP1f) and increases, later on, in lesson plans performed during the second period of instruction. Values are shown in table 25.

		LP1i	LP1f	LP2
Relative frequency of 5a actions	CASE A	0,25	0,16	0,18
	CASE B	0,12	0,22	-
Relative frequency of 5b actions	CASE A	0,23	0,19	0,09
	CASE B	0,04	0,07	-

Table 25. Tendencies of relative frequencies of 5a and 5b actions through instruction.

It is interesting to notice that, when the learning cycle is introduced (during the second period of instruction in CASE A and during the first period instruction in case B), preservice students tend to plan 5.a. and 5.b. actions within sessions that they identify as sessions "to structure knowledge" and, mainly, sessions "to apply knowledge". Common assignments within these sessions require students to answer individually questions (like in an examination); make schemas; murals, etc. (examples 5 and 6). Making models or other hands-on activities also appear in less frequency (example 7 and 8).

Example 5: (CASE B 1213.03.04f)

"*La mestra demanarà als alumnes que facin, individualment, un esquema a la llibreta de ciències que reculli les idees més importants del que s'ha fet al llarg de la unitat."*

(Preservice teachers identify this assignment as "to structure knowledge")

Example 6: (CASE A 1213.04.07)

"Per tal de recollir tota la informació obtinguda (...) els i les alumnes hauran d'elaborar un mapa conceptual de manera individual, on seleccionin la informació més rellevant i significativa per explicar tot el que han après."

"Amb aquest mapa conceptual volem que els i les alumnes sintetitzin els aspectes més fonamentals de tot el que han treballat, de manera que aconsegueixin un bon resum de tot el que han après."

(Preservice teachers identify this assignment as "to structure knowledge")

Example 7: (CASE A 1213.04.05)

"1. La mestra distribueix als alumnes en grups de cinc persones i els explica que hauran de realitzar uns maqueta per explicar que passa quan ens punxem amb un escuradents.

2. Els demanarà als alumnes que elaborin un model de sistema nerviós conjunct per poder elaborar la maqueta.

3. Després de ser avaluada per la mestra, els alumnes hauran de fer un croquis (…) acompanyat d'una breu explicació (…)"

4. Els infants hauran d'elaborar una llista amb els materials que puguin necessitar (…)

5. La maqueta s'anirà realitzant al llarg d'uns quants dies (…)"

(Preservice teachers identify this assignment as "to apply knowledge")

Example 8: (CASE B 1213.03.05f)

"Es demana als alumnes que a partir dels coneixements adquirits construeixin un rellotge de sol i expliquin com l'han creat i com funciona. Per grups exposaran el treball realitzat davant de la classe."

(Preservice teachers identify this assignment as "to apply knowledge")

The rol of the teacher within WE PAS is, in most cases, obviated. Furthermore, when described, it is only considered as a monitoring one (5e actions. Examples 9 and 10). In most sessions conceived to apply knowledge, preservice students explicitate that teachers should have a passive role (exemple 11). In reviewed lesson plans this role is slightly more announced.

Example 9: (CASE A 1112.03.07f)

*"**Rol del mestre**: el tutor proporciona les llavors i controla el procés que segueixen els alumnes tant alhora d'establir com plantar una llavor, com alhora de posar-ho en pràctica. Haurà d'estar atent per si els alumnes realitzen qualsevol acció que impedeixi el creixement de la planta."*

Example 10: (CASE B 1213.03.10i) In this example preservice teachers consider that teacher should perform: 4a actions (giving directions of what to do) and 5e actions (second paraghaph; controlling students performance). The second part of the first paragraph considers students performing 5c actions, regarding 4a actions.

"*El **rol del mestre** en aquesta activitat és molt passiu, ja que no ha d'explicar res més que no sigui el què faran a l'activitat. Els alumnes seran els qui agafaran el termòmetre i mesuraran la temperatura les dues vegades, és a dir, experimentaran ella mateixos.*

A partir d'aquestes preguntes i depenent del que et contestin els alumnes la mestra sabrà si van ben encaminats, si utilitzen la lògica, etc."

Example 11: (CASE A 1213.04.03)

"Aquesta activitat és d'aplicació i, per tant, la mestra en principi no intervindrà activament. Com que els infants han d'aplicar els coneixements adquirits en les activitats, la mestra deixarà que resolguin sols el problema."

Summary of main ideas:

- In all CASE A and CASE B lesson plans, actions to obtain data-evidence (5.c.) represent the bulk of actions within PAE PAS.

- The relative frequency of actions to obtain data-evidence in initial lesson plans is higher in CASE B than in CASE A. Furthermore, these actions are significantly better posed in CASE B initial lesson plans than in CASE A initial lesson plans.

- In both CASE A and CASE B, the relative frequency of actions to obtain data evidence (5c) increases over time. The relative frequency of well-posed 5c actions also increases over time.

- We PAS also contain "non-hand on" actions (5.a.) and "hands-on" actions (5.b.). The relative frequency of these actions is lower in CASE B initial lesson plans.

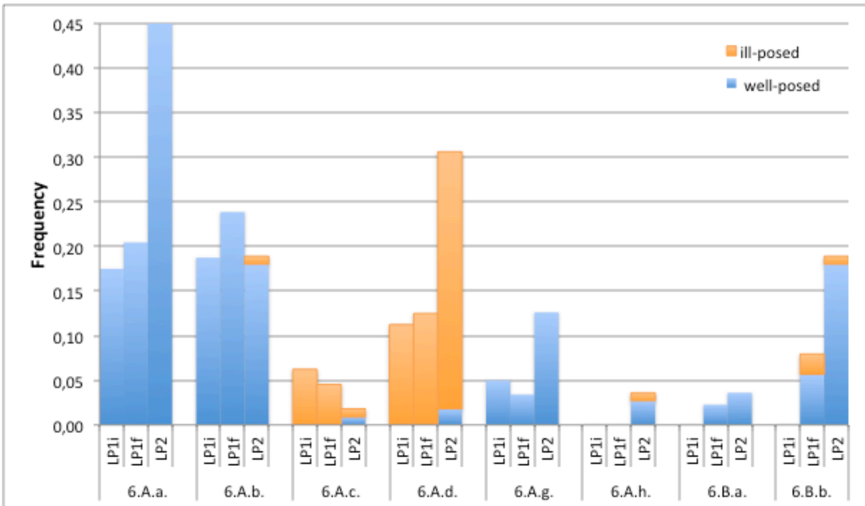
- When the learning cycle is introduced, preservice teachers tend to plan 5a and 5b actions in sessions that preservice identify as "to structure knowledge" or "to apply knowledge".

- The role of the teacher is obviated in most cases and, when described, it is only considered as a monitoring one (5e).

- When preservice teachers reflect on class intervention timing and classroom management and express satisfaction on performance without giving details.

5.4.7. Planned join activity structure: elaboration-conclusion PAS.

CASE A



CASE B

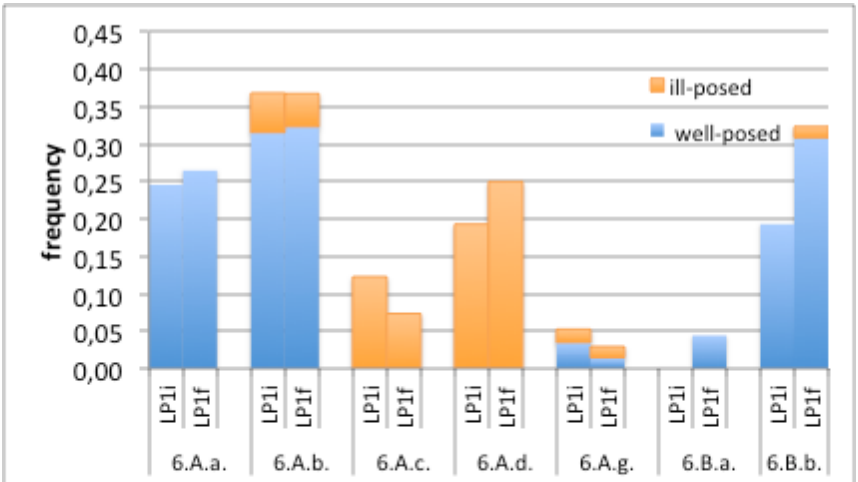


Chart 11. Chart 12. Relative frequency of actions in EC PAS. 6.A.a corresponds to "Sharing" action category; 6.A.b. corresponds to "Teachers' questioning dialogue"; 6.A.c. to "Socratic questioning"; 6.A.d. corresponds to "cross-discussion" and 6.A.g. corresponds to "Recapitulation" action category; 6.A.h. corresponds to "fill-in-the-blanks questioning"; 6.B.a corresponds to "Elaborate data/evidence" and 6.B.b to "Referring to data/evidence" (table 19). LP1i corresponds to lesson plans performed before instruction. LP1f corresponds to reviewed lesson plans, performed during the firs t period of instruction. LP2 corresponds to lesson plans performed during the second period of instruction (figure 14).

The relative frequency of the set of actions in EC PAS that appear in initial lesson plans (LP1i) is higher in CASE B than in CASE A. Nevertheless and although elaboration-conclusion PAS should be one of the most important PAS within a lesson-plan, their description occupies a relative short space in all CASE A and CASE B lesson plans. As it can be seen in charts 11 and 12, the total amount of actions within EC PAS increase, in both cases, over time. This tendency corresponds to larger descriptions in reviewed and final lesson plans.

In some cases actions within EC PAS are not described but pre-students state the conclusions to which students should arrive. In reviewed and final lesson plans these conclusions may refer to obtained data-evidence. However, preservice students do not specify how students should reach this conclusions, which actions they would do as teachers to help them, etc. (examples 1 and 2). Furthermore, in most cases, these "desired conclusions" are not directly inferred from data-evidence obtained (example 1).

"Example 1: (CASE A 1112.03.04f)

In this example, preservice students plan a DECV. After describing it, they write:

"*Establir resultats:*

El model d'avió amb les ales més petites recorre menys distància que el de les ales més grans."

"A partir d'aquestes dades podem concloure que com més gran és la superfície de les ales d'un avió, més aguanta el vol ja que la diferència entre corrents d'aire s'accentua."

Note that the final statement ("ja que la diferència entre corrents d'aire s'accentua") gives a reason for the conclusion that can directly inferred from results. These explanation it is poorly developed and refers to Bernoulli's principle. However, it can not be directly inferred from data abotained through lesson plan and would not be state by elementary students.

Example 2: (CASE B 1213.03.04i)

"Arribaran a la conclusió que la llum es propaga en línia recta."

As shown in charts 11 and 12, in both CASE A and CASE B lesson plans, EC PAS include, mainly, "data-sharing" actions (6.A.a) and "questioning dialogue" actions (6.A.b) –examples 3 to 5).

Example 3: (CASE A 1112.03.02f) (6.A.b)

After obtaining data-evidence, preservice teachers state that they would help students to reach conclusions (6.A.b.):

"(…) realitzant preguntes obertes per tal que els alumnes vagin més enllà en la seva observació. Aquestes poden ser:

- *Hi ha la mateixa quantitat de rovell que l'ou que vam obrir fa 4 dies?*
- *Quina forma té l'embrió? És gran?*
- *Quines parts observes?*
- *Quina part està més desenvolupada?*
- *Estan desenvolupades les extremitats? Com són?*
- *Hi ha una diferencia clara entre les ales i les potes de l'embrió? Se sent com piulen a dins l'ou?*

Note that they consider such questions as "open" while, most of them only have a specific answer.

Example 4: (CASE A 1112.03.07f)

After searching information preservice teachers state (6.A.a+6.A.b.)

"Seguidament, ho exposaran a la resta de grups i s'establirà la manera de plantar les llavors.

Preguntes que es realitzaran als alumnes:

- *Com hem de plantar les llavors?*
- *Quina característica ha de tenir la zona en la qual plantem les llavors? (fent referència a la superfície on s'ha de plantar i a la llum del sol que hi ha de tocar.)*
- *Hem de tenir en compte algun aspecte alhora de plantar les llavors? (separació entre les plantes, profunditat a la qual cal plantar, terra que utilitzarem...).*
- *Quin material hem d'utilitzar per plantar les Pisum sativum?*
- *Quines necessitats té la Pisum sativum un cop plantada?"*

Example 5: (CASE B 1213.03.01f) (6.A.a.+6.A.b)

In this example, preservice students pose the desired conclusion that they want students to reach and pose 6.A.a. and 6.A.b actions. Furthermore, they state that if these two actions do not lead to the appropriate conclusion, they would "guide" the discussion, without specifying what actions they would do.

"Després de posar en comú les observacions el docent farà dues preguntes sintetitzadores per tal de verificar que els alumnes han arribat a les conclusions esperades. Les preguntes seran les següents:

- És necessari olorar un objecte directament per poder percebre la seva olor?

- Per tant, en quin estat de la matèria creieu que es troba la olor?

El docent, en cas que els alumnes no arribin a extreure la conclusió, guiarà aquest moment de reflexió per tal que arribin a comprendre que les olors es troben a l'ambient en forma de gas."

As it can be seen in examples 3 to 5, but also in examples below, "data-sharing" actions usually accompany other kinds of actions. Furthermore and as shown in table 26 the relative frequency of 6.A.a actions within EC PAS tends to increase, in all cases, through instruction. It is especially noticeable the increase of 6.A. actions in lesson plans performed during the second period of instruction, in CASE A (LP2).

		LP1i	LP1f	LP2
Relative frequency of 5a actions	CASE A	0,18	0,20	0,45
	CASE B	0,25	0,26	-

Table 26. Tendencies of relative frequencies of 6.A.a. actions through instruction.

On the contrary, the relative frequency of 6.A.b actions within EC PAS tends to decrease through instruction although, in CASE A reviewed lesson plans (LP1f), it increases a little bit (table 27).

		LP1i	LP1f	LP2
Relative frequency of 5a actions	CASE A	0,19	0,24	0,18
	CASE B	0,37	0,36	-

Table 27. Tendencies of relative frequencies of 6.A.b. actions through instruction.

Although descriptions of actions within EC PAS are quite brief, in some cases, it is also possible to intuit that preservice students would use socratic questionings (6.A.c. actions, table 19) or cross-discussions (6.A.d. actions, table 19) to reach conclusions (examples 6 to 12). Nevertheless those actions are considered ill-posed in all cases as they are not described with enough extent to suppose that they would be carried out in a consistent way. Furthermore, in most cases they are considered in activities were big ideas are not well addressed, making it quite impossible to reach proper conclusions.

Example 6: (CASE A 1112.03.03i 6.A.c)

"*El docent farà de guia, en tot moment farà de moderador i provocarà que els infants reflexionin i participin a partir de les preguntes que faci per tal de conduir-los en el diàleg."*

Example 7: (CASE A 1112.03.03f 6.A.c)

"(...) i a través de preguntes d'orientació del docent, podran comprovar que es tracta de la càmara d'aire."

Example 8: (CASE A 1213.03.04i initial 6.A.d converted to 6.A.c –considered 6.A.c. for final recount)

"En el cas que no se'n surtin, la mestra anirà donant pistes o farà preguntes com per exemple; amb la llum tancada podem crear ombres? En aquesta activitat, la mestra té un paper de guia mentre que els alumnes, tenen un paper totalment actiu."

Example 9: (CASE B 1213.03.03i 6.A.c)

"Pretenem que s'adonin, a partir de preguntes, que hi ha una informació que passa de generació en generació (de pares a fills) però pot ser que es desenvolupi o no."

Example 10: (CASE A 1112.03.01f) (6.A.a.+6.A.d)

"Al final de l'activitat es proposa que els alumnes explicitin i comparteixin entre el grup classe les conclusions a les quals han arribat per, entre tots els infants, poder discutir i debatre quin pot ser el millor model que ens ajudi a descriure la relació entre el pes dels ocells i el seu vol."

Example 11: (CASE A 1213.04.02) (6.A.a.+6.A.d)

In this example, preservice teachers explain actions to collect data-evidence. After that, they require students to explain what has happened during the experience. In this case, they also state that the teacher should have a passive role.

"Un cop hagi passat el minut l'alumne s'ha d'eixugar les mans i tocar la barra d'alumini amb les dues mans i intentar explicar què ha passat"

"No s'ha de dir als alumnes perquè passa el que passa sinó que ha d'animar a la reflexió i a analitzar la situació que han viscut per tal d'extreure conclusions."

Example 12: (CASE B 1213.03.03i) (6.A.d)

"Finalment, realitzarem un debat a l'aula per analitzar si aquests comportaments són fruit de l'aprenentatge individual de mecanismes automatitzats o bé, venen determinats per l'herència genètica."

The relative frequency of 6.A.c. actions within EC PAS increases, in both cases, over time. In CASE B, the relative frequency 6.A.d. actions within EC PAS also increase through instruction. On the contrary, in CASE A, the relative frequency 6.A.d. actions within EC PAS decreases progressively through instruction (table 28).

		LP1i	LP1f	LP2
Relative frequency of 6.A.c. actions	CASE A	0,25	0,16	0,18
	CASE B	0,12	0,22	-
Relative frequency of 6.A.d. actions	CASE A	0,23	0,19	0,09
	CASE B	0,04	0,07	-

Table 28. Tendencies of relative frequencies of 6.A.c and 6.A.d. actions through instruction.

As shown in charts 11 and 12, specific science-content actions (19B) increase through instruction. However, it is only possible to find two actions belonging to this category: elaborating data-evidence (6.B.a actions, table 19) and refering to data-evidence when elaborating conclusions (6.B.b actions, table 19).

Table 29 shows that initial lesson plans in CASE A do not contain any of these specific science-content actions. On the contrary, CASE B lesson plans contain, from the very beggining, CASE B actions. The relative frequency of 6.B.a actions wihin EC plans increases, in all cases, over time. Nontheless, relative frequencies of 6.B.a actions wihin EC plans are always really low. The relative frequency of 6.B.b actions wihin EC plans also increases through instruction in both cases. However, the relative frequency of 6.B.b actions in final lesson plans in CASE A (LP2) is equivalent to the relative frequency of these actions in initial lesson plans in CASE B (LP1i, CASE B).

		LP1i	LP1f	LP2
Relative frequency of 6.B.a. actions	CASE A	0,00	0,02	0,04
	CASE B	0,00	0,04	-
Relative frequency of 6.B.b. actions	CASE A	0,00	0,08	0,19
	CASE B	0,19	0,32	-

Table 29. Tendencies of relative frequencies of 6.B.a and 6.B.b. actions through instruction.

Specific examples of of 6.B.a and 6.B.b. actions are shown below (examples 13 and 14). As it can be seen, these actions always accompain the actions within EC PAS discussed so far and are usually described without detail.

Example 13: (CASE A 1213.04.01) (6.A.a.+6.A.b+ 6.B.a.+6.B.b)

"Es pot proposar als alumnes que recullin dades i facin un gràfic posant en relació l'augment de la temperatura i el temps de cadascuna de les marques de la vareta"

"Posada en comú dels resultats obtinguts a partir de gràfics realitzats i de les observacions"

"El mestre farà la reflexió conjuntament amb els seus alumnes sobre l'observació que s'ha dut a terme a l'aula.

Preguntes: Com penseu que s'ha desplaçat la calor?

Si s'encallen: Ho podem relacionar amb el moviment de partícules?"

Example 14: (CASE B 1213.03.03f) (6.A.a.+6.A.b+ 6.B.a.+6.B.b)

"Seguidament, en petit grup (de 3 o 4 alumnes) analitzaran les dades. Per fer-ho, ompliran les graelles següents per cadascun dels aspectes demanats:" (**preservice students show an example of table to organize data)**

"Llavors, caldrà que els alumnes treguin conclusions sobre els resultats obtinguts. És a dir, escriuran l'afirmació a partir de les evidències que han anat observant. Aquesta reflexió l'anotaran a la llibreta."

"Una vegada a l'aula, quan tots tinguin la taula complerta, es farà una posada en comú"

In really low relative frequencies, 6.A.g and 6.A.h actions can also appear in EC PAS. As it can be seen in exemples 14 and 15, 6.A.g actions suppose a recapitulation of the main ideas being developed within a lesson plan/session. As seen in charts 11 and 12, in CASE B this type of actions decrease over time while, in case A they tend to increase in LP2. As shown in example 15, 2.A.g actions also appear in "class intervention assignments" .

Example 14: (CASE A 1213.03.05i) (6.A.a.+6.A.g)

"Posaran en comú totes les conclusions i experiments realitzats"

Example 15: (CASE B 1314.04.02, planning for classroom intervention) (6.A.g)

"Un cop haguem acabat amb totes les tasques previstes, el què farem sera fer un repàs de tot el que hem treballat amb els alumnes per tal d'assegurar-nos que tothom ho ha entès i que el model de partícules i lligams ha quedat clar."

"Fill-in-the-blanks questioning" actions (6.A.h) only appear in final lesson plans (LP2), in CASE A. As it can be seen in eample 16, they suppose actions where the teacher requires students to raise conclusions providing fill-in-the-blank paragraphs.

Example 16: (CASE A 1213.04.08)

"El mestre escriurà a la pissarra la pauta per elaborar les conclusions i els alumnes hauran de copiar-la i completar-la a la llibreta de ciències."

"Tal com recullen les dades, el tipus de.... afecta al fet que la llavor de repalassa s'hi enganxi o no. Per exemple, hem vist que hi ha materials com......, ... on és fàcil que la llavor s'hi enganxin. En canvi, hi ha materials com....... on la llavor no s'hi enganxa. Això ens fa pensar que en el cas dels animals......................"

