SUBJECT MATTER KNOWLEDGE IN PRIMARY EDUCATION TEACHER TRAINING

El conocimiento de la materia en la formación del profesorado de Educación Primaria

CRISTINA MORAL SANTAELLA[1] AND AGUSTÍN DE LA HERRÁN GASCÓN[2]
(1) Universidad de Granada (España)
(2) Universidad Autónoma de Madrid (España)

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Autor de contacto / *Corresponding autor*: Agustín de la Herrán Gascón. E-mail: agustin.delaherran@uam.es

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INTRODUCTION. The article questions a basic problem of didactics: the relevance of subject matter knowledge as a quality requirement in teacher training. Subject matter knowledge is assumed to be necessary to facilitate student learning and education. Specifically, it is understood as a requirement for teachers to be able to carry out didactic designs and developments that facilitate meaningful learning experiences and strengthen the conceptual structure of students. The objective of the research is to know if future Primary Education teachers and preservice Primary Education teachers have an adequate knowledge of subject matter knowledge. **METHOD**. To answer the objective, the type and organization of their knowledge is examined through concept maps, evaluating the productions with validated structural and semantic rubrics. **RESULTS**. The results show that, in general, teachers have a very poor organization of subject matter knowledge, with a weak didactic potential. **DISCUSSION**. Likewise, the data indicate that there are insignificant differences between the concept maps of teachers in training and those made by practicing teachers, which reflects a similar and cyclical knowledge structure. The conclusions point to the low and limited impact of teacher education programs on pre-service teachers' acquisition of subject matter knowledge, even though it is understood as a general didactic requirement for teacher education and, for the development of quality teaching.

Keywords: *Teacher education, Knowledge base for teaching, Pedagogical content knowledge, Teacher effectiveness.*

Introduction

Within a broad and rigorous conception of University Didactics (Zabalza, 2007), current teacher training programmes aim to produce competent educators fully equipped to offer quality, equitable teaching (Darling-Hammond *et al.,* 2017; OECD, 2019). To this end, pre-service teacher must be trained in a knowledge base that allows them to achieve these purposes. The search for this knowledge base continues to be of the utmost topical interest (v.g. Geddis, 2006; Lederman & Gess-Newsome, 2017; Velle, 2022). It was initiated by Shulman (1986, 1987), Grossman, Wilson, Shulman (1989, 2005), Leinhardt & Smith (1985), among others, and used by Darling-Hammond & Brandsford (2005), Grossman (2018) and Darling-Hammond & Oakes (2019), to define the core teaching practices and knowledge base that all teachers should have, amongst them subject matter knowledge (SMK).

Shulman (1987) saw SMK as the core of a "missing paradigm" in teachers' knowledge base, although later he nuanced this view, asserting that while in some parts of the world this paradigm had been lost, in others it had been adopted as the "chosen son" (Shulman, 2015). In the Spanish context, SMK, composed of knowledge of the conceptual, substantive and syntactic structure of content knowledge (CK), and the knowledge necessary to make subject content attractive and accessible to students, pedagogical content knowledge (PCK) (Grossman, Wilson & Shulman, 1989, 2005; Shulman, 1987), ceased to play a leading role in teacher training as it was considered something connected to the past and tradition, outside of a progressive movement (Gimeno Sacristán, 1988; Gimeno & Pérez Gómez, 1992; Rodríguez Diéguez, 1980; Angulo & Blanco, 1994). The reference to the SMK occupied a second place in all Spanish reference manuals for Didactics and curriculum design (Moral & Herrán, 2021), although it was recognised as an essential element in didactic design and to establish the basis for a true educational reform (Ball, Thames & Phelps, 2008; Kleickmann *et al.,* 2012; Zabalza, 1987).