When planning for classroom intervention, preservice students prepared, on demand, questions to help students to reach conclusions in reference to the obtained data-evidence. Therefore, the map of programmed activity segments corresponding to these lesson plans (see figure 23) only contains 6.A.b. and 6.B.b actions.

"Reflection on class intervention" assignments show that, in reality, those EC PAS included more actions. Furthermore, "reflection on class intervention" assignments enables a "deep insight" on preservice teachers' performace of actions within EC PAS.

In "reflection on class intervention" assignments preservice teachers explained how they helped students to reach conclusions and move from initial (Mi) to M1 models. In general terms, preservice teachers asserted that they were satisfied with their intervention. However, in most cases, they also pointed that they hat difficulties when guiding discussions to reach conclusions (example 17 to 21).

It is important to notice that most of this misconceptions appeared after students' interventions in relation to well-known misconceptions. Although most of these misconceptions appeared in the initial model evaluation activity, preservice teachers did not pre-plan scaffoldings regarding them.

Preservice teachers' reflections show that, in general terms, preservice teachers solved these situations giving direct explanations to students (examples 17 to 20). Furthermore, they give insight into preservice teachers insecurities' that can be attributed to:

a. weakness of science content knowledge and lack of specific pedagogical resources (examples 17 to 20).
b. expect specific "correct" anwers from students (example 21).

Finally, they also highlighted the importance of pre-planning scaffoldings as a way to overcome these difficulties (examples 22 and 23).

Example 17: (CASE B 1314.04.02 reflection on class intervention)

In this example, preservice teacher A guides students to reach conclusions satisfactorily. However, after the intervention of a student, preservice teacher A does not know what to do.

" (...) La sorpresa ha arribat al final quan ja estava tot clar una nena m'ha preguntat si el paper era un sòlid o un líquid. He demanat a la resta de companys que contestessin i tots han cridat sòlid. I ella m'ha qüestionat perquè canviava de forma doncs. Jo li he dit que això es degut a les diferències entre sòlids, ja que no tots ells tenen els lligams igual de forts. Però de totes maneres els sòlids tenen els lligams més forts que els líquids."

As it can be seen preservice teacher A overcomes the situation giving direct information to the student. However, preservice student A states: *"Al no estar segur d'aquesta resposta no puc afirmar que fes bé en respondre això, ja que puc haver donat un coneixement erronii als infants."*

Example 18: (CASE B 1314.04.03 reflection on class intervention)

preservice teacher A guides students

"En diversos moments, quan algun dels nens/es explicava la seva idea no acabava de saber com ho havia de fer per fer-li adonar que en realitat no era d'aquella manera que em deia."

"En molts moments, jo tenia clar el model de partícules però no sabia com fer-ho veure als infants. Per posar un exemple d'això: una de les nenes deia "les partícules de sòlid estan molt juntes i no hi ha enllaços entre elles. (...) Tot i que li deia que si que hi havia lligams entre les partícules, no sé si la vaig convèncer. Tampoc sabia com fer-ho per fer-li veure, així que li vaig dir que hi eren."

"(...) crec que no vaig prou preparada per fer el taller. En certes ocasions no sabia com actuar i com fer-ho per intentar canviar les idees errònies que tenien els alumnes. Així, que caldria fer una preparació prèvia més acurada."

Example 19: (CASE B 1314.04.05 reflection on class intervention)

"Una de les principals dificultats amb les que em vaig trobar en referència als continguts va ser en canviar la idea d'alguns dels alumnes quan justificaven la flotabilitat del suro o de la poma dient que era per l'aire que tenien aquests objectes dins. Aquesta idea va sorgir varies vegades i al principi influenciava a la resta, per tant, va ser un tema que vaig haver d'explicar amb el model de partícules ja que, pel que vaig poder veure, era un tema que ells ja havien treballat anteriorment i, a més a més, vaig pensar que explicant d'aquesta manera la diferència entre els materials a la llarga els ajudaria a entendre "el quid de ka cuestión" de la flotabilitat, que és la diferència dels materials amb que està fet cada objecte i que en definitiva això fa variar la seva densitat."

Example 20: (CASE B 1314.04.06 reflection on class intervention)

"La dificultat més important en relació al contingut que pretenia ensenyar als alumnes, ha estat el fet que responien moltes de les preguntes que els feia amb l'exemple dels vaixells. El fet de ser objectes molt grans i amb molt de pes coneguts per als alumnes, feia que els posessin d'exemples en preguntes com "És possible que un objecte de ferro floti?" en aquest cas la meva intenció era fer-los veure que un objecte de ferro mai podria flotar (...) ells al posar l'exemple del vaixell desmuntaven tot el meu argumentari. Ho vaig solucionar fent un petit parèntesi tot explicant-los que un vaixell no és fet només de ferro, que a dins hi ha mobles de fusta, aire, persones, aigua i tot d'altres materials que feien que un vaixell no fos absolutament fet de ferro. No va semblar que els convencés gaire." **(to convince students draws a ship, full of iron and without holes, on the blackboard).**

Example 21: (CASE B 1314.04.01 reflection on class intervention)

"Molts vegades tracten l'olor i l'aire com una "cosa" i aquesta idea inicial costa de modificar."

"La intervenció que va fer un alumne per dir-me que l'olor la porta el vent va fer-me dubtar en si endisnar-me o no en la idea que vent i aire són conceptes diferents. Vaig potar per no fer-ho ja que això podria portar confusions i embolics en tot allò que havíem estat fent."

"Crec que moltes vegades esperem que els infants responguin allò que volem sentir i amb les paraules que voldríem que utilitzessin."

Example 22: (CASE B 1314.04.01 reflection on class intervention)

Preservice teacher B:

"Crec que hi ha força aspectes que es podrien millorar amb la pràctica. Segurament es podrien introduir altres preguntes que fossin més significatives pels infants o bé, utilitzar algunes de les seves intervencions per treure'n més suc.

Si tornés a fer aquest taller em prepararia alguna altra pregunta de reflexió després de cada activitat. Penso que les experiències podrien donar molt més a parlar però la falta de pràctica va fer que les aprofités poc (...) Segurament amb la pràctica podrien sorgir preguntes molt interessants que despertessin als infants ganes de saber-ne més."

Preservice teacher C:

"Per altra banda, crec que per fer de mestre guia i ajudar a l'alumnat a evolucionar en les seves idees hauria d'haver fet més preguntes clau i significatives per tal d'orientar a l'alumne i posar èmfasi en els conceptes importants. Tot i així, considero que fer bones preguntes és una tasca complexa que s'ha d'anar adquirint amb l'experiència del dia a dia."

Example 23: (CASE B 1314.04.08 reflection on class intervention)

"Per una banda, en la planificació no pots preveure molts els comentaris que, de manera espontània, fan els infants i això fa que intervingui el factor improvisació mentre guies la teva intervenció. Per tant, durant el taller emfatitzes més algunes idees que, en moments determinats in situ penses que són necessaris de puntualitzar. A més, tampoc pots preveure com són els infants (...). No obstant això, considero que és important partir d'una bona planificació detallada perquè un cop a l'aula les decisions que prens com a guia poden ser més encertades."

"Fent referència a la planificació d'activitats, a part de les dues que vaig dur a terme amb els alumnes, vaig haver d'improvisar altres tasques per reforçar algunes idees, tal com he explicat en la descripció de la intervenció. Això va provocar que hagués de pensar in situ altres maneres perquè els infants comprenguessin les idees que estàvem treballant i no és una tasca gens fàcil quan és la primera vegada que portes a la pràctica un taller de ciències. Així que si hagués de tornar a realitzar aquestes activitats a l'escola amb alumnes que no han tractat el contingut de la llum ni el de les ombres, dissenyaria més bé les tasques que vaig mig improvisar per modificar alguns aspectes dels models inicials que tenen els nens i enfocar les seves idees cap a un model més científic."

Summary of main ideas:

- The description of EC PAS occupies a relative short space in all CASE A and CASE B lesson plans. Through instruction, larger descriptions containing major number of actions can be found.

- In some cases actions within EC PAS are not described but pre-students state the conclusions to which students should arrive.

- Predominant general actions within EC PAS include, in both cases, "data-sharing" actions and "questioning dialogue" actions. Other general actions that can be found in EC PAS are "socratic questionings" and "cross-discussions" actions. In minor proportion, it is possible to find "recapitulation" and (only in CASE A) "fill-in-the blanks questioning" actions.

- "Socratic questionings" and "cross-discussions" actions are always considered ill-posed actions as they are only briefly described not considering scaffoldings; nor addressing appropriate core concepts.

- The relative frequency of main general actions within EC PAS do not always follow, the same tendencies in CASE A and case B lesson plans.

*** ß of "data-sharing" increases over time in both cases.**

*** ß of "questioning dialogue" actions decreases over time although, in CASE A reviewed lesson plans (LP1f), it increases a little bit.**

*** ß of "socratic questionings" increases in both cases, over time.**

*** ß of "cross-discussions" actions tend to increase through instruction in CASE B lesson plans and tend to increase in CASE A lesson plans.**

- Within EC PAS it is only possible to find two specific science-content actions: "elaborating data-evidence" and "referring to data-evidence" actions. ß of these two actions increases through instruction in both cases. However, only CASE B initial lesson plans contain specific science-content actions.

- During classroom intervention, preservice teachers perform more actions in EC plans than planned.

- In reflections performed after classroom interventions, preservice teachers manifested difficulties in guiding discussions to draw conclusions. Most of these difficulties arise after specific students' interventions in relation to well-known common misconceptions. Most of these misconceptions appeared in the initial model evaluation activity but scaffoldings to deal with them were not pre-planned.

- Generally, preservice teachers overcome these difficulties giving direct explanations.

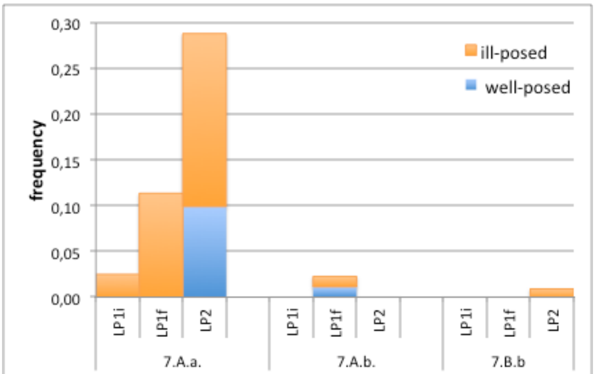
- Preservice teachers' reflections give insight into preservice teachers insecurities' that can be attributed to:

> **a. Weakness of science content knowledge.**
> **b. Lack of specific pedagogical resources.**
> **c. Expecting specific "correct" answers from students (example 18).**

- In final reflection, preservice teachers highlighted the importance of pre-planning scaffoldings as a way to overcome these difficulties.

5.4.8. Planned join activity structure: metacognition PAS.

CASE A **CASE B**



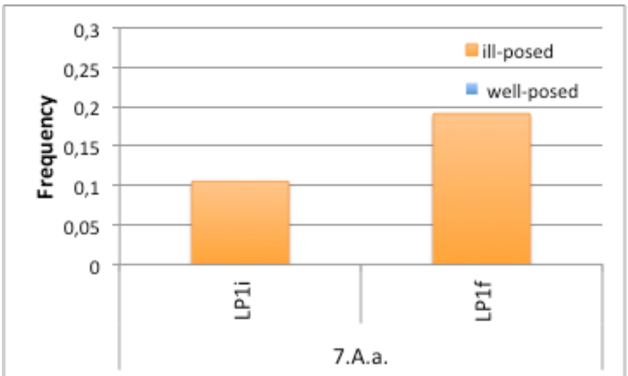


Chart 13. Chart 14. Relative frequency of actions in M PAS. 7.A.a corresponds to "revision of previous models" action category; 7.A.b. corresponds to "Reflecting on models" and 7.B.b. corresponds to "Thinking on the validity of data-evidence" action category (table 20). LP1i corresponds to lesson plans performed before instruction. LP1f corresponds to reviewed lesson plans, performed during the first period of instruction. LP2 corresponds to lesson plans performed during the second period of instruction (figure 14).

As it can be seen in maps of programmed activity segments (figures 18 to 23) and in charts 13 and 14, "metacognition PAS" and actions within them are largely absent. However, M PAS and actions within them, increase through instruction although the relative frequencies of all actions remain always very low.

In general terms, actions within M PAS correspond to "declarative metacognitive knowledge" (table 20-A) referred to models. As it can be seen in examples 1 to 5, these actions are described in a general way and suppose, mainly, the revision of previous models (examples 1, 2 and 3). In one CASE A reviewed lesson plan (LP1f), it is also possible to find actions to reflect on models (7.A.b, example 4). Furthermore, one CASE A lesson plan performed during the second period of instruction contains actions to think on the validity of the procedures used to obtain data (7.B.b action), in this case, a DECV (example 5).

In most cases, actions within M PAS, are considered ill-posed as they do not refer to appropriate ideas, they are generally described, are performed after ill-posed activities, etc. and they do not ensure the achieviement of the desired goal.

Example 1: (CASE A 1112.03.05 i)

"Necessiteu tota la informació que heu recaptat aquest dies, endreceu-la i un consell! Escriviu la vostra hipòtesis en un paper en brut i anoteu totes les vostres idees inicials i a continuació, totes les noves. Així podreu comprovar tot allò que no sabíeu i ara sí! I com el vostre coneixements s'ha transformat!"

Example 2: (CASE A 1213.03.07i)

"*Per acabar la sessió, revisarem els dibuixos fets a la primera sessió i preguntarem als alumnes què modificarien ara que ja sabem més coses sobre l'olfacte. Seguidament, tindran temps per modificar allò que creguin necessari."*

Example 3: (CASE B1213.03.10f)

"Finalment i, amb l'ajuda de totes les conclusions extretes analitzant les dades de l'exercici, es revisarà el model inicial de l'activitat anterior i, es farà un model consensuat amb tota la classe i l'ajuda de la mestra."

Example 4: (CASE A 1213.04.09)

"Després parlarem dels nous models (...), podem fer preguntes com: què han canviat? Perquè ho han canviat? (fent referència a que és molt útil fer experiments com els anteriors per aprendre nous coneixements) Què poden explicar ara que abans, sense fer els DECV, no podien explicar?

"Els hem de recordar, una altra vegada, que quan acabin d'escriure el seu model actual s'han de fer la pregunta: -aquest model serveix per explicar la realitat?-. (És molt bo que ampliïn informació o que la refacin, ja que d'aquesta manera s'adonen (i ens adonem com a mestres) del que han après)"

Example 5: (CASE A 1112.03.05f)

"*Un cop han obtingut tots els resultats i es disposen a fer les conclusions, és el moment oportú per reflexionar sobre el disseny experimental que han portat a terme i, per tant, valorar si allò que han realitzat ha els ha servit per respondre la pregunta investigable, si han pogut obtenir totes les dades necessàries, si ha estat viable, si s'han sentit còmodes realitzant el procés, etc.*"

In lesson plans performed before class intervention, preservice teachers include a M PAS which suppose the revision of previous models and, sometimes, a final recapitulation of the steps performed to gain new knowledge. In "reflection on intervention assignments" preservice teachers rarely reflect on this steps. As explained in the previous section, preservice teachers expose difficulties when guiding discussions to reach conclusions to modify previous models and, occasionally (example 6), explain the revision of models in terms of modification of initial drawings/exercises (performed to explore initial models).

Example 6: (CASE B 1314.04.01 reflection on class intervention)

"A continuació vam agafar els dibuixos que ja tenien a la taula i vam dir-los que els observessin i pensessin si, un cop fet el taller, canviarien alguna cosa. En aquest moment vam dibuixar a la pissarra el dibuix que ells tenien (el nas i la flor) i vam dir que la majoria d'ells havien fet punts o ralles que anaven directes de la flor al nas. Els vam demanar si ara canviarien alguna cosa i alguns van dir que sí. A l'atzar vam escollir un infant i vam dir-li que sortís a la pissarra a representar-ho. Va començar a fer punts que anaven des de la flor cap a totes direccions i vam demanar el per què. Va dir que l'olor de la

flor no només anava al nas de la persona sinó que anava a totes direccions, igual que l'encens. També ens va dir que dibuixava puntets per tal de fer-ho més visible però que ell era conscient que l'olor no es pot veure. Vam demanar als altres alumnes si hi estaven d'acord i van dir tots que sí."

Summary of main ideas:

- "Metacognition PAS" and actions within them are largely absent.

- M PAS increase through instruction although the relative frequencies of all actions within them remain always very low.

- Actions within M PAS are descried in general terms and suppose, mainly, the "revision of previous models". "Actions to reflect on models" and "actions to think on the validity of the procedures used" are also found, respectively, in one reviewed and final CASE A lesson plan.

- In most cases, actions within M PAS, are considered ill-posed.

- "Reflection on class intervention assignments contain few references to M PAS that always correspond to "revision of previous models actions".

6. Discussion

In the previous section, results are presented, addressing each analysis dimensions in turn. Here, findings are discussed in a holistic way, highlighting the overarching themes regarding to the different analysis dimensions and in relation to the research questions (chapter 3) and the theoretical framework (chapter 2). In doing so, we outline which aspects preservice elementary teachers' develop within the framework of specific MCI instructional supports and inform about the challenges they face. Implications of these findings are presented in chapter 7.

6.1. Discussion of results in relation to the first question of research.

The first research question in this study seeks to identify preservice students' common improvements and challenges when learning to design appropriate lesson plans according to MCI and when given specific support regarding these kind of instruction. Furthermore, it seeks to identify which specific instructional supports promote preservice teachers' PCK improvement for MCI.

In reference to this research question and based on data obtained in this research, a coherent picture of preservice teachers' initial PCK and their evolution through instruction is given. Factors that have emerged to be important and have impact on what happens in the analysed lesson plans are also outlined.

In general terms, it is possible to say that results confirm the initial hypothesis posed in chapter 3. As identified by a large variety of authors, when preservice teachers engage for the first time science education courses, they already have certain knowledge, values, beliefs, and attitudes about science, the teaching and learning of science, etc.. that influence the tasks they set, the ideas they reinforce, the questions they pose, etc. practices (Kagran, 1992; Pajares, 1992; Wilkins, 2008). Many of these images, knowledge and beliefs are inherited from earlier school years and tied to years of confirmation (i.e. Mellado, 1998; Albion & Etmer, 2002) while some others, are acquired during previous years of instruction.

As explained in section 4.3.1, the preservice teachers with whom we based this project lack any extensive education in science. However, they engaged in science education courses in their sixth and seventh semester of the Universitat de Vic undergraduate elementary teacher education program. This means that they had been previously introduced to educational foundations and general pedagogical issues in non-subject-specific courses (i.e. the design of lesson plans) and have had initial training experiences in school settings.

Unfortunately, and also in accordance with the literature review, many of these previous experiences (either as students or preservice teachers) did not allow preservice teachers to experience effective, reform-oriented science teaching practices –even less, according to MCI- (e.g., Lotter, 2004; Crawford, 2007; Watters & Diezmann, 2007). Whereby, preservice teachers had no valuable experiences on which to build new knowledge.

Overall, data suggests four main constraints in the design of initial lesson plans:

1. The conception of lesson planning as a formality and a way to have a kit of good activities.
2. The weak science subject matter knowledge.
3. The "inadequacy" of conceptions of science.
4. The unfamiliarity with learners' ideas about science content and how they learn.

As shown in results (chapter 5), preservice teachers put emphasis on writing objectives/competencies, etc. in standardized ways and on describing activities in a general way. The bulk of lesson plans is occupied by "planning of assignments" PAS. Other PAS, like "facilitate the representation of the task" are hardly inexistent. Furthermore, the number of described actions/scaffoldings within each PAS was, in general terms, very low.

One could think that lesson plan descriptions were constrained by the time preservice teachers had to do them. To do initial lesson plans, for example, preservice students only had few class sessions. In contrast, to review them or to do the second lesson plan (CASE A LP2), they had a whole semester. In accordance with this statement, initial lesson plans include less number of sessions than reviewed and lesson plans performed during the second period of instruction.

However, throughout instruction, similar trends are found regarding:

(1) the specific weight of each PAS within lesson plans; and

(2) the lack of scaffoldings/description of actions within PAS,

contributing to think that the importance relies on having a "kit of good activities" rather than anticipating the role of each component of the interactive triangle in a specific join-activity segment.

In accordance with the literature review on preservice teacher education for MCI (section 2.3.), results derived from the analysis of NOS views (section 5.1.), show that, at the beginning of the undergraduate course, most preservice students hold "inadequate" / "incomplete" ideas about science.

Furthermore, specific difficulties in the identification and unpacking of target models (CASE A, section 5.2.) informs (also in accordance with literature review) about preservice teachers' weak science subject matter knowledge (Abell, 2007) as well as the unfamiliarity with learners' ideas about science content and the way students learn. This last issue can also be seen when preservice students suppose situations that would hardly occur in real classroom settings in PAE PAS and when students reflect on classroom interventions.

As a result of these shortcomings, the learning cycles that emerge in CASE A initial lesson plans are far distant from the ideal lesson plan diagram (section 5.3.). As explained below in detail, preservice teachers fail to design lesson plans in accordance to socio-constructivist approaches. Preservice teachers use instructional approaches that involve activity and direct exposition with natural phenomena but that do not use this opportunities to engage students in the active construction of meanings.

Preservice teachers' difficulties in the identification and the unpacking of target models represent a major obstacle for lesson planning. In fact, and as shown in CASE A initial lesson plans, it hinders the selection of appropriate activities and impedes the whole process of planning in accordance with MCI. Besides, it also restricts the performance of reviewed lesson plans since this revision is constrained by the structure of initial lesson plans.

Giving the core ideas to work (CASE B lesson plans) facilitates the selection of appropriate activities and, therefore, enhances the overall quality of lesson plans. However, this does not guarantee the adequacy of lesson plan to MCI. The unsophisticated view of the nature of science and the unfamiliarity with learners' ideas hampers the performance in both, CASE A and CASE B lesson plans.

In general terms, CASE A initial lesson plans can be defined as an "activity set" ("busy work") masqueraded as "academic work". Although these lesson plans often appear masked by a constructivist speech, they are ultimately portrayed from a "positivist perspective": as a subject in which there are clear "right answers" and where data lead uncontroversially to agreed conclusions.

Consequently, and as shown in results (section 5.2.), in these lesson plans, preservice teachers tend to select what they identify as "unequivocal, unquestioned and uncontested facts of science" to be learned and tend to plan "activities that work" in order to, somehow, "deliver" the selected information.

Although student initial knowledge is explored in most cases, it is done in a general and inconsistent way (section 5.4.3.). In fact, activities are planned not based on the possible results of this initial exploration, but on the selected "collection of facts to be taught". Furthermore, as content has to be "delivered as prescrived" lesson plans include many transmissive episodes before or after doing assignmements to ensure this target (PI PAS, section 5.4.4.). Nevertheless, as preservice students have the idea that "transmissive" classes are not desirable, this transmission of content is presented, sometimes, as student's asking questions to experts or students' searching information ("indirect giving information" and "students' searching information" actions, section 5.4.4.).

In general terms, the proposed activities:

a. Do not engage students in scientific procedures; and
b. Limit the opportunities to facilitate students' active engagement in the process of learning.

In a great number of lessons, preservice teachers select assignments as vehicles for covering particular information and/or "motivating" students without considering the authenticity of the assignment.

As shown in section 5.4.6, preservice teachers plan either:

a. Activities to obtain data-evidence;
b. Hands-on activities; or
c. Other kinds of activities.

Although assignmements to obtain data-evidence show that some scientific practices (such as experimentation; forming-testing hypothesis) are somewhat familiar to preservice students most of them are ill-posed, thus informing about the "weakness" of knowledge regarding these practices and how to enhance them within classroom settings.

Furthermore, as activities became a foil for covering information, elaboration-conclusions PAS (section 5.4.7) are, in most cases not described. On the contrary, preservice students state the conclusions to which students should arrive. In other cases, pre-students plan questioning dialogues that seek to evaluate the degree of students' final knowledge or they just state that students would reach conclusions prevailing the idea that conclusions would emerge spontaneously from the assignment. Finally, metaknowledge PAS are hardly inexistent.

Therefore, in most lesson plans, the role of the teacher can be summarized as:

a. Explaining what to do with maximum detail and providing material;
b. Dispense content knowledge directly;
c. Monitoring the performance and results of the assignment.

Albeit in some cases preservice students state that they "would guide students" hardly ever it is possible to find other actions.

Meanwhile, students' role only supposes:

a. Listening and following instructions to perform the required assignment/to acquire knowledge;
b. Answering the required questions to confirm comprehension.

Accordingly, it is possible to conclude that the transfer of responsibility of the learning process is, in these lesson plans, abrupt. The teacher controls what to learn and specifies detailed steps to perform assignments. He holds the control of the learning process. Students are required to perform steps to learn the content assigned to them. However, the teacher does not guide the final step (even when they state so, they do not plan actions to do it): reaching conclusions emerges spontaneously. The responsibility for learning, ultimately, rests solely on the student.

In fewer lesson plans or in some specific sessions within lesson plans, the responsibility of the learning process relies, from the very beginning, only in students. In these sessions, students are required to define what to do to learn the content assigned. The role of the teacher is not defined and scaffoldings are almost non-existent.

Results show that CASE B initial lesson plans are best designed than CASE A initial lesson plans. Giving the core ideas to work (CASE B lesson plans) facilitates the selection of appropriate activities. As shown in sections 5.4.3 and 5.4.6, improvements are held on two main directions:

a. The definition of appropriate actions that aim to explore prior knowledge.
b. The inclusion of a major number of well-posed actions to obtain data-evidence.

Yet, findings also suggest that these improvements only suppose having an initial "kit of good activities". They do not ensure their final adequacy to MCI.

In CASE B preservice students plan, in general terms, actions to explore students' initial models in accordance with the given target model. Furthermore, they plan a greater number of activities to collect data-evidence in relation to the given core ideas. However, and despite the potential of these activities, CASE B initial lesson plans also fail, like in CASE A initial plans, to guarantee real feedbacks between the outcome of data analysis and the initial model.

As in CASE A initial lesson plans, preservice teachers describe steps to perform activities/experiments in great detail (i.e. like "cooking recipes") but do not foresee scaffoldings to reach conclusions from data. Likewise, little space, if any, is provided for meta-reflection and, therefore, the release of control is, once more, abrupt.

When comparing initial lesson plans to those performed at the end of the first period of instruction or during the second period of instruction, there is clear evidence that the undergraduate course had impact on teachers' ideas and abilities. However, outcomes also highlight that common pitfalls last over instruction.

In accordance to the literature review and initial hypothesis, MCI implies a serious reconceptualization of elementary science education (van Driel & Verloop, 2002; Justi & Gilbert, 2002a i b; Windschitl, et.al., 2008b). It represents, in terms of Kuhn, a "paradigm shift" (Kuhn, 2012). For preservice teachers, it supposes a big reconceptualization of their prior ideas on science teaching-learning which, in terms of Vigotsky, fall outside the ZPD.As supported by many authors, preservice initial ideas are very reluctant to change (Kagran, 1992; Pajares; 1992). Furthermore, as it has been broadly demonstrated by studies on conceptual change, shifts will be not abrupt but slowly and gradually produced (Vosniadou, 2007).

Consequently, results demonstrate that, in a relative short period of time (two semesters of instruction), only some things appear to change. In general terms, preservice teachers seem to become persuaded about the interest and importance of MCI as a way to promote scientific literacy. In this sense, findings reveal many attempts to incorporate elements derived from new knowledge acquired during the course that result in a clear increase of actions within all PAS.

However, preservice teachers only seem to have time to successfully incorporate those aspects that fall within their ZPD. To this regard, and as shown in sections 5.4.3. and 5.4.6, students easily incorporate changes related to:

a. Better design elicitation activities of the initial model (i.e. decrease of "brainstorming actions" and increase of well-posed "specific knowledge actions" and "posing a problem/scenario/seatwork actions" through instruction; appearance of "recapitulation" and "analysing actions").
b. An improvement in data/evidence collection (i.e. general increase, through instruction, of assignments to collect data/evidence; decrease of PI PAS; incorporation of actions to organize data/evidence, etc.).

It is important to notice that this enhancement of initial lesson plans is, in most cases, due to the incorporation of instruments given during the undergraduate course, without modifications and using the same guidelines that they have experienced as students in the undergraduate course (i.e. experimental designs, specific instruments to introduce this experimental designs in a classroom setting; incorporation of concept cartoons; instruments to analyse outcomings from students prior knowledge exploration, etc.).

Actions to ensure feedback to initial model and metaknowledge aspects seem to be most difficult to incorporate and, when incorporated, it seems not to be in a really consistent way. The introduction of a learning cycle does not seem to help to ensure these feedbacks as:

a. Preservice teachers tend to assimilate activities "to structure knowledge" and "to apply knowledge" to "hands-on" and/or "non-hands on" assignments.

b. Preservice teachers continue describing EC PAS and M PAS in general terms, without incorporating specific actions that ensure meaningful construction of knowledge, thus, giving to understand that conclusions/valid arguments would come naturally from data.

In another sense, although actions to formulate hypothesis increase, they are still ill-posed, as they suppose making a guess.

Overall and returning to our argument, these findings may suggest that, throughout a short period of instruction on MCI, preservice students may only configure what, in terms of Vosniadou could be considered as a "synthetic model" of what MCI is (Vosniadou, 2007). However, these preservice partial understandings, while can successfully engage students in some kind of "scholar science practice", they fail to provide real opportunities of authentic MCI practices.

One of the most significant impediment to progress in this direction seems to be the lack of teacher's pedagogical skills in scaffolding argumentative/metacognitive discourses within the classroom. Our observations show that, although preservice teachers contemplate these sorts of discourses (thus, recognizing their importance), they did not plan actions to perform them. To our understanding, this may suggest that they did not have the necessary skills to effectively organize group and class discussions.

"Reflections on classroom intervention" assignments reinforce these ideas giving insight in the fragility of the acquired knowledge and the force of the above outlined common pitfalls. In this sense:

a. Examples in section 5.4.3, for example, illustrate performaces and shortcomings and/or misconceptions resulting from this gradual conceptual change.
b. Examples in section 5.4.7 show that many preservice teachers had difficulties in guiding the above mentioned argumentative discourses to draw conclusions and revise initial knowledge.

Moreover, examples in sections 5.4.7. illustrate how unsettled knowledge on MCI implies, when difficulties appear, to return to the safety of the old assumptions and habits (i.e. giving direct information to students).

6.2. Discussion of results in relation to the second question of research.

The answer to the second question of research ("is it possible to identify initial predictors of success/difficulties for preservice teacher knowledge application?", chapter 3) is not as clear as the first one.

As explained below in detail, in general terms, findings show relative homogeneity in knowledge and abilities among all initial lesson plans. Therefore, obtained data appears to be non-informative when trying to identify initial predictors of success/difficulties for preservice teacher knowledge application. Even so, results also suggest possible correlations between students' peformances and prior knowledge and beliefs about science teaching and teaching-learning process, in general. However, to set clear conclusions, further specific analysis would be required.

As explained in chapter 4, different data allows characterizing the "starting point" of preservice teachers:

c. Their initial ability to identify and unpack target models.
d. Their initial knowledge/ideas/understandings/performance on NOS.
e. The learning cycle that emerges from initial lesson plans.
f. The detailed description of initial lesson plans.

Findings regarding these data show similar initial abilities in all cases.

The identification and the unpacking of target models appears to be the most limiting constraint as it directly implies the selection of activities regarding unsuitable goals, thus impeding the whole process of learning. Once the core ideas are given to undergraduate students, it appears that all of them are capable to select appropriate activities (results section 5.2, discussion section 9.1).

Furthermore, all students appear to have weak understandings on NOS as well as a lack of prior science instruction, thus showing similar prior knowledge and abilities in all cases. Due to these similarities, it is impossible to attribute final performances to initial differences on NOS.

Looking at the results obtained from the analysis of activities sequencing (section 5.3.) and relating them to other findings, it could seem that those preservice teachers whom initial lesson plans were more distant to the ideal model evolve more slowly than those closer to the ideal model. In this sense, results show that manipulative-transmisive initial lesson plans, do not evolve when reviewed.

However, the identification of common pitfalls in the acquisition of PCK regarding MCI (see section 9.1) suggests that, in our case, differences in performance may rely, mostly, in prior knowledge and beliefs about science teaching and teaching-learning process in general. Although this conclusion emerges from data obtained from the analysis on planned join activity structure, this research did not foresee any specific instrument of analysis regarding these factors and, therefore, it is not possible to establish conclusions.

As suggested in chapter 8, further in-depth research to investigate the relationship between preservice teachers' epistemic beliefs and prior knowledge, and their influence in performance in MCI, would be useful to add detail in the identification of these initial predictors.

7. Implications and directions of further research

Chapter 6 offers a general and structured discussion of results regarding research questions and hypotesis and in relation to the theoretical framework. This chapter extends this discussion a little further highlightig the implications of this results and suggesting directions of further research.

7.1. Implications

Results from this study have important implications for both research on science teacher education and the preparation of elementary science teachers. These implications are presented and discussed below.

One major implication of this work is the need to bring together discourses and practices from different disciplines in order to enhance effectiveness on both: research on science teacher education and the preparation of elementary science teachers.

The dominant university structure continues to emphasize professor autonomy. The endurance of this pattern hinders, frequently, attempts to create collaborative environments among professionals of different disciplines. As it has been explained, this research has been undertaken under a clear interdisciplinary approach, unifying discourses from teaching of science disciplines (science pedagogy) and learning psychology. The richness and depth of the results demonstrate the interest of promoting this type of collaboration not only for research, but also for the design of coordinated undergraduate courses.

In a different way but still related to the above statements, findings of this work suggest that the understanding and development of skills for classroom management expertise regarding MCI practices is likely to be a slow, staged process. Therefore, it is necessary to think on long term teacher education programs that not only prepare beginning teachers but also support them as novice teachers.

As mentioned, these teacher education programs should adopt unified approaches integrating generic pedagogy practices into science-subject-matter pedagogy, thereby recovering elements from other disciplines (i.e. classroom management practices; scaffoldings…) within the perspective of the field.

More specifically, major findings of this research also have direct implications for future versions of teachers' education programs based on MCI. In this study, we have seen valuable developments in preservice elementary teachers' PCK for scientific modeling. It has been demonstrated that, through instruction, preservice elementary teachers acquire major awareness of why and how translate knowledge on MCI in lesson plans. Through instruction, preservice teachers gain knowledge and successfully incorporate some aspects of scientific modeling.

Overall, these results suggest the importance to:

- Continue engaging preservice teachers in MCI.

- Extend the opportunities to put into practice instruction in real classroom situations and under the guidance of mentors.
- Promoting reflection as a way to support undergraduate students in integrating their MCI experiences into a personal schema for science teaching.

However, and despite these successes, findings also highlight some significant challenges regarding, mainly, to preservice teachers' ability to effectively and efficiently design scaffoldings to promote model revision –in coherence with data/evidence-; and to promote/incorporate metamodeling practices, in general. Based on specific results and in order to overcome these common pitfalls, different instructional refinements can be suggested.

Results from this research show that one of the main constraints preservice teachers face is the identification of target models. As discussed, this limitation hinders the whole process of planning in accordance with MCI. Therefore, it seems important:

- that preservice teachers have at their disposal repertories of disciplinary core ideas organized as learning progressions;
- to help teachers to reconstruct ideas presented in the curriculum or in textbooks into "science big ideas".

Furthermore, it is also imperative to reinforce, within MCI courses: knowledge of child development (i.e. common expected intuitive/intermediate models), learning process, and subject-specific pedagogy. In this sense, undergraduate courses should:

- Incorporate explicit examples of high-quality science instruction: using videotapes; case studies, etc. which provide preservice teachers rich, contextualized descriptions of classroom complexities and expert teachers' performances.

- Incorporate/extend the repertoire of specific instruments to help teachers imagine certain kinds of student performance and to assess students' thinking (i.e. using real examples of students' assessments of intuitive ideas).

- Incorporate/extend the availability of tools to support teachers in developing complex communication skills and instructional strategies (i.e. helping them to pose good questions; engaging students in argumentation; press students for evidence-based explanations, etc.) which, as shown in results do not seem intuitive for preservice students (even when they understand they have to do them).

Finally, but not less important, findings of the presented research also suggest the importance of understanding lesson planning as a way to anticipate possible classroom difficulties before classroom intervention. In this sense, emphasis should be put not only on formalisms inherent to lesson plans but also on helping preservice students to imagine their role in each situation and plan specific actions/scaffoldings regarding them.

7.2. Directions for future research

Findings of this research open several areas worth to justify for additional inquiry. One area for further exploration concerns the analysis, in finer detail, of the relationship between preservice teachers' epistemic beliefs and prior knowledge and their influence in performance in MCI. As explained, this study examined preservice teachers' NOS knowledge in a general way. However, more detailed analysis of preservice teachers' epistemic beliefs and prior knowledge on science, model and modeling practices, learning-teaching science; etc. would give rich information regarding possible initial constraints and ways to overcome them. Do they constitute limiting factors? In which sense and to which degree do they constraint preservice teachers' instructional approaches, ideas about, and confidence, for teaching in accordance to MCI?

Future research also could examine the role of specific scaffoldings (i.e. videotapes, case studies…) in helping preservice teachers to foresee join-activity and acquire classroom management tools. Which scaffoldings help? How should be used in undergraduate courses? What is the role of teacher educators when using them?

Another potential line of research concerns to the transition from university courses to first years of instruction. How do we ensure support and further learning during the first years of instruction?

These are but few examples of research questions that might reasonably be asked on the basis of this study's outcomes. The possibilities for research in this area are numerous, and will hopefully lead to improvements in the effective preparation elementary science teachers.

8. Limitations of the study

This study examines the role of an elementary science teachers' undergraduate course in helping preservice teachers to move towards (an plan according) to MCI approaches. Findings and discussions presented in previous chapters (chapters 5 and 6) demonstrate the potential that have the selected strategy, the empirical approach and the analytical instruments, in order to provide new insights into preservice elementary teachers' development of PKC regarding MCI practices. However, as in any study, decisions related to the design and execution of the research involve trade-offs that suppose specific limitations and shortcomings of the used approach. Accordingly, this section highlights limitations of this research suggesting ways in which future studies could improve the approach stated here.

This study is performed under a general inductive framework using a case study methodology enriched with quantitative results. As explained in chapter 4 and, specifically, in section 4.5.3., different strategies have been used to ensure rigor of analysis. However, results are, ultimately, unique to the cases under study and therefore, this study suffers from the lack of generalizability inherent to a case study research design. Future work examining a greater number of experiences would provide a broader empirical basis for theories of teacher learning and development.

A second limitation of this study is due to the novelty of the analytical instruments. Overall, these tools appear to be consistent with the theoretical framework and ensure deep, rich, and highly internally-consistent data. However, these instruments are susceptible to an improvement. Further clarifying of the units of analysis, categories, subcategories and operational criteria would improve these instruments and make them more consistent for their use in other cases.

Finally, improvements could also be implemented in the collection of data during class intervention. In this sense, videotaping classroom interventions would suppose a greater improvement in the quality and richness of data obtained from these interventions.

9. Conclusions

The two main questions proposed in chapter 3 guided the research presented here. Based on results presented in chapter 5, chapter 6 discusses our tentative answer to these questions and chapter 7 presents implications of these findings and how they generate new questions to be solved in further research. Now we expose in a nutshell, major contributions of this work.

The approximation to the research questions has been performed through an interdisciplinary approach, unifying discourses from teaching of science disciplines (science pedagogy) and learning psychology. Moreover, and as explained in chapter 4, this study has been performed under a general inductive framework, using a case study methodology enriched with quantitative results.

To meet requirements of this methodological framework, new analytical instruments have been created (chapter 4). These instruments can be considered, per se, a first contribution of this study as they have been proved to be a suitable formal apparatus to understand how preservice students conceive join-activity within a lesson plan.

Furthermore, this research contributes to the literature about preservice teachers and scientific modeling practices in ways that are consistent with others' findings. In accordance with other previous studies (Schwarz & White, 2005; Windschitl et al., 2008, Nelson & Davis, 2012) it is possible to conclude that:

a. Initial preservice elementary teachers' knowledge about MCI is weak at best.

b. Some aspects within MCI appear to be inconsistent with existing beliefs or presuppositions about learning of most preservice teachers. In terms of Vigotsky, these aspects fall outside the ZPD (Vygostky, 1978) and, therefore, require a great conceptual change for most of them.

c. Engagement in MCI practices during teacher education courses support preservice teacher learning about MCI.

However, this study also provides new elements for a deeper understanding of the key points to contribute to a drift from a classical teaching model of verbal transmission or a "hands-on" approach to MCI and it also highlights major constraints to meet requirements for this science education framework. In this sense, major conclusions from this work can be summarized as:

a. Preservice teachers easily recognize the importance of engaging children with elements of MCI.

b. Preservice teachres easily incorporate/enhance those aspects which seem to fall into their ZPD (Vygostky, 1978):
   - Understanding the relevance of mental model elicitation as the starting point of the knowledge generation process, thus incorporating adequate strategies into their lesson plans.

   - Enhancing the process of data collection through the use of standardized methods (i.e. experimental designs).

c. When undergraduate students enhance their initial lesson plans, they tend to use the instruments given by the professor during the undergraduate course without further elaboration.

d. The strongest constraints for the adequate acquisition of MCI appear to be:
   - The difficulty to identify adequate target models based on science core ideas that hinders the whole process of planning in accordance with MCI.
   - The absence of real feedback between the outcome of data analysis and the initial model as a consequence of preservice teachers inability to plan adequate scaffoldings to guide real classroom discussions.

Finally, as a result of these findings, this dissertation contributes to the improvement of future versions of teachers' education programs based on MCI. Overall, these results suggest the importance to:

a. Continue engaging preservice teachers in MCI.
b. Extend the opportunities to put into practice instruction in real classroom situations and under the guidance of mentors.
c. Promoting reflection as a way to support undergraduate students in integrating their MCI experiences into a personal schema for science teaching.
d. Promoting interdisciplinary approaches in the design of undergraduate courses.
e. Facilitate the disposal repertories of disciplinary core ideas organized as learning progressions and/or tools to help teachers to reconstruct ideas presented in the curriculum or in textbooks to big ideas.
f. Incorporate and/or reinforce, within MCI courses specific knowledge on:
   - child development (i.e. common expected intuitive/intermediate models);
   - learning process; and
   - subject-specific pedagogy (i.e. specific ways to scaffold the construction of arguments regarding obtained data; posing questions, etc.).