No pedagogical research has found that SMK is irrelevant to teacher education; on the contrary, recent scholarship in cognitive psychology and neuroscience indicates that the organization and structuring of the knowledge and content to be learned is a decisive factor in meaningful learning among students (McTighe & Willis, 2019; Novak, 2010; Sousa, 2017; Weinstein & Sumeracki, 2019). These studies offer guidelines for developing teaching-learning activities that not only do not leave SMK aside but see it as essential to an education that can facilitate meaningful and deep learning (Darling-Hammond & Oakes, 2019). According to Wiggins & McTigue (2011) and Sewell (2018), the design of teaching units oriented towards the comprehension, transference and development of meaningful, creative learning focuses on the central ideas or concepts to be imparted, and this requires suitable SMK on the teachers' part (Miles-Uzzo *et al.,* 2018).

These studies provide indications for the elaboration of didactic designs that do not neglect the issue of SMK. On the contrary, they consider that without a good base that structures and organises the knowledge to be communicated to students, it will not be possible to develop a didactic design that promotes meaningful and deep learning (Darling-Hammond & Oakes, 2019).

Bearing in mind this basic premise, SMK is an essential knowledge that every good teacher must possess in order to provide deep and meaningful learning, the present work arises from the experience carried out training Primary Education teachers in the subject of General Didactics, which develops practices on the design of didactic units. The SMK shown by the preservice

teachers when they carry out the practices on the design of didactic units and they are asked to select, organise and sequence the content to be communicated to the pupils, on any topic of the Primary Curriculum Decree, is weak and very precarious.

This fact is the problem that gives rise to the working hypothesis of this research, because it considers, like Shulman (1986), that SMK has ceased to be important in teacher education programmes. This lack of value given to SMK leads to poor teacher training, a fact that has been occurring for decades, and as a consequence causes stagnation in the construction of the mental structure of students, future active members of our society. For this reason, the article aims to recover and highlight the importance of SMK in its two components, CK and PCK for teacher training, showing the positive implications of training future teachers in this direction.

Main components and principles of subject matter knowledge

According to Ball *et al.* (2008), Kleickmann *et al.* (2012), SMK is made up of two types of knowledge: CK and PCK. These two types of knowledge are interdependent (Copur-Genturk *et al.* 2019). CK refers to the way in which the subject matter is organised and structured for being presented to the students. It includes the analysis of facts, concepts, principles and rules that legitimise, order and establish relationships between the concepts in their fields of meaning. PCK refers to what makes subject matter content accessible and understandable to students. It includes analogies, examples, representations, explanations, materials, etc., in addition to students' habitual errors and difficulties when tackling this knowledge. Ball *et al.* (2008) see CK as a pure type of knowledge, required as a foundation of PCK. In contrast, they do not see PCK as pure, since it is associated with factors relating to students and teaching.

Education oriented towards conceptual and meaningful learning – not merely representational or rote learning (Novak, 2010) – requires appropriate teacher training in CK and PCK (Miles-Uzzo *et al.*, 2018). While both are necessary for facilitating school students' learning, they do not normally underpin teaching practice. This is indicated by studies made nowadays in a range of different areas of the curriculum, such as maths (Edwards *et al.*, 2017), the sciences (Hamilton & Duschl, 2017) and history (Levstik, 2017). These studies all agree that student difficulties in successfully performing simple reasoning exercises and organizing their knowledge for problem-solving call for teaching models based on building and rebuilding their knowledge structure.

CK responds to three questions on the substantive, structural and semantic aspects of what is taught. The first question is that of how knowledge is originated and meaningfully retained in the memory. Neuroscience (Álvarez, 2013; Sousa, 2017) tells us that human knowledge arises through information processing. This is the foundation on which knowledge is built, and enables us to think and act, through interactions between concepts, in a semantically coherent field of meanings. Students can build knowledge if they can give functional or theoretical meaning to the knowledge they are acquiring. If this information relates to their prior knowledge patterns and structures, then it is meaningfully processed and stored in long-term memory. If this is not the case, information provided from the outside stays only in short-term memory and tends to be forgotten. Meaningful relationships among concepts are achieved through connecting propositions. Using these units of meaning, "chunks" are constructed, linked to more complex blocks of related meanings. This process takes place when working memory receives a series of

disconnected data and then associates them with a structure that has meaning, thereby building semantic memory (Brandsford *et al.,* 2000; Klimesch, 2015; Sousa, 2017; Weinstein & Sumeracki, 2019).

The second question is that of the choice of knowledge to communicate to students. The trend in schools is to impart a large amount of information on the what, but little on the why, the what for and the how, or on the implications, perspectives, etc., of what is studied (Marton, 2015; Walker & Soltis, 2004). Working in this way, the potential for meaningful learning is lessened. On the contrary, meaningless retention and memorization activities increase, linked to rote learning and superficial memorization with little conceptual hold (Mayer, 2002; Novak, 2010).

The third question concerns how to organise the content to be communicated to students. In order to facilitate information processing, meaningfully grouped blocks of content should be provided. This approach aids the construction of the conceptual structure appropriate to each school subject (Sousa, 2017) and boosts knowledge structure favouring long-term memory (Klimesch, 2015). To organise content, we should make use of central information organisers, or core questions. These questions can work as meaningful, functional information connectors, enabling us to explain the why, the what for, the when and the how of what is learned, to see it from differing perspectives, to develop empathy and become aware of the utility or implications of the content (McTigue & Willis, 2019; Wiggins & McTighe, 2005). Sousa (2017) suggests organizing information into interlinked blocks, which rather than being fragmented and independent, would be meaningfully connected in semantic networks (Klimesch, 2015).

PCK makes learning understandable to students (Shulman, 1986). It has three essential aspects. The first is how to use the content in class. Broudy *et al.* (1963) identified the following ways of using content: replicative, associative, applicative and interpretive. Schools make abundant use of replication: remembering, saying and writing names, concepts, classifications, types, etc. (Wiggins & McTigue, 2005). Sousa (2017) takes up Bloom's learning taxonomies, updated by Anderson & Krathwohl (2001), encompassing different ways of using content in class, beyond mere memorization/replication. His approach is to adopt critical and creative approaches, and to develop students' commitment to what is learned.

The second aspect of PCK refers to the potential for knowledge transference, seen as the end objective of learning and as the basis of the creative processes taking place in and through problem-solving (Brandsford *et al.,* 2000). Transference requires us to make advances in our approach to knowledge. Taking as a model the SOLO taxonomy ("Structure of Observed Learning Outcome"), developed by Biggs & Collis in 1982, Hattie & Clark (2019) suggest that we should shift from using isolated ideas (superficial learning) towards connected ones. In this transition, ideas from different fields connect with each other, thereby allowing for their transference and application to different contexts (deep learning).

The third aspect is the extent to which the knowledge imparted connects with students' experiences and feelings. The experience of meaningful learning combines thinking, feeling and acting (Novak, 2010), with experiment, reflection and further action (Kolb, 2015). The teacher should

constructively combine these different facets so that students can engage with them and achieve metacognitive awareness and a sense of responsibility for their own education.

The answers to these questions on the structure, distribution, organization, choice, use, transference and connection of subject matter content to be taught with students' educational activity, and their current and future lives, underpins quality in education. When the subject matter content presented to the students has a sound structural and semantic base, is rich, well-ordered, appealing, and has a range of different potentials for practical application, transference and connection with students' lives, then it will serve as a principled grounding and guide for the design and delivery of teaching-learning activities. In this way we can go beyond mere superficial learning based on labelling, and instead boost conceptual learning, grounded in establishing meaningful relationships between the concepts and the fundamental principles in students' mental structures (Weinstein & Sumeracki, 2019).