10. References

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, *82*(4), 417-436.

Abell, S. K. (2007). Research on science teacher knowledge. *Handbook of research on science education*, 1105-1149.

Acher, A. et al. (2007). Modeling as a teaching learning process for understanding materials: A case study in primary education. *Science Education*, 91(3), 398–418.

Albion, P. R., & Ertmer, P. A. (2002). Beyond the foundations: The role of vision and belief in teachers' preparation for integration of technology. *TechTrends*, *46*(5), 34-38.

Anderson, R. D., & Mitchener, C. P. (1994). Research on science teacher education. *Handbook of research on science teaching and learning*, 3-44.

Appleton, K. (Ed.). (2006). *Elementary science teacher education: International perspectives on contemporary issues and practice*. Mahwah, NJ: Lawrence Erlbaum Associates.

Adúriz-Bravo, A. (2009). Hacia un consenso metateórico en torno a la noción de modelo con valor para la educación científica. *Enseñanza de las Ciencias*, Número Extra. VIII Congreso Internacional sobre Investigación en Didáctica de las Ciencias, Barcelona. pp. 2616-2620.

Ausubel, D., et al. (1983). Psicología educativa. Un punto de vista cognoscitivo. México. Editorial Trillas.

Bartholomew, H., et al. (2004). Teaching students "ideas‐about‐science": Five dimensions of effective practice. *Science Education*, *88*(5), 655-682.

Bell, R. L., et al. (2000). Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of research in science teaching*, *37*(6), 563-581.

Berliner, D. (2002). Educational Research: The hardest science of all. *Educational Researcher, 31 (8),* 18-20.

BOE (2006) Real Decreto 1513/2006, de 7 de diciembre, por el que se establecen las enseñanzas mínimas de la Educación Primaria.

Bruner, J. (1986). *Actual Minds, Possible Worlds.* Cambridge, MA: Harvard University Press.

Bruner, J., et. al. (1956). *A Study of Thinking*. New York: NY Science Editions.

Bybee, R. W. et al. (2006). The BSCS 5E instructional model: Origins, effectiveness, and applications, Colorado Springs: BSCS.

Carey, S. (1999). Sources of conceptual change. In Scholnick, E.K., et. al. (Eds.), *Conceptual development: Piaget's legacy* (pp. 293-326). Mahwah, NJ: Lawrence Erlbaum Associates.

Carey, S. (1991). Knowledge acquisition: Enrichment or conceptual change? In S. Carey & R. Gelman (Eds.), *The epigenesis of mind* (pp. 257-291). Hillsdale, NJ: Lawrence Erlbaum Associates.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.

Carruthers, et al. (2002). *The cognitive basis of science*. Cambridge University Press.

Charpak, et al. (2006). *Los niños y la ciencia: la aventura de "Las manos en la masa".* Buenos Aires, Siglo XXI. Editores Argentina.

Chi, M. T., & Slotta, J. D. (1993). *The ontological coherence of intuitive physics*. Cognition and Instruction, 10(2 & 3), 249-260.

Chi, M. T. (1992). Conceptual change within and across ontological categories: Examples from learning and discovery in science. In R. N. Giere (Ed.), *Cognitive models of science:* Vol. 15. Minnesota studies in the philosophy of science (pp. 129-186) Minneapolis, MN: University of Minesota Press.

Chi, M. T., et al. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive science*, *5*(2), 121-152.

Chin, C. (2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of research in Science Teaching*, *44*(6), 815-843.

Chinn, C.A. & Malhotra, B. (2002). Epistemologically authentic inquiry in schools: a theoretical framework for evaluating inquiry tasks. *Science Education,* 86(2), 175-218.

Clement, J. (2003). Imagistic simulation in scientific model construction. In *Proceedings of the twenty-fifth annual conference of the cognitive science society* (Vol. 25, pp. 258-263). Mahwah, NJ, Erlbaum.

Clement, J., & Steinberg, M. S. (2002). Step-Wise Evolution of Mental Models of Electric C ircuits: A" Learning-Aloud" Case Study. *The Journal of the Learning Sciences*, *11*(4), 389-452.

Clement, J. (2000). Model based learning as a key research area for science education. *International Journal of Science Education*, *22*(9), 1041-1053.

Clement, J. (1998). Expert novice similarities and instruction using analogies. International Journal of Science Education, 20 (10), 1271-1286.

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of research in science teaching*, *30*(10), 1241-1257.

Clement, J. (1989). Learning via model construction and criticism: Protocol evidence on sources of creativity in science. Glover, J., Ronning, R., and Reynolds, C. (Eds.) Handbook of creativity: Assessment, theory and research. NY: Plenum, 341-381.

Clement, J. (1988). Observed methods for generating analogies in scientific problem solving. Cognitive Science, 12: 563-586.

Coll, C. (2001). Constructivismo y educación: la concepción constructivista de la enseñanza y el aprendizaje. En C. Coll; J. Palacios i A. Marchesi, *Desarrollo Psicológico y educación, 2. Psicología de la Educación* (157-186). Madrid: Alianza Psicología.

Coll, C. (1997). La construcció del coneixement a l'escola: cap a l'elaboració d'un marc global de referència per a l'educació escolar. En C. Coll (coord.), *Psicologia de la Instrucció* (425-503). Barcelona: EDIUOC.

Coll, C. & Onrubia, J. (1999). Evaluación de los aprendizajes y atención a la diversidad. En C. Coll (Coord.), *Psicología de la instrucción: la enseñanza y el aprendizaje en la educación secundaria* (141-168). Barcelona: ICE-Horsori.

Coll, C., et al. (1995). Actividad conjunta y habla: una aproximación al estudio de los mecanismos de influencia educativa. In Fernández Berrocal & Melero (comp.), *La interacción social en contextos educativos* (193-326). Madrid: Siglo XXI.

Coll & Edwards, (Eds.) (1997) Teaching*,* learning and classroom discourse*. Approaches to the study of educational* discourse*.* Madrid*:* Fundación Infancia y Aprendizaje.

Colomina, R. & Onrubia, J. (2001). Interacción educativa y aprendizaje escolar: la interacción entre alumnos. In C. Coll; J. Palacios & A. Marchesi, *Desarrollo Psicológico y educación, 2. Psicología de la Educación* (415-435). Madrid: Alianza Psicología.

Colomina, R., et al. (2001). Interactividad, mecanismos de influencia educativa y construcción del conocimiento en el aula. In Coll c., et al. *Desarrollo Psicológico y educación, 2. Psicología de la Educación* (437-458). Madrid: Alianza Psicología.

Cotterman, M. (2009). *The Development of Preservice Elementary Teachers' Pedagogical Content Knowledge for Scientific Modeling*. (Doctoral Dissertation). Wright State University.

Couso, D., et al. (2009). Las propiedades acústicas de los materials: Una propuesta didáctica de modelización e indagación sobre Ciencia de Materiales. *Alambique. Didáctica de las Ciencias Experimentales*, *59*, pp. 66-78.

Craik, K. (1943). *The nature of explanation.* Cambridge: Cambridge University Pess.

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of research in science teaching*, *44*(4), 613-642.

Denzin, N.K. (1970). *The research act: A theoretical introduction to sociological methods*. Chicago: Aldine.

diSessa, A. A. (1988). Knowledge in pieces. In G. Forman & P. B. Pufall (Eds.), Constructivism in the computer age (pp. 49–70). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

diSessa, A. A. (1993). Toward an epistemology of physics. Cognition and Instruction, 10(2 & 3), 105-225.

DOGC (2015) Decret 119/2015, pel qual s'estableix l'ordenació dels ensenyaments de l'educació primària.

Driver, R., et al. (1996). *Young people's images of science*. Buckingham: Open University Press.

Driver, R., et al. (1994). Constructing scientific knowledge in the classroom. *Educational researcher*, *23*(7), 5-12.

Duschl, et al. (Eds). (2007). *Taking science to school: Learning and teaching science in grades K-8.* Washington, DC: National Academies Press.

Duschl, R. & Wright, E. (1989). A case study of high school teachers' decision making models for planning and teaching science. *Journal of research in science teaching*, *26*(6), 467-501.

Edwards, D. & Mercer, N. (1988). *El conocimiento compartido. El desarrollo de la comprensión en el aula.* Barcelona: Paidós/MEC.

Eisenkraft, A. (2003). Expanding the 5E model. *Science Teacher*, 70 (6), 56-59.

Erduran, S. (1998) *Modeling in chemistry as cultural practice: a theoretical framework with implications for chemistry education*. Paper presented at the Annual Meeting of the American Educational Research Association (San Diego, CA).

Esterberg, K. G. (2002). *Qualitative methods in social research* (No. 300.18 E8). Boston: McGraw-Hill.

Ford, M. J., & Wargo, B. M. (2007). Routines, roles, and responsibilities for aligning scientific and classroom practices. *Science Education,* 91(1), 133-157.

Gentner, D. & Stevens, A. L. (Eds.), (1983). *Mental models.* Hillsdale, NJ: Erlbaum.

Giere, R. N. (2004). How models are used to represent reality. *Philosophy of science*. 71, 742-752.

Giere, R. N. (1999). Using models to represent reality. In Magnani, L., Nersessian, N., & Thagard, P. (Eds.). *Model-based reasoning in scientific discovery*. (pp. 41-57). Springer Science & Business Media.

Giere, R. (1993). *Cognitive Models of Science*. Minneapolis, MN: University of Minnesota Press.

Giere, R. N. (1988). *Explaining science: A cognitive approach*. University of Chicago Press.

Gilbert, J., et. al. (2000). Positioning models in science education and in design and technology education. In J.K. Gilbert, & C. J. Boulter (Eds.), *Developing models in science education* (pp. 3-17). The Netherlands: Kluwer Academic Publishers.

Gilbert, J. & Boulter, C.J. (1998c). Learning science through models and modeling. In B.J. Fraser, & K.G. Tobin (Eds), *International Handbook of Science Education* (pp.53-66). Dordrecht: Kluwer Academic Publishers.

Gilbert, J., et al. (1998a). Models in explanations, Part 1: Horses for courses?. *International Journal of Science Education*, *20*(1), 83-97.

Gilbert, J., et al. (1998b). Models in explanations, Part 2: Whose voice? Whose ears?. *International Journal of Science Education*, *20*(2), 187-203.

Gilbert, J. K. & Boulter, C. (1993). Models and modeling in science education. *Association of Science Education, Hatfield, UK*.

Glynn, S. M. (1991). Explaining science concepts: A teaching-with-analogies model. *The psychology of learning science*, 219-240.

Goetz, J. P. & LeCompte, M. D. (1984). *Ethnography and qualitative design in educational research* (Vol. 19). Orlando, FL: Academic Press.

Gomez-Zwiep, S. (2008). Elementary teachers' understanding of students' science misconceptions: Implications for practice and teacher education. *Journal of Science Teacher Education*, *19*(5), 437-454.

Grosslight, L., et al. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. *Journal of Research in Science teaching*, *28*(9), 799-822.

Guba, E. G. & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Newbury Park, CA: Sage.

Guba, E. G. & Lincoln, Y. S. (1982). Epistemological and methodological bases of naturalistic inquiry. *Educational Communication and Technology Journal,* 30 (4), 233-252.

Guba, E. G. & Lincoln, Y. S. (1981). *Effective evaluation: Improving the usefulness of evaluation results through responsive and naturalistic approaches*. San Francisco, CA: Jossey-Bass.

Haefner, L.A. & Zembal-Saul, C. (2004). Learning by doing? Prospective elementary teachers' developing understandings of scientific inquiry and science teaching and learning. *International Journal of Science Education*, 26(13), 1653-1674.

Harlen, W. (1998). *Enseñanza y aprendizaje de las ciencias*. Madrid: Morata.

Harrison, A. & Treagust, D. (2000). A typology of school science models. *International Journal of Science Education*, 22(9), 1011- 1026. 4- 31.

Inhelder, B. & Piaget, J. (1958). *The growth of logical thinking from childhood to adolescence: An essay on the construction of formal operational structures* (Vol. 22). Psychology Press.

Izquierdo et al. (1999). Caracterización y fundamentación de la ciencia escolar. *Enseñanza de las Ciencias*, número extra, 79-91.

Johnson-Laird, P. N. & Byrne R.M.J. (1991). *Deduction*. Hillsdale, NJ: Erlbaum.

Johnson-Laird, P. N. (1983). *Mental models*. Cambridge, MA: Harvard University Press.

Johnson-Laird, P.N. (1980). Mental Models in Cognitive Science. *Cognitive Science,* 4, 71-115.

Justi, R. & van Driel, J. (2006). The use of the interconnected model of teacher professional growth for understanding the development of science teachers' knowledge on models and modelling. *Teaching and Teacher Education*, *22*(4), 437-450.

Justi, R. & Van Driel, J. (2005). The development of science teachers' knowledge on models and modelling: promoting, characterizing, and understanding the process. *International Journal of Science Education*, *27*(5), 549-573.

Justi, R. & Gilbert, J.K. (2002a). Modelling, teachers' views on the nature of modelling, implications for the education of modellers, *International Journal of Science Education*, 24(4), 369-387. 894. 4- 31.

Justi, R. & Gilbert, J.K. (2002b). Science teachers' knowledge about attitudes towards the use of models and modeling in learning science. *International Journal of Science Education* 24(12), 1273-1292.

Kagan, D. M. (1992). Implications of research on teacher beliefs. Educational Psychologist, 27(1), 65-90.

Kenyon, L., et al. (2011). Design Approaches to Support Preservice Teachers in Scientific Modeling. *Journal of Science Teacher Education* 22:1–21.

Kenyon, L., et al. (2008). The benefits of scientific modeling: Constructing, using, evaluating, and revising scientific models helps students advance their scientific ideas, learn to think critically, and understand the nature of science. Science and Children, 46(2), 40–44.

Kuhn, T. S. (2012). *The structure of scientific revolutions*. University of Chicago press.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of research in science teaching*, *36*(8), 916-929.

Lehrer, R. & Schauble, L. (2010). What Kind of Explanation is a Model?. In *Instructional explanations in the disciplines* (pp. 9-22). Springer US.

Lehrer, R. & Schauble, L. (2000). Developing model-based reasoning in mathematics and science. *Journal of Applied Developmental Psychology*, *21*(1), 39-48.

Lemke, J. (1997). *Aprender a hablar ciencia. Lenguaje, aprendizaje, valores*. Barcelona, Paidós Iberica.

Lincoln, Y.S. & Guba, E.G. (2000). Paradigmatic controversies, contradictions, and emerging confluences. In N.K. Denzin & Y.S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., 163-188). Thousand Oaks, CA: Sage.

Linnenbrink, E. A. & Pintrich, P. R. (2002). The role of motivational beliefs in conceptual change. In Limón, M. & Mason, L. (Eds.) *Reconsidering conceptual change: Issues in theory and practice* (pp. 115-135). Dordecht, The Netherlands: Kluwer Academic Press.

Lotter, C. (2004). Preservice Science Teachers' Concerns through Classroom Observations and Student Teaching: Special Focus on Inquiry Teaching. *Science Educator*, *13*(1), 29-38.

Magnusson, S. et al. (1999). Nature, sources and development of pedagogical content knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95-132). Dordrecht, The Netherlands: Kluwer Academic Press.

Mason, L. (2007). Introduction: Bridging the cognitive and sociocultural approaches to research on conceptual change: Is it Feasible? [Special Issue] Educational Psychologist, 42(1), 1-7.

Mauri, T. & Rochera, M.J. (1997). Aprender a regular el propio aprendizaje. *Aula de Innovación Educativa, 67,* 48-52.

Mellado, V. (1998). The classroom practice of preservice teachers and their conceptions of teaching and learning science. Science Education, 82, 197-214.

Mercer, N. (2001). *Palabras y mentes.* Barcelona: Paidós.

Mercer, N. (1997). Language, education and the guided construction of knowledge. Anais do Encontro sobre Teoria e Pesquisa em Ensino de Ciências/Linguagem, cultura e cognição: reflexões para o ensino de ciências, Faculdade de Educação, UFMG, 46-68

Metz, K.E. (2004). Children' understanding of scientific inquiry: their conceptualization of uncertainty in investigations of their own design. *Cognition and Instruction*, 22(2), 219-290.

Nelson, M. & Davis, E. (2012). Preservice Elementary Teachers' Evaluations of Elementary Students' Scientific Models: An aspect of pedagogical content knowledge for scientific modeling, International. *Journal of Science Education, 34(12)*, 1931-1959.

Nersessian, N. (2008). *Creating scientific concepts*. MIT press.

Nersessian, N. J. (2006). The cognitive-cultural systems of the research laboratory. *Organization Studies*, *27*(1), 125-145.

Nersessian, N. J. (2002). The cognitive basis of model-based reasoning in science. In Carruthers, P., Stich, S., & Siegal, M. (Eds.). (2002). *The cognitive basis of science* (133-153). Cambridge University Press.

Nersessian, N. J. (1999). Model-based reasoning in conceptual change. In *Model-based reasoning in scientific discovery* (pp. 5-22). Springer US.

Nersessian, N. J. (1995). Should physicists preach what they practice?. *Science & Education*, *4*(3), 203-226.

Nersessian, N. J. (1992a). In the theoretician's laboratory: Thought experimenting as mental modeling. In *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association* (pp. 291-301). Philosophy of Science Association.

Nersessian, N. J. (1992b). How do scientists think? Capturing the dynamics of conceptual change in science. *Cognitive models of science*, *15*, 3-44.

Newell, A., & Simon, H. A. (1972). *Human Problem Solving*. Oxford, England: Prentice-Hall.

NGSS Lead States (2013). *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

Onrubia, J. (1996). La escuela como contexto de aprendizaje y desarrollo. En A. Barca i otros (eds.), *Psicología de la Instrucción. Vol. 3. Componentes contextuales y relacionales del aprendizaje escolar*. Barcelona: Ediciones de la UB.

Onrubia, J. (1993). La atención a la diversidad en la Enseñanza Secundaria Obligatoria: algunas reflexiones y criterios psicopedagógicos. *Aula*, *12,* 45- 49.

Onwuegbuzie, A. J. (2002). Positivists, post-positivists, post-structuralists, and post-modernists: Why can't we all get along? Towards a framework for unifying research paradigms. Education, 122, 518–530.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. London: The Nuffield Foundation.

Otero, V. K. & Nathan, M. J. (2008). Preservice elementary teachers' views of their students' prior knowledge of science. *Journal of Research in Science Teaching*, *45*(4), 497-523.

Özdemir, G. & Clark, D. B. (2007). An overview of conceptual change theories. *Eurasia Journal of Mathematics, Science & Technology Education*, *3*(4), 351-361.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. Review of Educational Research, 62, 307-332.

Piaget, J. (1958). The growth of logical thinking from childhood to adolescence. *AMC, 10,* 12.

Pintrich, P.R. (2000). Educational Psychology at the Millennium: A Look Back and a Look Forward. *Educational Psychologist, 35 (4),* 221-226.

Pintrich, et al. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational research*, *63*(2), 167-199.

Posner, G. J., et. al. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science education*, *66*(2), 211-227.

Pozo, J. I. (1999). Más allá del cambio conceptual: el aprendizaje de la ciencia como cambio representacional. *Enseñanza de las Ciencias*, *17(3)*, 513-520.

Pujol, R.M. (2003). *Didáctica de las ciencias en la educación primaria.* Madrid: Síntesis.

Quecedo, R. & Castaño, C. (2002). Introducción a la metodología de investigación cualitativa. *Revista de psicodidáctica*, *14*, 1-27.

Ramsey, J. (1993). Developing conceptual storylines with the learning cycle. *Journal of Elementary Science Education*, 5(2), 1-20.

Rea-Ramirez, M. A., et al. (2008). An instructional model derived from model construction and criticism theory. In *Model based learning and instruction in science* (pp. 23-43). Springer Netherlands.

Rea-Ramirez, M. A. (2008). Determining target models and effective learning pathways for developing understanding of biological topics. In *Model based learning and instruction in science* (pp. 45-58). Springer Netherlands.

Rea-Ramirez, M. A. (1998). Model of conceptual understanding in human respiration and strategies for instruction (Doctoral Dissertation). DAI – 9909208, *Universty of Massachusetts, Amherst.*

Rea-Ramirez, M. A. & Clement, J. (1998). In Search of Dissonance: The Evolution of Dissonance in Conceptual Change Theory.

Rocard, et al. (2007). Science Education NOW: A Renewed Pedagogy for the Future of Europe. European Commission EUR22845.

Rochera, M., et al. (1999). Organización social del aula, formas de interactividad y mecanismos de influencia educativa. *Investigación en la Escuela*, (39), 49-62.

Salvador, C. C., et al. (2008). Ayudar a aprender en contextos educativos: el ejercicio de la influencia educativa y el análisis de la enseñanza. *Revista de educación*, (346), 33-70.

Schauble, L., et al. (1991). Causal models and experimentation strategies in scientific reasoning. *The Journal of the Learning Sciences*, *1*(2), 201-238.

Schulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4- 31.

Schwarz, C. (2009). Developing preservice elementary teachers' knowledge and practices through modeling-centred scientific inquiry. *Science Education*, 93(4), 720–744.

Schwarz, C. et al. (2009). Developing a learning Progression for scientific modeling: making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching,* 46(6), 632-654.

Schwarz, C. & White, Y. (2005). Metamodeling knowledge: Developing students' understanding of scientific modeling. *Cognition and instruction*, *23*(2), 165-205.