Method

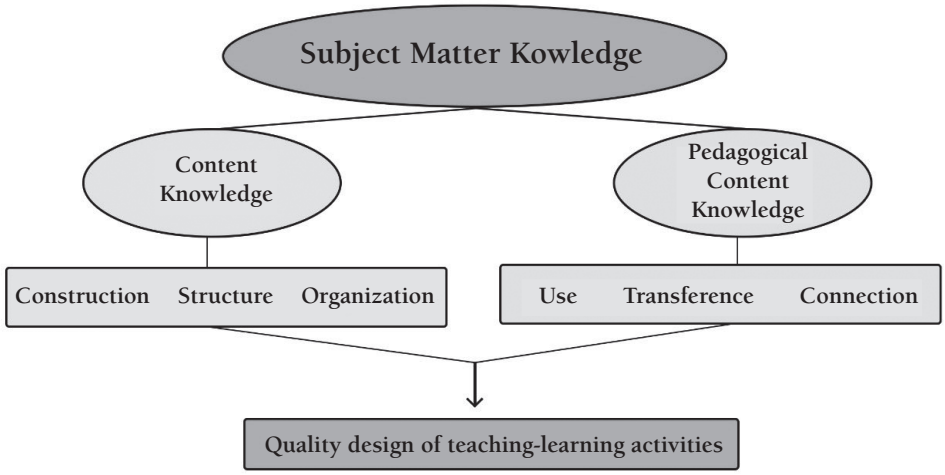
Approach

This study was carried out in the context of the first year of the Degree in Primary Education at a Spanish public university, where future teachers were taking the General Didactics module, which, in turn, is included in the subject of Educational Processes and Contexts, for basic initial training in the theory and practice of teaching. This module encompasses, amongst other things, planning teaching programmes and units for the classroom. Attention to SMK (both CK and PCK) is a basic part of this field, in addition to other polyvalent content with which SMK should be meaningfully combined.

The approach of the study was strongly phenomenological (Holstein & Gubrium, 1994). Using a sample of preservice and practising teachers, the aim is to analyse the differences in the structure of SMK, using concept mapping, on any topic of the Primary Education Curriculum Decree, as a measure for analysing the degree of SMK achieved. The analysis of their concept maps will show the differences or similarities in the level of structural and semantic complexity of the maps, reflecting their levels of SMK. The purpose of this analysis is to verify whether, once preservice teachers receive specific training in SMK during the course of General Didactics in the Degree of Primary Education, they will modify the organisation and structuring of the subject matter they will communicate to students, and whether there are significant differences or changes in the elaboration of the maps, depending on whether they go through the teacher training programme (from the first to the fourth year), or the exercise of the profession.

The hypothesis underlying the study is based on the premise that teachers cannot construct a good didactic design without having a good SMK base, in particular, without having a good base of CK and PCK, which make preservice teachers reflect on the structure and semantics of the content they will communicate to students. Once teachers reach a good level of SMK, they will be able to build a good argument on which to base an adequate didactical design (Figure 1).

Figure 1. The didactic process: from SMK to quality teaching design



Four population segments were included in a stratified probability sample:

- Students on the first year of the Primary Education Teaching module without SMK training – No training (1º SNT).
- Students on the first year of the Primary Education Teaching module with SMK training – (1º SWT).
- Students on the fourth year of the Primary Education Teaching module (4ºS).
- Practising school teachers (PT).

In each segment a simple representative random sample was chosen, large enough to ensure representativeness and to allow us to reach conclusions with a confidence interval of 85%. This ensured the suitability and effectiveness of all analyses. Participation was voluntary and in accordance with the requirements of the university ethical committee. Table 1 shows the characteristics of the participants:

Table 1. Study participants

	First-year students (with and without training)	Fourth-year students	In-service teachers
Ages	18-27	21-27	27-55
Participants (total)	116	53	38
Women	82	46	30
Men	34	7	8

The study had three guiding questions:

- Does the lack of SMK training (in both CK and PCK) among participants hinder the design of teaching activities aimed at creating meaningful learning and strengthening students' conceptual structures?
- Will trainee teachers receiving such specific training be equipped to design better teaching activities with this end in mind?
- Are there any significant changes or differences in the organization of SMK that can be traced to pre-service training or professional teaching experience?

Procedure

The methodological procedure was as follows. During the practicum of the General Didactics module for the 2019-20 academic year, the content of the Primary Curriculum Decree on the subject of "Animals", from the second cycle of Natural Sciences, was chosen, and participants were asked to develop a teaching unit around it. The task rubric read: *You are to present the topic "Animals" to your students. Draw up a concept map reflecting the content you will teach.* Participants were given sheets of paper and 30 minutes to complete the task.

The same activity was carried out with fourth-year students at the end of their practicum, and also with practising teachers from state primary schools in the same province. After drawing up their maps, the first-year students received specific training in SMK as part of the General Didactics module, including instruction on what a concept map is, its use and structure. Subsequently they were asked to produce a new concept map.

Drawing up concept maps was considered an appropriate way to determine the outcomes of training in SMK, since these diagrams represent the conceptual and semantic structure of a subject matter after meaningful learning (Cañas *et al.,* 2015; Novak, 2010). They are made up of both content and structure, and show the relationships between the concepts of a subject matter through propositions acting as links between concepts and building networks of meaning (Novak, 2010; Sousa, 2017).

To analyse the concept maps we used the structural and semantic rubrics devised and validated by Cañas (2006), Cañas *et al.* (2015), Miller & Cañas (2008a, 2008b) and Safayeni *et al.* (2005).

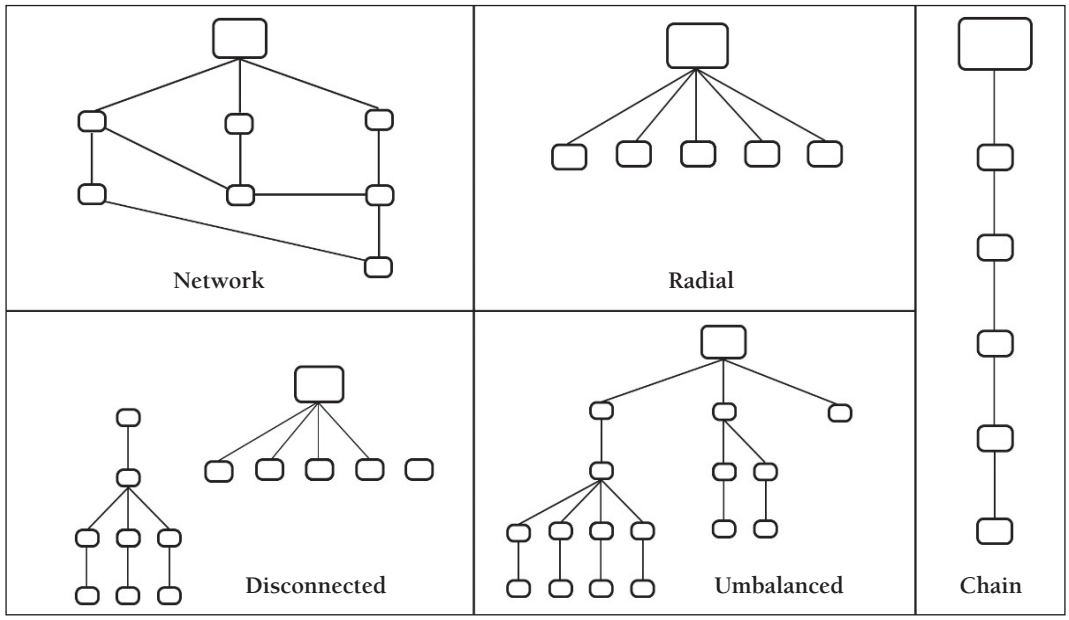
The structural rubric included the following criteria (Cañas 2006; Cañas *et al.,* 2015):

1. The number of concepts.
2. The depth of hierarchy, i.e. the number of links from the root concept to that furthest from the root.
3. Ramification, i.e., the number of nodes or concepts that the map is divided into (the number of branches in each concept was not counted).
4. The number of crossed links connecting concepts from different branches through propositions.

Concept maps position ideas in relation to each other, reflecting precision and semantic richness. For this reason, we used two classifications of concept map structure: that of Kinchin *et al.* (2000), which distinguishes between chain, radial and network maps, and that of Buhmann & Kingsbury (2015), differentiating balanced from unbalanced and disconnected maps.