Schwartz, R. S., et al. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science education*, *88*(4), 610-645.

Scott, P. H. (1992). Pathways in learning science: A case study of the development of one student's ideas relating to the structure of matter. *Research in physics learning: Theoretical issues and empirical studies*, 203-224.

Seel, N. M. (2003). Model-centred learning and instruction. *Technology, Instruction, Cognition and Learning*, *1*(1), 59-85.

Sinatra, G. & Pintrich, P. R. (Eds.) (2003). Intentional conceptual change. Mahwah, NJ: Erlbaum.

Snyder, J. L. (2000). An investigation of the knowledge structures of experts, intermediates and novices in physics. *International Journal of Science Education*, *22*(9), 979-992.

Solé, I. (1993). Disponibilidad en el aprendizaje y sentido del aprendizaje. En C. Coll y otros, *El constructivismo en el aula.* Barcelona: Graó.

Stake, R. E. (1995). *The art of case study research*. Sage.

Stamp, N. & O'Brien, T. (2005). GK-12 Partnership: A model to advance change in science education. *BioScience*, 55 (1), 70-77.

Stewart, J., Cartier, J. L., & Passmore, C. M. (2005). Developing understanding through model-based inquiry. *How students learn*, 515-565.

Strike, K. A. & Posner, G. J. (1992). A revisionist theory of conceptual change. *Philosophy of science, cognitive psychology, and educational theory and practice*, *176*.

Stokes, D. (1997). *Pasteur's quadrant: Basic science and technological innovation.* Washington, DC: Brookings Institute.

Thagard, P. (2008). Conceptual change in the history of science: Life, mind, and disease. *International handbook of research on conceptual change*, 374-387.

Thagard, P. (1992). *Conceptual revolutions*. Princeton University Press.

Treagust, D. F., et al. (1996). Using an analogical teaching approach to engender conceptual change. *International Journal of Science Education*, *18*(2), 213-229.

Tweney, R. D., et. al. (1981). *On Scientific Thinking*. New York, NY: Columbia University Press.

Van Driel, J. H., & Verloop, N. (2002). Experienced teachers' knowledge of teaching and learning of models and modelling in science education. *International Journal of Science Education*, 24(12), 1255-1272.

Van Zee, E. H. & Minstrell, J. (1997). Reflective discourse: Developing shared understandings in a physics classroom. *International Journal of Science Education*, *19*(2), 209-228.

Vera, A. & Simon, H. (1993). Situated cognition: A symbolic interpretation. *Cognitive Science,* 17, 4-48.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes* Cambridge, Mass.: Harvard University Press.

Vygotsky, L. S. (1979). *El desarrollo de los procesos psicológicos superiores.* Barcelona: Grijalbo.

Vosniadou, S. (2007). The cognitive-situative divide and the problem of conceptual change. Educational Psychologist, 42(1), 55-66.

Vosniadou, S. et al. (2001). Designing learning environments to promote conceptual change in science, *Learning and Instruction*, 11, 381-419.

Vosniadou, S. & Ioannides, C. (1998). From conceptual development to science education: A psychological point of view. *International Journal of Science Education*, *20*(10), 1213-1230.

Wason, P. C. (1960). On the failure to eliminate hypotheses in a conceptual task. *Quarterly journal of experimental psychology*, *12*(3), 129-140.

Wason, P. C. (1968). Reasoning about a rule. *Quarterly Journal of Experimental Psychology*, 20, 273–281.

Watters, J. J. & Diezmann, C. M. (2007). Multimedia resources to bridge the praxis gap: Modeling practice in elementary science education. *Journal of Science Teacher Education*, 18(3), 349-375.

Wilkins, J. L. (2008). The relationship among elementary teachers' content knowledge, attitudes, beliefs, and practices. *Journal of Mathematics Teacher Education*, *11*(2), 139-164.

Windschitl, M. (2003). Inquiry projects in science teacher education: what can investigative experiences reveal about teacher thinking and eventual classroom practice? *Science Education*, 87(1), 112-143.

Windschitl, M. et. al. (2008a). Beyond the scientific method: model based inquiry as a new paradigm of preference for school science investigations. *Science Education,* 92(5), 941 – 967.

Windschitl, M. et. al. (2008b). How novice science teachers appropriate epistemic discourses around model-based inquiry for use in classrooms. *Cognition and Instruction,* 26(3), 310-378.

Windschitl, M. & Thomson, J. (2006). Transcending simple forms of school science investigation: the impact of preservice instruction on teachers' understandings of model-based inquiry. *American Educational Research Journal,* 43(4), 783-835.

Wiser, M. & Carey, S. (1983). When heat and temperature were one. *Mental models*, 267-297.

Yin, R. K. (2013). *Case study research: Design and methods*. Sage publications.

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review,* 27, 172-2.

Appendix 1: initial questionnaire

QÜESTIONARI INICIAL

Nom:

Edat:

< 21 anys ☐	21-24 anys ☐	25-27 anys ☐	>27 anys ☐

Fins quan has estudiat ciències abans d'entrar a la universitat?

4t ESO/2n BUP ☐	2nBAT/COU ☐	FPII quina?) ☐	Universitat ☐

Observacions:

A. Concepcions sobre la ciència

1. **Per tu, què és la ciència?**
2. **Explica com construeixen el coneixement científic els homes i dones que es dediquen a la ciència.**

B. Concepcions sobre l'aprenentatge de les ciències

3. **Explica com et sembla que els nens i nenes construeixen coneixement sobre els fenòmens físics i naturals del seu entorn. Remarca les coses que creguis imprescindibles perquè puguin aprendre.**

C. Experiència escolar i interès sobre les ciències

4. Com van ser les teves classes de ciències a Primària i a l'ESO/BATX? Identifica els aspectes que consideres més positius i els que consideres més negatius de la teva experiència com a alumne/a?

5. Ordena de més a menys interès (1r més, 7è menys) el teu interès actual en les àrees de coneixement que hi ha la taula

Àrea	Puntuació	Observacions
Llengües		
Matemàtiques		
Socials		
Ciències		
Expressió plàstica		
Música		
Educació Física		

6. Creus que les classes que vas viure han influït en el teu interès per les ciències? (justifica la teva resposta)

E. Concepcions sobre l'ensenyament de les ciències

7. En funció de com has descrit l'aprenentatge a la pregunta 3, exposa com creus que caldria ensenyar: quines activitats són més adients? de quina manera les hauries de plantejar com a mestre/a?

8. Si demà haguessis de fer una classe de ciències, amb quines 3 dificultats principals et trobaries?

9. Què ha de saber i saber fer un bon mestre de ciències?

10. A la taula següent hi apareixen una sèrie d'activitats i dinàmiques que es porten a terme a les classes de ciències.

- **Indica amb un SÍ aquelles amb les quals et sents identificat/da, i amb un NO aquelles amb les quals no et sents identificat/da.**

		M'hi sento identificat/da
1	Estàs ensenyant una unitat sobre l'espai. Cada dia llegeixes a la classe un fragment del llibre de text sobre el sistema solar. Després de llegir sobre un determinat planeta, preguntes als alumnes que diguin una cosa que saben de nou sobre el planeta. Reculls les afirmacions a la pissarra i després les copien a la seva llibreta.	
2	Vols que els alumnes aprenguin sobre els insectes. Decideixes que la millora manera per fer-ho és que els alumnes retallin les parts del cos i les ajuntin per formar un insecte que enganxaran en un mural.	
3	En una unitat sobre cèl·lules, decideixes que la millor manera d'aprendre les parts de la cèl·lula és que els alumnes manipulin una cèl·lula de gelatina, en què llaminadures de diverses formes representaran les diferents parts de la cèl·lula.	
4	Comences una nova unitat preguntant als alumnes el que ja saben sobre el tema. Uses una taula de "què sabem" i "què volem saber " per registrar els coneixements previs dels alumnes.	
5	Demanes als alumnes que observin cucs de terra i que facin preguntes sobre el comportament dels cucs de terra a partir de les observacions que han fet. Cada grup dissenya i porta a terme el seu propi experiment per posar a prova una hipòtesi relacionada amb una de les preguntes del grup.	
6	Proposes als alumnes de participar en una Fira d'Experiments científics. Recordes als alumnes i als pares que el fet de fer ciència és més important que no pas els resultats.	
7	Els alumnes estan intrigats per una joguina que un ha portat a classe. Amb el grup classe identifiqueu preguntes i formes d'explorar com funciona la joguina. Tu ajudes els alumnes a organitzar-se en equips d'investigació, i investigues amb ells.	
8	En una unitat en què estàs ensenyant sobre reciclatge, un dia exposes a tota la classe la informació més important que cal saber sobre el reciclatge.	
9	Animes els alumnes a explorar els seus propis interessos sobre el medi natural. Un dels alumnes usa llibres de la biblioteca per buscar informació sobre les balenes, mentre que un altre es proposa una investigació per estudiar les floridures del pa.	

	Deixes que cadascú respongui al seu interès.	
10	Prepares racons d'aprenentatge per a una unitat sobre el moviment dels objectes. Usant llibres de la biblioteca com a recurs, selecciones unes quantes activitats divertides i fàcils de fer i col·loques el material necessari a cadascun dels racons perquè els alumnes explorin sols	
11	Vols que els alumnes aprenguin sobre les màquines. Decideixes que la millor manera de fer-ho és donar als alumnes electrodomèstics trencats perquè els desmuntin.	
12	Prepares un racó sobre flotabilitat en un extrem de l'aula. Setmanalment canvies els materials del racó.	
13	Vols que els alumnes aprenguin sobre les fases de la Lluna. Decideixes fer que els alumnes observin i facin dibuixos de la Lluna cada nit durant un mes.	
14	Vols que els alumnes aprenguin sobre la classificació dels éssers vius. Per això fas que ordenin una col·lecció de fulles en diferents categories en base a les característiques que tenen les fulles.	
15	En una unitat sobre l'electricitat, dones als alumnes bombetes, piles i cables elèctrics. Els animes perquè trobin totes les maneres possibles d'engegar la bombeta.	
16	Per començar una unitat didàctica sempre planteges una pregunta general que servirà de guia a les activitats que es van fent durant tota la unitat. Per exemple una de les unitats comença amb la pregunta: Totes les substàncies es dissolen en aigua?	
17	Poses menjadores d'ocells a fora el pati, que es poden veure des de la finestra. Preguntes als alumnes que registrin acuradament les seves observacions en un arxiu de Word.	
18	Els alumnes han acabat el seu projecte de fer un pont. Per a la propera unitat sobre màquines simples, demanes que facin que el pont es pugui moure usant una combinació de 2 o més màquines simples (palanques, politges, engranatges, etc.)	
19	Dissenyes una UD sobre l'aigua en què primer hi ha les teves explicacions a classe i discussions en gran grup i després fan exercicis del llibre de text.	
20	En una UD primer impliques els alumnes en activitats de laboratori i després els proposes que discuteixin en gran grup els resultats.	
21	Com a sistema d'avaluació, proposes als alumnes que per grups facin un joc de rol sobre el moviment de les partícules d'un gas.	
22	Penses que la millor manera perquè aprenguin sobre els volcans és fer-los construir maquetes de volcans	
23	En una unitat sobre el temps meteorològic, fas que els alumnes anotin diàriament la temperatura i la pluja i que observin l'estat del cel	
24	Comences una unitat exposant la teoria i el vocabulari necessaris, per tal que quedin clars els conceptes. Després aneu al laboratori a fer experiments per comprovar que la teoria és correcta.	
25	Organitzes una UD sobre l'aigua fent que els alumnes dissenyin les seves pròpies	

	investigacions relacionades amb l'aigua	
26	Comences una UD sobre els pèndols, donant als alumnes pesos i fils. Els deixes explorar autònomament, per tal que trobin quina variable (el pes o la longitud de la corda) afecta el nombre d'oscil·lacions per minut.	
27	Decideixes que la millor manera per aprendre sobre les substàncies, és que cada petit grup busqui informació a internet i la presenti als seus companys fent servir la pissarra digital	
28	Per avaluar els alumnes, fas un examen tipus test	
29	Comences una unitat sobre la llum preguntant als alumnes com és que poden veure les lletres de la pissarra	
30	Quan dissenyes activitats de experimentals, inclous guions fàcils de seguir que mostrin clarament els passos que cal que els alumnes segueixin	
31	Fas memoritzar el nom de les parts de l'aparell digestiu i organitzes un joc de rol per avaluar qui se les ha après	
32	Fas una unitat sobre els imants amb un seguit d'experiments perquè els alumnes aprenen més si poden veure i experimentar les coses.	
33	Comences la unitat explicant un conte en què apareix el fenomen que us proposeu estudiar	

- **Ordena de més a menys les activitats/dinàmiques amb què et sents molt identificat/da, i les activitats/dinàmiques amb les que no et sents gens identificat/da i justifica perquè. Només assenyala les quatre que hi ha a la taula.**

		Nº activitat	Justificació
Molt identificat/da	**1**		
	2		
Gens identificat/da	**32**		
	33		

Appendix 2: instructions to perform and review lesson plans

ELABORACIÓ D'UNA SEQÜÈNCIA D'ACTIVITATS

Objectiu:

- Elaborar una seqüència d'activitats d'un àmbit conceptual de l'Àrea de Coneixement del Medi Natural dirigida a cicle superior de Primària.
- Aquesta seqüència inicial s'anirà revisant al llarg de l'assignatura. El treball a presentar al final de l'assignatura serà la revisió justificada d'aquesta seqüència inicial d'activitats.

Passos a seguir:

1. Seleccionar el tema (veure taula)

2. Elaborar la seqüència. Ha de contenir:
    a. Fer un llistat amb els **principis pedagògics** que inspiraran la vostra seqüència d'activitats i que són consensuats entre tots els membres del grup.
    b. Seleccionar les **idees científiques** que es pretenen treballar i escriure-les en forma de frases curtes (Pex: les llavors per germinar necessiten aigua).
    c. Seleccionar **una/es pregunta/es** que serveixin de fil conductor de les diferents activitats.
    d. Descriure les **activitats** que es proposen amb el màxim de detall
        i. Número d'ordre
        ii. Objectiu de l'activitat: *Amb aquesta activitat es pretén que....*
        iii. Descripció de l'activitat: explicar què es farà i com es farà (rol dels nens i nenes, rol del mestre, materials, espais). Cal concretar al màxim (dinàmica de la sessió, fitxes d'observació, preguntes que es faran, material que es donarà als alumnes, etc...).
    e. Explicar com es portarà a terme l'**avaluació de la seqüència** (què s'avaluarà, com s'avaluarà, quan s'avaluarà i amb quins instruments)

Organització

- **Grups:** de 3-4 persones.

- **Lliurament:** data màxima divendres 16 de març a les carpetes del campus en format word (veure la normativa de presentació de treballs).

Temes
1. El gust i l'olfacte 2. El desenvolupament dels ocells 3. El vol dels ocells 4. Herència 5. La funció del color en els éssers vius

TREBALL: REVISIÓ DE LA UNITAT DIDÀCTICA INICIAL

Parts del treball:

1. **Introducció**
(breu introducció al treball)

2. **Part I: Anàlisi de la unitat didàctica**
(cal col·locar-hi les 4 graelles. Cal que cada graella sigui completa i, sobretot que la part de resum i propostes de modificació estigui completada. Cal afegir un apartat final de propostes de modificació justificades).

3. **Part II. Unitat didàctica modificada**
(la modificació de la UD pot ser feta a partir d'afegir noves activitats, treure activitats, canviar activitats d'ordre, modificar alguns aspectes de les activitats que ja hi havia a la UD, o una combinació d'aquestes coses. Cal fer totes les modificacions de **color blau**).

TAULES PER A L'ANÀLISI I REVISIÓ DE LA UNITAT DIDÀCTICA

A continuació trobareu les taules que hauríeu de fer servir per analitzar diversos aspectes de la UD. En conjunt es proposa analitzar quatre aspectes: (1) la presència i el tipus de preguntes, (2) la presència de realitat, (3) la presència d'activitat científica dirigida a obtenir dades reals i establir fets, i (4) la presència d'activitat científica dirigida a construir i defensar explicacions a través de models, hipòtesis i prediccions. De moment teniu les taules per a l'anàlisi de (1), (2) i (3).

En les taules es proposa usar cada activitat com a unitat mínima d'anàlisi però recordeu que la unitat didàctica és un tot i que no cal que cada aspecte que analitzeu hagi de ser present a totes i cadascuna de les activitats que formen part de la UD que vàreu proposar. Per això, al final de cada taula cal exposar el resultat final de l'anàlisi de tota la UD i fer les propostes de millora en relació al tema analitzat.

Les propostes de millora poden ser: modificar més o menys coses mantenint l'essència de l'activitat, proposar activitats completament noves, eliminar activitats de la seqüència inicial, canviar l'ordre de les activitats.

ANÀLISI 1. Presència i tipologia de preguntes

Presència i tipologia de preguntes que apareixen a la UD						
ACTIVITATS	**PREGUNTES** **que apareixen a l'activitat**	**A** **Segons el paper en la investigació**	**B** **Segons el paper en l'aprenentatge**	**C** **Segons si és del *què* o del *com/per què***	**D** **Segons el que proposeu als alumnes que han de fer per respondre-la**	**E** **Segons els conceptes clau per treballar els éssers vius**
1	Com funciona el sentit del gust?	Marc	Productiva	Com/Per què? (explicar)	Exposar els propis coneixements	Ø
	Quins són els òrgans implicats?	Marc	Reproductiva	Què? (descriure)	Buscar informació	Composició-Estructura
....						
Anàlisi general dels resultats	Els resultats de l'anàlisi mostren que.....					
Proposta de modificacions	En base a l'anàlisi realitzada i al model didàctic que ens serveix de referència teòrica proposem les següents modificacions: 1. 2. ...					

Categories d'anàlisi per a la dimensió A: Marc, Investigable, Modelitzadora, Metodològica, Reguladora, Ø (=no es pot classificar).

Categories d'anàlisi per a la dimensió B: Reproductiva (els alumnes la poden contestar reproduint la informació del mestre, del llibre o de fets que són ben coneguts per ells), Productiva (els alumnes han de mobilitzar coneixements nous per respondre-la), Ø (=no es pot classificar).

Categories d'anàlisi per a la dimensió C: Què?(descriure), Com/Per què?(explicar), Ø (=no es pot classificar).

Categories d'anàlisi per a la dimensió D: Buscar informació, Exposar els propis coneixements, Investigar, Ø (=no es pot classificar)..

Categories d'anàlisi per al a dimensió E: Canvi, Escala, Interacció, Composició/Estructura, Comparació, Relació Estructura-Funció, Ø (=no es pot classificar).

Anàlisi 2: Presència de realitat a la UD

Presència de realitat a la UD			
Activitat nº	**Hi ha contacte amb la realitat en aquesta activitat.** **RESPOSTA: SÍ /NO.** **Quin tipus de contacte?**	**Amb quina finalitat es produeix el contacte amb la realitat?**	**Com s'utilitza el contacte amb la realitat en les activitats posteriors**
Activitat 1	Sí. Sortida al bosc	Observació de fenòmens	Les dades recollides no s'usen enlloc
...			
Activitat 3	No	---	---
...			
Activitat 7	Sí. Manipulació de fulles reals	Classificar els tipus de fulla	En l'activitat 8 es fan servir els resultats d'aquesta activitat.

Anàlisi general dels resultats	Els resultats de l'anàlisi mostren que....
Propostes de modificació	En base a l'anàlisi realitzada i al model didàctic que ens serveix de referència teòrica proposem les següents modificacions: 1.

Anàlisi 3: La presència d'activitat científica a l'aula (I). Obtenir dades i Establir fets

La presència d'activitat científica a l'aula (I). Obtenir dades i Establir fets					
Activitat nº	**Aquesta activitat conté episodis que serveixen per obtenir, representar i analitzar dades :** **RESPOSTA: SÍ / NO +** **identificar l'episodi concret**	**Aquesta activitat conté episodis que serveixen per establir fets:** **RESPOSTA: SÍ / NO +** **identificar l'episodi concret**	**Qui paper tenen alumnes i mestra en el procés d'obtenir, representar i analitzar dades o d'establir fets**		**Quins tipus de processos es fan servir en aquesta activitat (1)**
			ALUMNES	**MESTRA** **(o font externa)**	
Activitat 1	Sí Quan es proposa que mesurin l'alçada de la planta	NO	Segueixen consignes	Proposa el que s'ha de fer	Mesurar
	NO	Sí La mestra explica per on creix la planta	Escolten	La mestra exposa el fet	Escoltar una explicació
Activitat 2	NO	NO	--	--	--
...					
Anàlisi general dels resultats	Els resultats de l'anàlisi mostren que....				

Propostes de modificació	En base a l'anàlisi realitzada i al model didàctic que ens serveix de referència teòrica proposem les següents modificacions: 1. ...

(1) Llista de possibles processos (n'hi podeu afegir d'altres): observar, realitzar experiments amb control de variables, classificar, mesurar, comparar, escoltar una explicació, consultar una font d'informació, representar dades, identificar patrons, expressar resultats per escrit,.....

Anàlisi 4: La presència d'activitat científica (II): Construir explicacions, usar models, argumentar.

Explicacions, models, arguments			
Activitat nº	**L'activitat condueix a generar una explicació? Sí/No perquè** **Qui explica? , el mestre, els alumnes, una altra font**	**Es proposa als alumnes que creïn, revisin o usin models?** **Sí/No, perquè....**	**Els alumnes argumenten?** **(argumentar és defensar la validesa d'una explicació en base a les evidències disponibles)**
Activitat 1	Sí, per què hi ha una pregunta que demana. "Per què l'aigua s'escalfa?" Els alumnes	Sí. Es proposa que creïn i usin models, per què es demana: "dibuixa com t'imagines que és l'aigua per dins i explica què li passa quan s'escalfa". No es proposa que es revisin.	No
...			
Activitat 3	Sí. Per què la mestra fa una explicació de l'experiment que han fet. La mestra	No	No

...			
Activitat 7	No	No	No
Anàlisi general dels resultats	Els resultats de l'anàlisi mostren que....		
Propostes de modificació	En base a l'anàlisi realitzada i al model didàctic que ens serveix de referència teòrica proposem les següents modificacions: 1. 2. ...		

Appendix 3: examples of activities performed during instruction

This appendix shows some of the most significant activities performed during instruction. Each activity is briefly presented and discussed. It is important to notice that these are not

Example 1: Activity performed at the beginning of the first period of instruction. In this activity pre-service students had to chose aims for the learning-teaching of science. The activity was performed in order to explore initial pre-service teachers' beliefs and was later on reviewed and discussed.

Les finalitats de l'ensenyament de les ciències

Nom:

Omple la taula següent en funció de la teva opinió:

Finalitats de l'ensenyament de les ciències	Molt important	Bastant important	Poc important	Gens important
Adquirir coneixements científics teòrics				
Despertar la consciència respecte la necessitate de conserver el medi natural I la salut				
Adquirir coneixements sobre les aplicacions de la ciència I la tecnologia				
Preparar elsnens i nenes per ser capaços de seguir sense dificultats estudis posteriors de ciències				
Aprendre a gaudir de la ciència				
Desenvolupar la curiositat pels fenòmens de l'entorn físic i natural				
Desenvolupar l'esperit crític davant dels efectes de la ciència I la tecnologia en la societat				
Desenvolupar el rigor i la precisió en el treball				
Aprendre a formular hipòtesis				
Aprendre a observar				
Aprendre a dissenyar i a portar a terme experiments senzills				
Aprendre a buscar informació				
Aprendre a comunicar la informció als companys (per escrit, oralment o per altres mitjans)				
Desenvolupar el pensament científic				
Aprendre a treballar en grup				
Desenvolupar actituds positives I interès cap a la ciència i el seu aprenentatge				
Aprendre a solucionar problemes de la vida quotidiana (investigar un fenomen, saber com funciona un aparell, etc.)				

Example 2: Instructions given to students to use a science notebook during instruction. Example of notes within science notebooks are also included.

La llibreta de ciències.

Aspectes generals.

Activitat individual de caràcter obligatori per a tots els estudiants.

Ponderació en l'avaluació final de l'assignatura, 15% de la qualificació global.

Eina de treball que tindrà continuïtat

Criteris d'avaluació. La seva realització. Sistematització en la recollida de dades. Qualitat de la informació. Interès de les reflexions i propostes de treball i de recerca. Lliurament obligatori el darrer dia de classe del semestre.

Fonaments.

És una eina bàsica en el treball de tots "el científics", s'hi recullen dades, observacions, dubtes, idees i necessitats detectades durant el treball pràctic ja sigui al camp o al laboratori. Sense aquest suport, amb tota seguretat, la ciència no hauria arribat al seu nivell actual.

Entenent que és una eina, considerem que cal introduir-la i donar-la a conèixer des de les primeres etapes educatives i per això ocupa un espai destacat en les assignatures de ciències experimentals. El professorat responsable de la docència d'aquesta àrea considera que és un material "clau" per intentar canviar metodologies de treball convencionals. En la mateixa línia us hem de dir que la llibreta tindrà continuïtat en l'assignatura Didàctica de les Ciències Experimentals II que s'impartirà a 4t curs del grau de Mestre en Educació Primària.

Ens servirà per fer memòria, per recordar i per preparar informes. Serà un recull de la nostra història com a investigadors.

Com ha de ser?

- De dimensions mitjanes. Ni gran ni petita. De bon desar i que no dificulti l'escriptura en situacions una mica incòmodes com ara una sortida de camp.
- Una mica resistent, de tapes una mica dures i que resisteixi la humitat.
- Ideal de paper quadriculat per facilitar dibuixar-hi, fer-hi gràfics

Què s'hi ha de fer constar?

Observacions, dades, idees, dubtes, reflexions, preguntes, prediccions

Tots aquests elements han d'estar convenientment datats, amb l'horari si cal, reflectits de manera breu i sempre que sigui possible gràfica.

<u>Quines iniciatives hi quedaran reflectides?</u>

- Una activitat "lliure", sense guió de treball.

  - Quatre llavors.

    El primer dia us facilitarem quatre llavors i l'encàrrec de fer-les treballar, tot pensant com fer-ho i observant com es comporten. La iniciativa persegueix incentivar la vostra capacitat investigadora. Pretenem que els primers dies us feu preguntes i que els següents feu el que considereu per intentar respondre-les. Durant el procés haureu d'intentar documentar gràficament alguns moments clau del que heu fet. La darrera setmana de curs haureu de tancar un breu informe sobre aquesta experiència i portar les vostres llavors o el que en quedi en funció del tracte que els hi hàgiu donat.

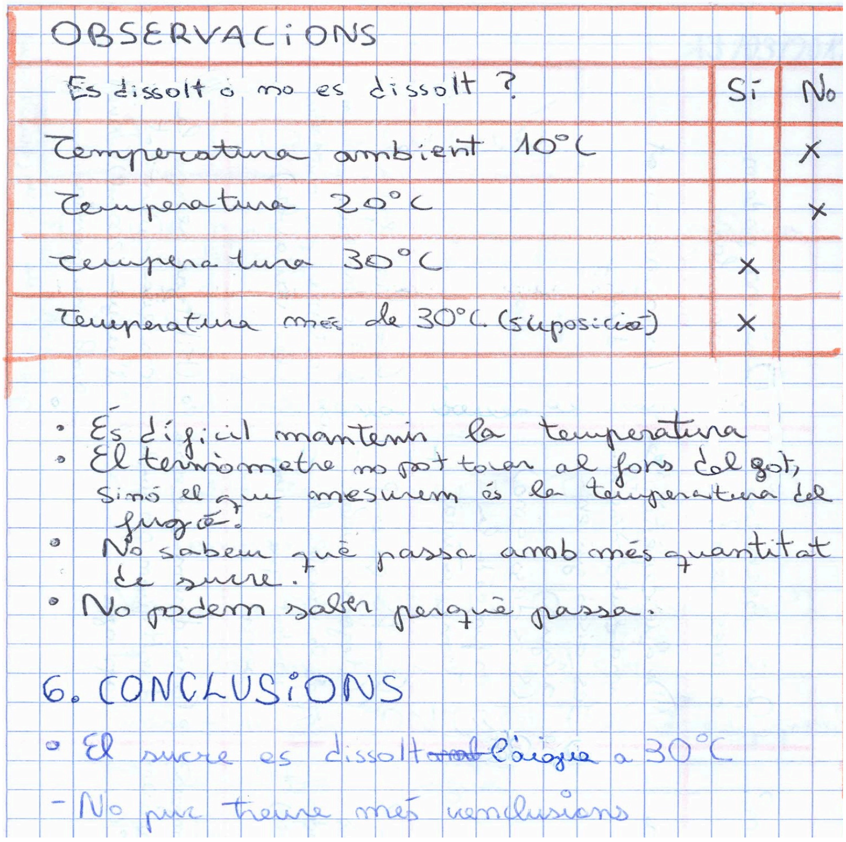
- Una activitat guiada

  - Observació, anàlisi i conclusions en relació al comportament d'un animal ben proper o conegut per tots. Durant el desenvolupament de l'assignatura us en donarem els detalls.

- Diverses activitats pràctiques.

  - Per coherència amb la metodologia de treball i el criteris didàctics que regiran aquesta matèria, en cada bloc de treball desenvoluparem una o més activitats que hauran de quedar degudament consignades en la vostra llibreta de ciències

Example of science notebook 1: notes taken during a guided experience about solutions.



OBSERVACIONS

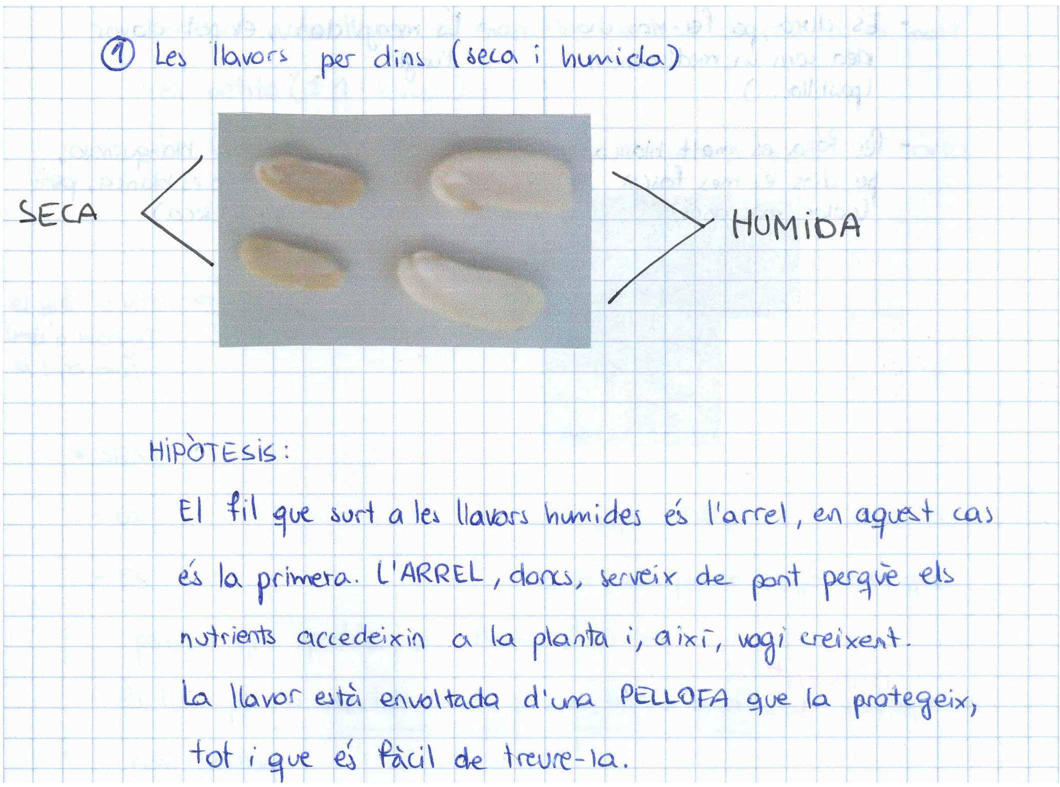
Es dissolt o no es dissolt ?	Si	No
Temperatura ambient 10°C		X
Temperatura 20°C		X
Temperatura 30°C	X	
Temperatura més de 30°C (suposició)	X	

- És difícil mantenir la temperatura
- El termòmetre no pot tocar al fons del got, sinó el que mesurem és la temperatura del fogó!
- No sabem què passa amb més quantitat de sucre.
- No podem saber perquè passa.

6. CONCLUSIONS

- El sucre es dissolt ~~amb~~ l'aigua a 30°C
- No puc treure més conclusions

E xample of science notebook 2: notes taken during a guided experience were students had to observe and make hypothesis about seeds.



HIPÒTESIS:

El fil que surt a les llavors humides és l'arrel, en aquest cas és la primera. L'ARREL, doncs, serveix de pont perquè els nutrients accedeixin a la planta i, així, vagi creixent.

La llavor està envoltada d'una PELLOFA que la protegeix, tot i que és fàcil de treure-la.

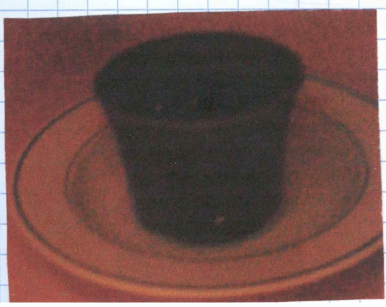
Example of science notebook 3:

24/3/2012

Aquesta setmana faré un disseny experimental per posar en pràctica amb les meves llavors:

Com afecta la llum en el creixement de les llavors?

QUÈ CANVIAREM?	QUÈ OBSERVAREM?	QUÈ NO MODIFICAREM?
La quantitat de llum a la qual exposem la llavor.	El creixement de les llavors.	• El tipus de llavor • La quantitat d'aigua
COM HO FAREM?	COM HO FAREM?	COM HO FAREM?
Plantarem en dos testos una llavor a cadascun. Un dels testos el deixarem a prop d'una finestra i l'altre dins d'un armari.	Farem una observació cada dia de les dues llavors per veure quina llavor tarda més a créixer i si hi ha diferències significatives entre les plantes (color...)	Plantarem en els dos testos la mateixa llavor. Regarem les llavors cada dos dies.



Example 3: Activity performed during the first period of instruction in order to think about the use of hands-on and inquiry activities within a classroom setting and the different ways to guide these activities in order to promote science literacy in coherence with MCI. Due to time constraints this activity was done and discussed as a whole group although it was initially thought to be done individually.

Manipular, investigar, experimentar... aprendre?

Gairebé ningú posa en dubte que, per aprendre ciències, cal fer activitats manipulatives. Tanmateix, totes les activitats manipulatives són iguals ? Quin ha de ser el rol del docent? Quin tipus d'activitat hem de propiciar per tal de fer que els nostres alumnes acabin sent científicament competents?

Davant d'una situació i d'un mateix contingut, se'ns proposen tres maneres diferents d'actuar. Analitzeu aquests 3 casos a partir de:

1. GRAELLA 1: Identificar les característiques generals de cadascun dels 3 enfocs considerant aspectes com:
   - Definició d'expectatives/objectius: són clares? Qui les defineix?..
   - Grau de motivació de l'alumnat
   - Oportunitats de treball en equip
   - Grau en que potencia la competència científica
   - Possibilitat de posar en pràctica els processos propis de l'activitat científica.
   - (...)

2. GRAELLA 2 Comparar els tres enfocs en termes de possessió de control en el procés d'ensenyament-aprenentatge.

3. GRAELLA 3: Analitzar els possibles situacions on es podrien utilitzar cadascun dels tres enfocs.

CAS A:

Darrerament, els alumnes de 6è estan molt engrescats amb les baldufes i la Marta, la seva tutora, creu que pot ser interessant aprofitar l'avinentesa per treballar alguns aspectes sobre què afecta al moviment d'aquestes i que, de ben segur, més endavant els poden ser útils per aprendre nous conceptes sobre les forces i el moviment. Per aquest motiu els engresca a crear la seva pròpia baldufa i posar-la a prova (per parelles) tot seguint les indicacions següents:

1. **Amb l'ajuda d'un compàs, feu un cercle de 10cm de diàmetre i talleu-lo.**

2. **Poseu un llapis "tipus ikea" pel centre, tal com mostra la figura 1, de manera que la part de la punta sobresurti uns 2cm.**

3. **Poseu una goma de elàstica a cada banda del cercle per tal d'estabilitzar el llapis i posar-lo perpendicular al disc.**

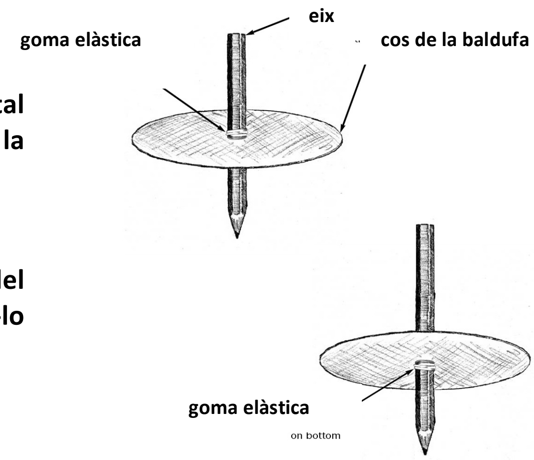


Fig.1

4. **Feu anar la baldufa diverses vegades per tal d'assegurar-vos que el llapis queda fix i perpendicular.**

5. **Utilitzant cinta adhesiva, enganxeu 4 monedes de 5 cèntims al disc, tocant al llapis, tal com mostra la figura 2.**

6. **Feu uns quants girs de prova i, després, mesureu-ne tres. Anoteu els temps obtinguts. Recordeu: el temps deixa de comptar-se quan la baldufa s'atura completament.**

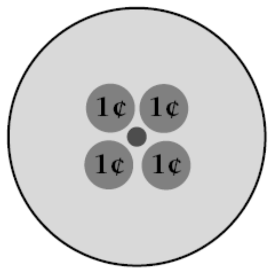


Fig.2

Monedes juntes: ***gir 1*** ☐ ***gir 2*** ☐ ***gir 3*** ☐

7. **Moveu les monedes cap a la part exterior del cercle (tal com mostra la fig.3) i torneu a fer girar la baldufa.**

Monedes separades:

gir 1 ☐ ***gir 2*** ☐ ***gir 3*** ☐

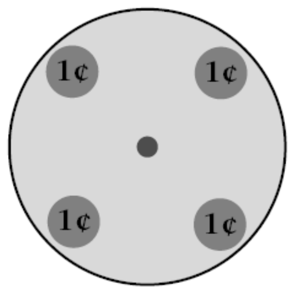


Fig.3

A. **Quins han estat els vostres millors registres?**

Monedes juntes: ☐ ***Monedes separades:*** ☐

B. Què has pogut descobrir?

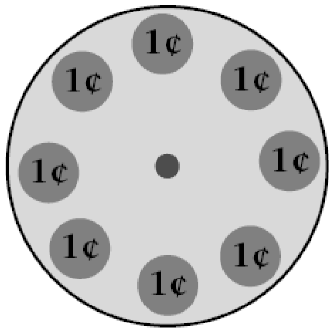
___

___

C. Basant-te en els resultats obtinguts, què creus que passarà si allunyes encara més el pes respecte l'eix? Creus que la baldufa rodarà...

Més temps ☐ ***Menys temps*** ☐ ***El mateix temps*** ☐

8. Afegiu 4 monedes més intercalant-les segons es mostra a la fig. 4 i torneu a fer girar la baldufa.



8 monedes:

gir 1 ☐ ***gir 2*** ☐ ***gir 3*** ☐

Fig.4

D. Quin és l'efecte sobre el temps de gir?

___

___

Un cop acabada l'activitat, la Marta els fa compartir els resultats tot demanant-los: "Quan heu separat les monedes de l'eix, què ha fet la baldufa, ha girat més o menys? I quan li heu afegit més monedes?" Per acabar l'activitat, la Marta ha reforçat les idees clau treballades: "Moure la massa (pes) cap enfora i/o afegir més pes, fa que la baldufa es torni més estable."

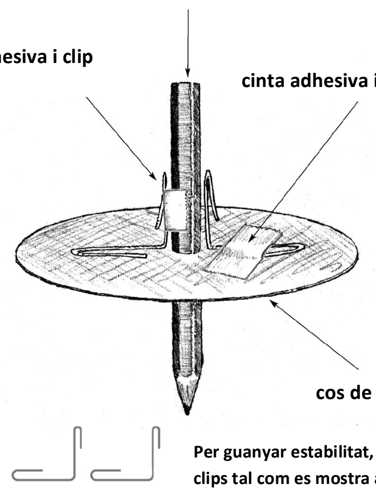
CAS B:

Darrerament, els alumnes de 6è estan molt engrescats amb les baldufes i la Marta, la seva tutora, creu que pot ser interessant aprofitar l'avinentesa per treballar alguns aspectes sobre què afecta al moviment d'aquestes i que, de ben segur, més endavant els poden ser útils per aprendre nous conceptes sobre les forces i el moviment. Per aquest motiu els engresca a crear la seva pròpia baldufa i posar-la a prova.

La Marta posa a la disposició de l'alumnat tota una sèrie de material (tisores, compàs, monedes, cinta adhesiva, cronòmetres, gomes elàstiques, llapis, pals tipus "pinxo", plastelina, cartolina, regles, clips, paper de vidre, maquinetes, plats de paper i de plàstic de diferents mides, cartró...). Després, els mostra com fer una baldufa amb materials casolans (fig.1) i aleshores, per parelles, els proposa els reptes següents:

- **Fer una baldufa amb l'eix que sobresurti 4cm per sota del cos i que pugui arribar a girar 10 segons.**
- **Fer una baldufa amb l'eix que sobresurti 8 cm per sota del cos i que pugui arribar a girar 10 segons.**
- **Fer una baldufa amb l'eix que sobresurti 8 cm per sota del cos i que pugui arribar a girar tant com sigui possible.**

Per aconseguir aquests reptes, l'alumnat pot fer servir el material disponible de la manera que vulgui i pot modificar el disseny de la baldufa inicial. D'altra banda, la Marta els demana que, a mesura que treballen, vagin anotant aquells factors que veuen que fan que la baldufa giri més estona.



Després de deixar que provin a fer les baldufes i fer-les girar durant una estona, la Marta els posa en gran grup per compartir els resultats tot fent-los preguntes com:

- **Quan ha estat més fàcil estabilitzar la baldufa, amb l'eix de 4cm o amb el de 8cm?**
- **Quines proves han fet? Quin factors han fet que girés més o menys estona?**
- **Algú ha intentat fer una baldufa amb un cos més ample? Quins han estat els resultats?**
- **Algú ha mirat de posar-hi més pes? Quins han estat els resultats?**
- **Algú ha mirat de moure la massa cap a l'exterior del cos?**
- **(...)**

A partir del debat generat, la Mestra fa que els infants arribin a certes generalitzacions i, posteriorment, ella en fa un resum com a conclusió final.

CAS C:

Darrerament, els alumnes de 6è estan molt engrescats amb les baldufes i la Marta, la seva tutora, creu que pot ser interessant aprofitar l'avinentesa per treballar alguns aspectes sobre què afecta al moviment d'aquestes i que, de ben segur, més endavant els poden ser útils per aprendre nous conceptes sobre les forces i el moviment. Així doncs, la Marta posa a la disposició de l'alumnat tota una sèrie de material (tisores, compàs, monedes, cinta adhesiva, cronòmetres, gomes elàstiques, llapis, pals tipus "pinxo", plastelina, cartolina, regles, clips, paper de vidre, maquinetes, plats de paper i de plàstic de diferents mides, cartró...) i, amb aquest, els encoratja a crear les seves pròpies baldufes i a posar-les a prova tot dissenyant algun tipus d'experiència que els permeti descobrir el que vulguin sobre les baldufes i el seu moviment.

La Marta organitza els infants en petit grup. En primer lloc, els deixa uns minuts per tal que es puguin posar d'acord sobre qu`pe volen descobrir i com ho poden fer. Després deixa una bona estona per tal que els infants posin a prova els seus propis reptes. Mentre els infants treballen, la mestra va passant pels diferents grups fent suggeriments que:

- **encoratgin l'exploració (per exemple: "A veure si podeu fer la baldufa més gran/més complexa (...) de totes..."**
- **ajudin a resoldre els problemes tècnics (per exemple: donant trucs que permetin estabilitzar millor les baldufes; suggerint que l'eix de la baldufa passi pel centre de masses, etc.).**
- **fixin l'atenció de l'alumnat i els obliguin a no distreure's amb la decoració de les baldufes i/o altres aspectes no importants, per exemple.**

Un cop fetes les exploracions, la Marta propicia un espai de posada en comú on els infants poden compartir els objectius que s'havien proposat, les preguntes que s'han fet, la manera de procedir, les seves descobertes, les seves conclusions... La informació obtinguda es va posant en comú i, entre tots, s'analitzen per tal d'establir unes conclusions finals que permetin establir teories sobre el moviment de les baldufes. En tot aquest procés final, la mestra segueix fent de guia intervenint per tal que es posin de manifest resultats significatius dels diferents grups, conduint les conclusions finals, destacant connexions entre resultats, etc.

GRAELLA 1: IDENTIFICACIÓ DE LES PRINCIPLAS CARACTERÍSTIQUES DELS DIFERENTS ENFOCS		
Cas A	**Cas B**	**Cas C**

GRAELLA 2: Anàlisi sobre la possessió del control en el procésd'ensenyament-aprenentatge

Qui té el control...	***CAS A***	***CAS B***	***CAS C***
Sobre el **problema/pregunta** a resoldre?			
Sobre els **processos** i/o aspectes procedimenals? (material a utilitzar, passos a seguir... com anotar els resultats?			
Sobre els **resultat** i/o aspectes procedimenals? (material a utilitzar, passos a seguir... com anotar els resultats?			

Quines implicacions pot tenir el fet que l'alumnat tingui més o menys control sobre el seu procés d'aprenentatge? Com pot afectar al seu aprenenatge?

Quin ha de ser el rol del mestre en el cas C?

GRAELLA 3: Possibles situacions per a l'ús dels diferents enfocs

CAS A	*CAS B*	*CAS C*
•		•

Example 4: Supports given to students in order to learn to plan an experiment design and reach conclusions from data/evidences. As explained in chapter 6 pre-service teachers incorporated this charts in their reviewed lesson plans. In general terms, when they incorporated them, they did not make any changes. Pre-service teachers also used these supports, as students, in the performance of classroom inquiries.

EXEMPLE DE TAULA PER EXPOSAR LA SELECCIÓ DE VARIABLES

Experiment 1		
Pregunta que investiguem:		
Què canviarem?	Què observarem o mesurarem?	Què no podem modificar?
Com ho farem? (categories/valors de la variable independent)	Com ho farem? (categories/valors de la variable independent)	Com ho farem? (accions de control)

Experiment 2		
Pregunta que investiguem: la flotabilitat d'un objecte depèn del tipus d'objecte?		
Què canviarem?	Què observarem o mesurarem?	Què no podem modificar?
El tipus d'objecte	Si sura o no sura.	La massa La quantitat d'aigua El tipus de líquid.
Com ho farem? (categories/valors de la variable independent)	Com ho farem? (categories/valors de la variable dependent)	Com ho farem? (accions de control)
Farem servir poma i patata.	Considerarem que sura si l'objecte no va al fons, Considerarem que no sura si l'objecte va al fons	Posarem trossos de poma i de patata de la mateixa massa (100g). Posarem els diferents trossos en vasos amb una mateixa quantitat d'aigua (250ml). El líquid sempre serà aigua.

A les taules de resultats només cal que hi hagi la variable independent i la variable dependent

Model A

	Flotabilitat (variable dependent)	
Tipus d'objecte (variable independent)	Sura	No sura
Poma		
Patata		

Model B

(variable independent) Tipus de material	(variable dependent) Flotabilitat
Poma	Sura
Patata	Sura

Exemples d'estructures de frase útils per fer preguntes investigables quan el problema és saber si hi ha relació entre dues variables

1. Què li passa a (variable dependent) quan modifiquem (variable independent)... (ex: Què li passa a la flotabilitat quan modifico la massa de l'objecte?).
2. Com afecta a (variable independent) el fet de modificar (variable dependent) (ex: com afecta a la flotabilitat el fet de modificar la massa de l'objecte?).
3. Quan canvio (variable independent), què li passa a (variable dependent)? (quan canvio la massa de l'objecte, què li passa a la flotabilitat?).
4. Què li passa a (variable dependent), quan canviem (variable dependent)? (què li passa a la flotabilitat, quan canviem la massa de l'objecte?

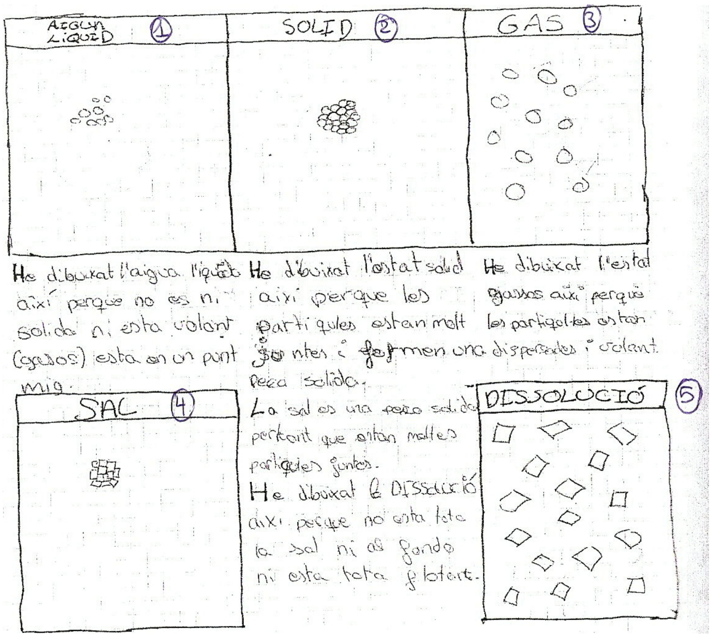
Com ajudar a escriure correctament les conclusions d'una experimentació (continuació)

a) **La mestra** explica que **usant només aquestes dades ja n'hi ha prou per poder fer una afirmació**. Explica la utilitat d'estructures com "per això podem afirmar que.." o "així doncs, podem afirmar que..." que serveixin per donar inici a l'afirmació que sempre es formularà de manera general, sense usar dades concretes (com ara: quan més/menys.... més/menys). Acaba d'escriure l'exemple: "*per això, podem afirmar que quan més* petita és la superfície del terrari, *més* trobades agressives hi ha entre les aranyes".

b) **L'escrit complert** quedaria de la següent manera: *Com afecta la reducció de l'espai a l'agressivitat de les aranyes?* ***Quan*** *fem l'espai més petit****,*** *les aranyes es tornen més agressives.* ***Per exemple****, en un terrari de* $100cm^2$ *hi ha hagut 10 trobades agressives,* ***en canvi*** en un terrari de $600cm^2$ *només* hi ha hagut 2 trobades agressives. ***Per això, podem afirmar que*** *quan més petita és la superfície del terrari, més trobades agressives hi ha entre les aranyes".*

Example 5: Example of activity were pre-service teachers were required to analyse elementary students' models and purpose actuations, as teachers, to promote their evolution. Similar activities were performed through the whole period of instruction. In this case the assignment was performed individually but in other cases it was made as a whole gruoup or working in small group.

Revisió del model de partícules i del model de dissolució dels nens i nenes de 6è de primària[2].



a. Com valores els dibuixos que fan els nens i nenes sobre com són els gasos, liquids i solids per dins? Com valores les seves explicacions? Són coherents les maneres d'expressar els models?

b. Com valores el dibuix que fan els nens I nenes per representar el que passa en una dissolució? Com valores l'explicació? Són coherents les maneres d'expressar el fenòmen?

c. A partir del que hem treballat a l'aula, proposa actuacions que podries fer, com a mestre, per ajudar a fer evolucionar aquests models.

---

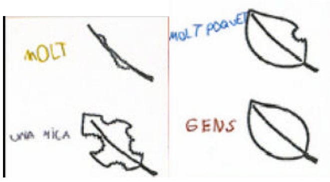
2 Initially this activity contained more than one elementary students' notebook example.

Example 6: Through instruction, pre-service students were required to put into practice the acquired knowledge on inquiry procedures. They were required to design and report experimental designs and communicate them. Below, there examples of science articles/posters used as guidelines for pre-service students. An example of a pre-service students' poster and article are also enclosed.

Poster made from a classroom experience and used aa an example for pre-servie students.

Quin menjar els agrada més als insectes pal?

Per tal d'esbrinar quin és el menjar que agrada més als insectes pal que tenim a l'aula, hem fet el següent disseny experimental:

Què canviem?	**Què mesurarem?**	**Que haurem de controlar?**
Tipus de menjar	*Quantitat de fulles que han menjat*	*- Quantitat de menjar que posem a cada terrari - Condicions ambientals del terrari (llum, humitat, temperatura) - Objectes dins del terrari - Nombre d'insectes pal dins cada terrari - Estona que esperem per mirar els resultats*
Utilitzarem: - enciam - heura - fulla de magnolia seca - fulla de plataner - fulla de m?	***Establirem les categories següents:*** 	*Crearem un terrari per cada tipus de fulla amb el mateix nombre d'insectes pal (3 a cada terrari) i les mateixes condicions: Tots els terraris estaran dins de l'aula, al costat de la finestra i hi posarem un pot amb la mateixa quantitat d'aigua per mantenir constant la humitat. A tots els terraris hi haurà un tronc i dues pedres. Posarem 20g de fulles a cada terrari. Quan hagi passat una setmana, mirarem quant han menjat.*

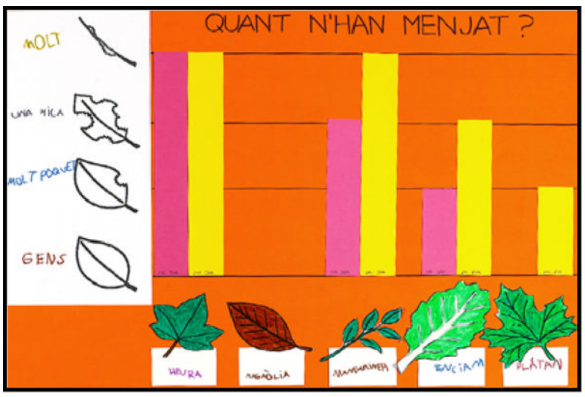
Hem fet les mesures dues vegades, per tal d'estar segurs del nostre resultat.

Fig. 1 Imatges de dos dels terraris preparats per al disseny experimental. Terrari 1 : amb l'heura (abans de l'experiment), terrari 2 amb l'enciam (després de l'experiment)

Hipòtesis :

- *Mengen heura perquè ens els han portat amb heura.*
- *Mengen més coses perquè al bosc (on viuen) hi ha més coses.*
- *Poden menjar fulles seques perquè al bosc també n'hi ha.*

Resultats obtinguts :



Conclusions:

Tal com es veu a la gràfica, els insectes no mengen fulles seques (no n'han menjat mai). També veiem que mengen diferents tipus de fulla verda tot i que prefereixen l'heura. D'heura n'han menjat molt tots dos cops. Després prefereixen la m? ja que un dia n'han menjat una mica i l'altre molt. La tercera fulla preferida és l'enciam perquè el primer cop en van menjar molt poquet i el segon una mica. Finalment hi ha les fulles de plataner que la primera setmana no en van menjar però la segona en van menjar molt poquet.

Aquests resultats confirmen les hipòtesis que als insectes pal els agrada l'heura però que, alhora, poden menjar altres coses. Els resultats també ens fan rebutjar una de les hipòtesis que havíem fet ja que veiem que no mengen fulles seques.

Creiem que potser estaria bé seguir fent l'experiment més temps ja que els resultats de la primera setmana i els de la segona són diferents i podria ser que repetint-ho més vegades veiéssim que també mengen fulles seques.

Example of a pre-service students poster.

Article made from a classroom experience and used aa an example for pre-servie students.

Què hem de pensar per preparar un article científic?

Títol: hauria de ser un mini-resum de l'article

Primer rastre d'au trobat al CEIP Andersen

Resum: tot i que està a l'inici, és l'últim que s'escriu. S'acostuma a escriure amb lletra més petita. La seva funció és la de resumir els resultats i conclusions de l'article de manera que quan algú el llegeix, sap de què va.

En aquest article s'explica com, a partir de les mostres trobades al passadís de 6è del CEIP Andersen, vam saber que una tòrtora turca havia estat depredada per un carnívor, segurament, un gat.

Introducció: justifica la investigació i explica els objectius d'aquesta

En aquest article s'explica la investigació que vam fer per…

En aquest article s'explica la investigació que vam fer per saber a quina espècie d'ocell pertanyia l'ala i les plomes que vam trobar al passadís de 6è del CEIP Andersen, el dia 5 de febrer de 2010. També s'expliquen les investigacions fetes per saber quina havia estat la causa de la mort de l'au. Estudiar els rastres d'animals és una de les feines dels naturalistes i, a través d'aquesta investigació, nosaltres hem pogut aprendre com ho fan.

Procediment: explica què s'ha fet, pas per pas i amb tot detall. No s'hi ha de posar els resultats.

Per tal de........ primer vam.....
Després...
Finalment...

Per tal de saber de quina au es tractava i quina havia estat la causa de la mort, **primer vam** observar atentament les restes al lloc on les vam trobar: vam mirar com estaven situades, les restes de menjar i altres deposicions. **Després**, vam recollir mostres i les vam analitzar al laboratori. Vam comparar la nostra ala amb els dibuixos d'aus de la guia i amb els dibuixos de rastres de la fitxa. **Finalment**, vam contrastar opinions entre nosaltres per arribar a un acord final.

Resultats: es poden presentar com a redactat però en la majoria d'articles es presenten en forma de dibuix, foto, taula, gràfic... Les imatges, dibuixos, taules, gràfics... han d'anar acompanyats d'una petita explicació que indiqui què és i/o que ajudin a la interpretació de resultats de la taula-gràfic.

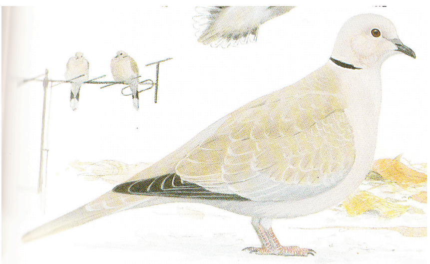


Figura 1: comparació de l'ala trobada amb el dibuix de la guia d'ocells.

Conclusions: Han de servir per veure si els resultats obtinguts expliquen els nostres objectius i com ho fan; si els resultats són fiables; si ha sortit alguna cosa inesperada... Sempre ha d'estar justificat.

Després d'analitzar els resultats obtinguts creiem que.........
ja que/perquè.....
i, per tant....
a més...
així doncs podem concloure que...

Després d'analitzar els resultats obtinguts creiem que el rastre trobat pertanyia a una tórtora turca **ja que** els colors de l'ala coincidien amb els del dibuix de la guia**. A més**, creiem que segurament se la va menjar un gat de matinada **perquè** la forma en que havia deixat els rastres és la d'un carnívor i, a l'escola hem vist gats.

Bibliografia: al final, cal citar les fonts d'informació que hem consultat.

Primer rastre d'au trobat al CEIP Andersen

En aquest article s'explica com, a partir de les mostres trobades al passadís de 6è del CEIP Andersen, vam saber que una tòrtora turca havia estat depredada per un carnívor, segurament, un gat

En aquest article s'explica la investigació que vam fer per saber a quina espècie d'ocell pertanyia l'ala i les plomes que vam trobar al passadís de 6è del CEIP Andersen, el dia 5 de febrer de 2010. També s'expliquen les investigacions fetes per saber quina havia estat la causa de la mort de l'au. Estudiar els rastres d'animals és una de les feines dels naturalistes i, a través d'aquesta investigació, nosaltres hem pogut aprendre com ho fan.

Per tal de saber de quina au es tractava i quina havia estat la causa de la mort, **primer vam** observar atentament les restes al lloc on les vam trobar: vam mirar com estaven situades, les restes de menjar i altres deposicions. **Després**, vam recollir mostres i les vam analitzar al laboratori. Vam comparar la nostra ala amb els dibuixos d'aus de la guia i amb els dibuixos de rastres de la fitxa. **Finalment**, vam contrastar opinions entre nosaltres per arribar a un acord final.


Figura 1: comparació de l'ala trobada amb el dibuix de la guia d'ocells.

Després d'analitzar els resultats obtinguts creiem que el rastre trobat pertanyia a una tórtora turca **ja que** els colors de l'ala coincidien amb els del dibuix de la guia**. A més**, creiem que segurament se la va menjar un gat de matinada **perquè** la forma en que havia deixat els rastres és la d'un carnívor i, a l'escola hem vist gats.

Bibliografia

- JONSSONS, Lars (1994). *Ocells d'Europa*. Barcelona: edicions Omega.

PAUTES PER A L'ESCRIPTURA DE L'ARTICLE CIENTÍFIC:

Pregunta formulada pel Cda (camp d'aprenentatge) del delta de l'Ebre: **L'aigua del mar pot muntar riu amunt alguns dies o èpoques de l'any?**

INTRODUCCIÓ	**PROCEDIMENT**	**RESULTATS**	**CONCLUSIONS**
- Qui ha fet la investigació - Perquè fem la investigació: - Respondre la pregunta del Cda. - Saber com es comporta l'aigua dolça i l'aigua salada (què passa amb l'aigua del riu - aigua dolça- quan arriba a la seva desembocadura i es troba amb l'aigua de mar – salada -.	- Cal explicar **detalladament** el passos que vam fer en els dos experiments on vam treballar tot el tema de la densitat: Experiment 1: 2 pots de iogurt, un amb aigua dolça i un amb aigua salada tenyida.... Experiment 2: el que vam utilitzar l'oli, la mel, l'aigua i l'alcohol... **Atenció!** - NO hi hem d'explicar els resultats que vam obtenir. - És MOLT important posar totes les dades quantitatives que tinguem.	- Cal mostrar els resultats que hem obtingut presentats en forma de taula, dibuix, fotografia, gràfic... i ho acompanyem amb una petita explicació. **Atenció!** - Les taules les teniu a la llibreta de ciències. - Cal ser curosos i anotar les unitats de mesura (grams, mil·lilitres...)	- Cal respondre la pregunta del Cda tot relacionant-ho amb els resultats obtinguts i els experiments que em fet (cal explicar què passa quan l'aigua del riu arriba a la seva desembocadura tot justificant-ho amb els resultats i relacionant-ho amb la densitat...) - Cal dir si aquests resultats són es mateixos que vosaltres esperàveu (si coincideixen amb les vostres hipòtesis), si us han sorprès, si us han servit per aprendre alguna cosa nova, etc.

Vocabulari útil per a l'article:

- **solució**: és una mescla homogènia; és a dir: barreja de substàncies en la qual no podem distingir els diferents components a simple vista (per exemple: sal+aigua).
- **dissolvent:** és la substància més abundat en una solució (si dissolem sal en aigua, l'aigua és el dissolvent).
- **solut:** és la substància menys abundant en una solució (si dissolem sal en aigua, la sal és el solut).
- **densitat:** és la relació que hi ha entre la massa d'un cos i el volum que ocupa (densitat = massa/volum).

Example of a pre-service students' article.

El comportament dels grills domèstics en funció del cant que escolten

Autores: Mireia Rafart i Noemi Vila, alumnes de 4t curs del Grau en Mestre d'Educació Primària de la Universitat de Vic

Resum

Com a alumnes de la Universitat de Vic hem desenvolupat una investigació sobre el comportament dels grills domèstics quan escolten el seu propi cant, quan aquest és de zel i quan estan en silenci. La investigació s'ha portat a terme amb tres parelles per separat en funció del sexe: un mascle i una femella, dues femelles i dos mascles. Llavors, vam recollir les dades a partir de les observacions fetes amb etogrames. Així, la conclusió a la qual vam arribar és que els grills domèstics es comporten de manera semblant indiferentment del cant que escoltin.

Paraules clau: grills, comportament, cant, silenci, etograma.

Abstract

As students of the Universitat de Vic*, we have developed an investigation about the conduct of pet crickets when they hear their own song, when this is zeal and when they are silent. The research has been carried out with three couples separately depending on sex: a male and a female, two females and two males. Then, we collect data from observations made with* etogrames. *So, the conclusion that we get is that the conduct of pet crickets is similarly regardless of the song them hear.*

Key words: *crickets, conduct, song, silence, etograma.*

Presentació

Al 4t curs del Grau de Mestre d'Educació Primària hem dut a terme una investigació científica sobre els grills domèstics. La pregunta a partir de la qual s'ha desenvolupat és: com afecta el cant dels grills domèstics en el seu comportament? Ens hem centrat en el cant que produeixen aquests, quan estan amb zel i si no se sent cap so, és a dir, estan en silenci.

Metodologia

En aquest apartat, hi ha explicats els passos que vam seguir per dur a terme la investigació i aquests són els següents:

En primer lloc, vam plantejar-nos la pregunta a investigar, és a dir, quin comportament tenen els grills domèstics quan escolten diferents cants de la seva espècie o estan en silenci.

En segon lloc, vam decidir com portar a terme la nostra investigació. D'aquesta manera, vam considerar oportú fixar-nos en tres parelles de grills en funció del seu sexe, és a dir, un mascle i una famella, dues famelles i dos mascles.

En tercer lloc, vam concretar què observaríem i en quins entorns. D'una banda, volíem fixar-nos en el que feien els dos grills de cada parella i com interactuaven. D'altra banda, els entorns en els quals es trobarien els grills serien els tres següents: en silenci, amb el cant dels grills de la seva espècie i amb el cant dels grills amb zel.

En quart lloc, vam col·locar en terraris transparents les parelles de grills per separat i, a través dels "etogrames", vam anar anotant les conductes dels grills quan escoltaven els cants amb el reproductor de música i quan estaven en silenci. Val a dir que les observacions es feien durant 1'5 minuts.

Dades

En aquest apartat hi ha els resultats de la nostra investigació organitzades en taules a partir de les observacions realitzades.

Com s'ha esmentat en l'apartat anterior, vam utilitzar etogrames per recollir les dades i, a continuació, es mostren aquestes taules. A la part esquerra de les taules, hi ha un seguit de comportaments dels grills. Per una banda, s'hi troben els que fan referència a la seva locomoció, com ara: caminar, moure les antenes i estar-se quiets. Per altra banda, hi ha els que estan relacionats amb la seva interacció, com poden ser: mirar-se, barallar-se i ignorar-se. A la part dreta, hi ha les observacions fetes de les tres modalitats de cant. Les dades obtingudes s'han diferenciat pels següents colors: amb el blanc s'ha marcat les conductes que no s'observaven gens, amb el taronja les conductes que s'observaven en poques ocasions i amb el vermell les que s'observaven amb molta freqüència. Hi ha una taula per cadascun dels terraris en els quals hi havia les parelles de grills.

A continuació s'analitzen les dades obtingudes pera cada parella de grills:

Terrari 1: dues femelles

Pel que fa a les dues femelles, les dades de les quals estan a la taula 1, hem observat que les conductes que fan amb més freqüència i en els tres entorns observats són: caminar i moure les antenes. També, els comportaments que van tenir en els tres entorns però amb menor freqüència van ser enfilar-se per les parets i ignorar-se mútuament. En canvi, els comportaments que no van fer en cap moment van ser saltar i mossegar-se. Tanmateix, hi ha hagut algunes conductes observades esporàdicament i que són: córrer, estar quiet, mirar-se i barallar-se.

<table>
<tr><td colspan="3" rowspan="2"></td><td colspan="3">TERRARI 1:
DUES FEMELLES</td></tr>
<tr><td>SENSE MÚSICA</td><td>CANT DE GRILLS</td><td>CANT DE GRILLS AMB ZEL</td></tr>
<tr><td rowspan="11">CONDUCTES</td><td rowspan="6">LOCOMOCIÓ</td><td>SALTAR</td><td></td><td></td><td></td></tr>
<tr><td>CAMINAR</td><td style="background-color:red"></td><td style="background-color:red"></td><td style="background-color:red"></td></tr>
<tr><td>CÓRRER</td><td style="background-color:orange"></td><td></td><td></td></tr>
<tr><td>MOURE ANTENES</td><td style="background-color:red"></td><td style="background-color:red"></td><td style="background-color:red"></td></tr>
<tr><td>ESTAR QUIET</td><td></td><td style="background-color:orange"></td><td></td></tr>
<tr><td>ENFILAR-SE PER LES PARETS</td><td style="background-color:orange"></td><td style="background-color:orange"></td><td style="background-color:orange"></td></tr>
<tr><td rowspan="5">INTERACCIÓ</td><td>EMPAITAR-SE</td><td style="background-color:orange"></td><td></td><td></td></tr>
<tr><td>MIRAR-SE</td><td></td><td></td><td style="background-color:orange"></td></tr>
<tr><td>BARALLAR-SE</td><td></td><td style="background-color:orange"></td><td></td></tr>
<tr><td>MOSSEGAR-SE</td><td></td><td></td><td></td></tr>
<tr><td>IGNORAR-SE</td><td style="background-color:orange"></td><td style="background-color:orange"></td><td style="background-color:orange"></td></tr>
</table>

Taula 1: dues femelles

Terrari 2: dos mascles

En aquest cas, tenint en compte la taula 2 on hi ha les dades observades amb els dos mascles, hem observat que les conductes que més vegades es repeteixen en els tres entorns són: caminar i moure les antenes. A més a més, altres conductes observades però amb menor freqüència són: estar-se quiets i ignorar-se mútuament. Al contrari, les conductes no observades són:saltar, córrer, enfilar-se per les parets, empaitar-se, barallar-se i mossegar-se.

En l'entorn en el qual escoltaven el cant dels grills domèstics, pel que fa a la locomoció, vam poder observar que les conductes que tenien amb més freqüència eren caminar i moure les antenes; en canvi, també es va poder observar que estaven quiets, tot i que amb menys freqüència. Pel que fa a la interacció entre ells, la conducta que vam poder observar més era com s'ignoraven. Tot i això, hi va haver conductes que no es van observar en cap moment, com per exemple saltar, córrer, mirar-se i mossegar-se. Tanmateix, la conducta observada en dos dels entorn ha estat mirar-se entre ells.

			TERRARI 2: DOS MASCLES		
			SENSE MÚSICA	CANT DE GRILLS	CANT DE GRILLS AMB ZEL
CONDUCTES	LOCOMOCIÓ	SALTAR			
		CAMINAR			
		CÓRRER			
		MOURE ANTENES			
		ESTAR QUIET			
		ENFILAR-SE PER LES PARETS			
	INTERACCIÓ	EMPAITAR-SE			
		MIRAR-SE			
		BARALLAR-SE			
		MOSSEGAR-SE			
		IGNORAR-SE			

Taula 2: dos mascles

Terrari 3: un mascle i una femella

Referent en aquest terrari, on les dades estan a la taula 3, les conductes que hem observat amb major freqüència en tots els entorns són: caminar i moure les antenes. A més a més, les que també hem observat però amb menys freqüència són: estar-se quiets i ignorar-se. En canvi, la resta de conductes no han estat observades en cap moment.

			TERRARI 3: MASCLE (M) I FAMELLA (F)		
			SENSE MÚSICA	CANT DE GRILLS	CANT DE GRILLS AMB ZEL
CONDUCTES	LOCOMOCIÓ	SALTAR			
		CAMINAR	Molt	Molt	Molt
		CÓRRER			
		MOURE ANTENES	Molt	Molt	Molt
		ESTAR QUIET	Poc	Poc	Poc
		ENFILAR-SE PER LES PARETS			
	INTERACCIÓ	EMPAITAR-SE			
		MIRAR-SE			
		BARALLAR-SE			
		MOSSEGAR-SE			
		IGNORAR-SE	Poc	Poc	Poc

Taula 3: un mascle i una femella

Llegenda

(blanc)	**Gens**
(taronja)	**Poc**
(vermell)	**Molt**

Conclusions

A partir dels resultats que hem obtingut en l'apartat anterior, podem respondre a la pregunta que ens vam plantejar al principi de la nostra investigació i que recuperem a continuació: *Com afecta el cant dels grills domèstics en el seu comportament?*

En l'entorn que hi ha silenci, les conductes més freqüents dels grills, tan de locomoció com d'interacció entre ells, són: caminar, moure les antenes i ignorar-se. En els entorns on se sent el cant de grills i aquest amb zel, les conductes més freqüents són les mateixes i es mostren constants. D'aquesta manera, podem afirmar que el tipus de cant dels grills no afecta al seu comportament, ja que s'han pogut observar les mateixes conductes.

Finalment, pel que fa a la interacció nul·la que hi ha hagut entre femella i mascle, creiem que es deu al fet que no és època de reproducció.

Referències bibliogràfiques

Alumnes de cicle superior de l'escola Valldeneu de Sant Martí de Centelles (2013). *Com afecta el temps meteorològic al comportament de les gallines* [en línia]. Sant Martí de Centelles: Escola Valldeneu. Disponible a:<http://mon.uvic.cat/femciencia/>

Guia sonora dels insectes de Catalunya: grills, saltamartins i cigales (2010) [CD-ROM]. Granollers: Alosa.

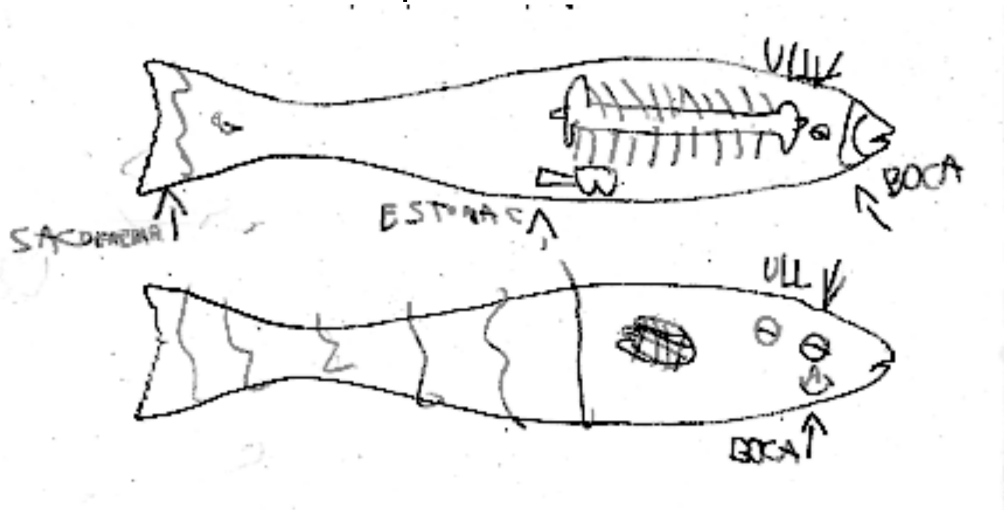
Example 7: questionnaire exploring pre-service understandings on models performed at the beginning of the second period of instruction and reviewed afterwards.

QÜESTIONARI INICIAL MODELS

Nom:

1a Explica amb les teves paraules què s'entén per model en ciències i quin creus que hauria de ser el seu paper en la ciència escolar.

1b Segons el que has contestat a l'apartat anterior, creus que aquest dibuix és un model? Justifica la teva resposta.



2. Digues en quins d'aquests casos podem parlar de model. Justifica la teva resposta.

2a. Un mural d'una aula on s'hi llegeix "*Un imant atrau als metalls"* i on, després de fer tot un seguit d'experiències amb imants, els infants consensuen modificar la sentència posant-hi "*Un imant atrau al ferro, al coure i al níquel però no altres metalls".*

2b. Un terrari.

2c. L'ús d'uns espaguetis per representar els raig de llum i el seu comportament davant determinades situacions.

2d. La fórmula matemàtica: $E = mc^2$

2e. L'esquema del cicle de l'aigua d'un llibre de text.

2f. La reproducció d'un esquelet humà que podem trobar en una aula de ciències.

Example 8: activity used to introduce sequencing done during the second period of instruction. Pre-service teachers were required to choose among different activities and sequence them taking accound the given learning topic and goals. The activity was performed in small-groups and reviewed afterwards.

Exercici: Selecció i seqüenciació d'activitats

Activitat

1. Llegiu la proposta d'activitats i l'objectiu general de la seqüència que tens a continuació.
2. Seleccioneu les 5 activitats que considereu més idònies per ensenyar el tema proposat.
3. Ordeneu les 5 activitats seleccionades en funció de com creieu que s'hauria de desenvolupar la seqüència d'activitats.
4. Justifiqueu la selecció i la seqüenciació que heu proposat. *Hem escollit aquestes activitats perquè...... Les hem ordenades d'aquesta manera perquè....*

Màxim 2 fulls.

Termini i lloc de lliurament

Dia 8 de març a l'apartat de lliuraments de l'aula virtual. Anomeneu el vostre arxiu de word seguint la pauta: Cognom_Nom_SeqüènciaActivitats.doc (useu el nom d'un dels membres del grup). Al primer full hi poseu el nom de tots els components del grup).

ESTUDIAR LES ROQUES

L'objectiu de les activitats que es proposen a continuació és ajudar els alumnes a entendre com es apreciar la diversitat de roques que existeixen. Forma part d'una unitat més àmplia sobre el cicle geològic, que es treballa a 6è curs.

1. Els alumnes fan servir guies de camp de roques adequades a l'edat amb informació sobre els diferents tipus de roques, amb l'objectiu d'identificar les mostres de roques que la mestra els ha donat (o que els alumnes han portat de casa).
2. Els alumnes porten una roca de casa. En gran grup, col·locats en cercle, observen i comenten la roca que cada nen ha portat. Al final, la mestra tanca la sessió demanant als alumnes que escriguin sobre: a) què penseu que és una roca? i, b) d'on provenen les roques?.
3. Als alumnes se'ls proporciona una mostra de roques, que han d'ordenar segons les característiques que ells mateixos determinen com ara el color, la textura, la flotabilitat, etc. La mestra proposa als alumnes que pensin en els criteris que serien o no serien útils per classificar les roques (per exemple, dues roques poden ser el mateix tipus de roca, però ser de diferent grandària i forma, de manera que la mida o la forma no són bons criteris per classificar). (1)
4. La mestra ensenya als alumnes a cantar la cançó del "Cicle de les Roques" de la qual ella mateixa ha inventat la lletra (usant la melodia de *La lluna, la pruna*), per ajudar-los a recordar que hi ha tres tipus de roques: ígnies, metamòrfiques i sedimentàries.
5. Els alumnes fan cartells del cicle de les roques, utilitzant l'esquema del seu llibre de text com a guia, i pengen aquests cartells a l'aula.
6. Els alumnes, com a grup classe, fan una llista de les maneres en què les persones fan servir les roques. Els alumnes proposen exemples com ara: jardineria, materials de construcció, escultures artístiques. (2)
7. La classe participa en un "intercanvi de roques" amb alumnes d'una altra escola. Per això preparen una caixa amb roques trobades a l'entorn de la seva escola per enviar-les als nens i nenes de l'altra escola. Quan reben la caixa dels seus "amics de roques" comparen les propietats de les roques rebudes en relació a les roques que es troben al voltant de la seva escola, i suggereixen raons per les quals podria tractar-se de la mateixa roca o d'una roca diferent. (5)
8. La classe fa una excursió a un parc natural proper. Allà, un guarda del parc els fa una xerrada sobre la geologia local de la zona, i com aquesta ha canviat al llarg de la història. (4)
9. Els estudiants exploren un web interactiu que explica les diferents etapes del cicle de les roques, com es formen i com es transformen les roques al llarg del cicle. (3)

Appendix 4: instructions given to pre-service teachers in order to plan and reflect on classroom intervention

TREBALL: TALLERS DE CIÈNCIES A LES ESCOLES

Fase 1: Preparació dels tallers

- Selecció de la idea que es vol treballar amb els alumnes de les que s'havien seleccionat a la Seqüència d'Activitats.
- Identificar possibles dificultats relacionades amb la comprensió de la idea seleccionada (fruit de la cerca d'informació o de la reflexió didàctica) i utilizar-les en la planificació dels tallers.
- Selecció de les pràctiques científiques que es volen treballar amb els alumnes de les que es treballaven a la Seqüència d'Activitats.
- Identificació del material necessari (fitxes de treball, material de laboratori, etc.). Cal especificar quantitats.
- Planificació de l'organització d'aula.

Producte: Guió del taller

Parts del Guió:

1. Idea seleccionada (llista) i resum de la informació sobre les possibles dificultats de comprensió.
2. Pràctiques científiques seleccionades (llista).
3. Llistat de material
4. Descripció del desenvolupament del taller (incorpora rol dels mestres, dels alumnes, l'organització dels alumnes).

Fase 2: Realització del taller

Els tallers es portaran a terme a l'Escola Andersen de Vic, la setmana del 18 al 22 al noviembre i al curs i cicle assignats.

És fonamental recollir les idees inicials dels alumnes (en format dibuix, conversa, explicació escrita….) i recollir les idees finals. Si és posible, seria interessant de disposar de gravacions d'audio.

Fase 3: Avaluació del taller

GUIÓ ORIENTATIU PER FER EL TREBALL SOBRE LA INTERVENCIÓ EDUCATIVA

1. **Introducció (Part comuna) (màx. 1 pàgina)**

2. **Idees/fets científics treballats (Part comuna) (màxim 1 pàgina)**: quins fets / idees treballeu en el vostre taller. Relacioneu aquestes idees/fets com a part d'un model escolar més ampli sobre el tema del taller (llum i ombres, model de partícules, calor, olfacte, flotabilitat).

3. **Planificació del treball realitzat a l'aula (Part comuna) (màx. 8 pàgines)**
   a. **Objectius de l'activitat:** redacció dels objectius bàsics de cada activitat.
   b. **Descripció de les activitats:** versió final de les activitats, just abans d'entrar a l'aula.
   c. **Fulls de treball:** fulls de treball, fitxes o concept-cartoons utilitzats durant el taller.

4. **Descripció i anàlisi de la intervenció (Part individual, màx. 8 pàgines)**
   a. **Descripció de la intervenció:** narració sobre la vostra intervenció en el taller fent èmfasi tant en les interaccions amb l'alumnat, en la gestió dels recursos i materials i en la gestió de les idees i raonaments dels nens i nenes. Destaqueu els processos d'activitat científica que heu portat a terme.
      - Preguntes de guia:
        1. *Com heu organitzat l'alumnat?*
        2. *Com heu gestionat els recursos i materials?*
        3. *Com heu organitzat el temps?*
        4. *Quin tipus de preguntes heu fet a l'alumnat?*
        5. *Quin tipus de resposta us han donat?*
        6. *Com heu gestionat les idees i raonaments dels nens i nenes?*

   b. **Anàlisi de la intervenció:** text analitzant i justificant les decisions preses durant el procés i la situació d'aula.
      - Preguntes de guia:
        1. *Quines diferències trobeu entre la planificació prevista i l'executada? Com justificaríeu aquestes diferències?*
        2. *Quines dificultats en el contingut heu tingut? Alguna intervenció de l'alumnat us ha posat en dificultats?*
        3. *Amb quines dificultats de gestió d'aula us heu trobat?*
        4. *Quines creus que han estat les teves intervencions clau, per fer evolucionar les idees de l'alumnat?*

c. **Propostes de millora:** reflexió sobre alguns punts què milloraríeu de la vostra intervenció.
   - Preguntes de guia:
     1. *Si tornessis a fer la mateixa activitat quines dues coses millloraries?*

5. **Anàlisi de les idees dels alumnes (Part comuna) (màx. 8 pàgines)**
   a. **Anàlisi de les idees inicials:** anàlisi dels models inicials de l'alumnat (a partir d'una xarxa sistèmica) i comparació amb la teoria realitzada a classe, i algun text d'investigació.
      - Preguntes de guia:
        1. *Quin tipus d'idees inicial heu trobat?*
        2. *Aquestes idees inicials es corresponen amb alguns dels pressupòsits epistemològics o ontològics que hem treballat a classe com a component de les teories intuïtives dels nens i nenes? Es relacionen amb alguns dels biaixos cognitius plantejats a classe com a components de les formes de raonar pròpies del coneixement intuïtiu?*
        3. *Són idees que ja s'han detectat en altres estudis concrets sobre el tema?*

   b. Anàlisi de les idees finals: reflexió sobre els models finals de l'alumnat i comparació amb els seus models inicials.
      - Preguntes de guia:
        1. *Vàreu detectar algun canvi en les idees inicials que tenien els alumnes? Poseu algun exemple*
        2. *Detecteu alguna idea resistent al canvi? Poseu algun exemple.*

Lectures recomanades
Driver, R. et al. (1999) *Dando sentido a la ciencia en secundaria. Investigaciones sobre las ideas de los niños*. Visor: Madrid.
Driver, R.; Guesne, E.; Tiberghien, A. (1999) *Ideas científicas en la infancia y la adolescencia*. Morata: Madrid.

"If there were only one truth, you couldn't paint a hundred canvases on the same theme."

Pablo Picasso, 1966