Chain-style concept maps reflect a sequential-linear view of reality. Radial maps organize concepts around a central meaning, creating simple associations. They are common among beginners, and tend to coincide with the structures of national curricula, in which the content of different fields is associated with specific concepts, features, etc. Network-style maps show complex relationships between different concept levels, and tend to be created by experts, deploying deep knowledge to develop them. Balanced maps show harmony and knowledge of the whole subject. Disconnected and unbalanced maps reflect lack of organization, lack of understanding and conceptual incoherence (Figure 2).

Figure 2. Concept map structures



The semantic rubric (Miller & Cañas, 2008a, 2008b; Safayeni *et al.,* 2005) included the following analytical criteria:

- The presence of static propositions connecting concepts; for example, those known as "static-descriptive", using connectors ("it is", "they are", "it has", etc.) and those known as "static-classifying", which order and itemise content into types, classes, categories, etc.
- The presence of dynamic propositions, developed through core questions that enquire into the *what*, *how*, *why*, *what for*, etc. of the concepts. These connect concepts in an interconnected and functional way, through relationships of movement, action, association, change, dependence, cause, and effect, etc.

- The presence of connections between concepts in the form of phrases explaining the features of the concept, intended to facilitate memorization.
- The use of examples.
- The presence of repeated connecting propositions.

The analytical criteria used to identify changes in students' competences stemming from their improved grasp of SMK were:

- The level of knowledge organisation among first-year students with no specific training in the SMK (CK and PCK) of the chosen topic (animals).
- The level of knowledge organisation among first-year students after receiving SMK training.
- The level of knowledge organisation among fourth-year students after completion of their pre-service training.
- The level of knowledge organisation in SMK among practicing teachers.
- Differences in SMK organisation among the four groups of participants.

The concept maps of the pre- and in-service teachers were separately and manually assessed by two different researchers, using various rubrics, and following recommendations from Neuendorf (2017) for content analysis without technological support. Subsequently the analyses were combined, and 100% concurrence achieved. Multiple χ^2 homogeneity tests were performed on the data obtained from the structural and semantic analysis of the maps, after confirmation of the hypotheses necessary for correct application (Garthwaite *et al.,* 2002). The homogeneity tests were carried out in Excel and later verified using the RStudio program to ensure reliability of results.

A simple proportional analysis would not have allowed us to draw valid conclusions, as the data were not directly comparable in absolute terms, except in the case of the two first-year groups (with and without training). However, the differences in size between the three samples (first-year group, four-year group, and practising teachers) were not problematic for homogeneity tests. When focusing on semantic content, due to the prevalence in all four groups' maps of relationships classifying the types of living beings, an analysis was made of the most common static-classifying propositions used to categorise animal types, according to the criteria: skeleton, feeding habits, reproduction, habitat, locomotion and body covering. The remaining static and dynamic propositions, due to their variety and diversity, were not taken into account, since their analysis did not yield significant conclusions.

Discussion of results

The creation of knowledge structures is a gradual constructive and reconstructive process whose organization and reorganization come from outside the student (Sousa, 2017; Weinstein & Sumeracki, 2019). Teachers have an essential role to play in this process of building students' semantic memory (Klimesc, 2015). For this to happen, teachers must have an adequate level of SMK (Novak, 2010).

However, the results of this study shows that both pre-service teacher and practising teachers had weak SMK formation. Both groups of teachers show very homogeneous results. Not being equipped with SMK inevitably weakens teaching for well-developed, transferable structural and semantic knowledge. On the basis of the concept structures reflected in the analysed maps, it would be difficult to design teaching-learning activities enabling students to go beyond superficial memorisation-style learning (Mayer, 2002).

The specific training in SMK (CK and PCK) given on the General Didactics module improved knowledge structure and facilitated acquisition of the competency of planning meaningful, deep teaching-learning activities. First-year students with SMK training had more concept structures organised in networks with crossed links and greater balance between static and dynamic propositions. This enables access to knowledge on the *what* and the *how*, but also permits interpretation, transference and a certain empathy with what is being learnt.

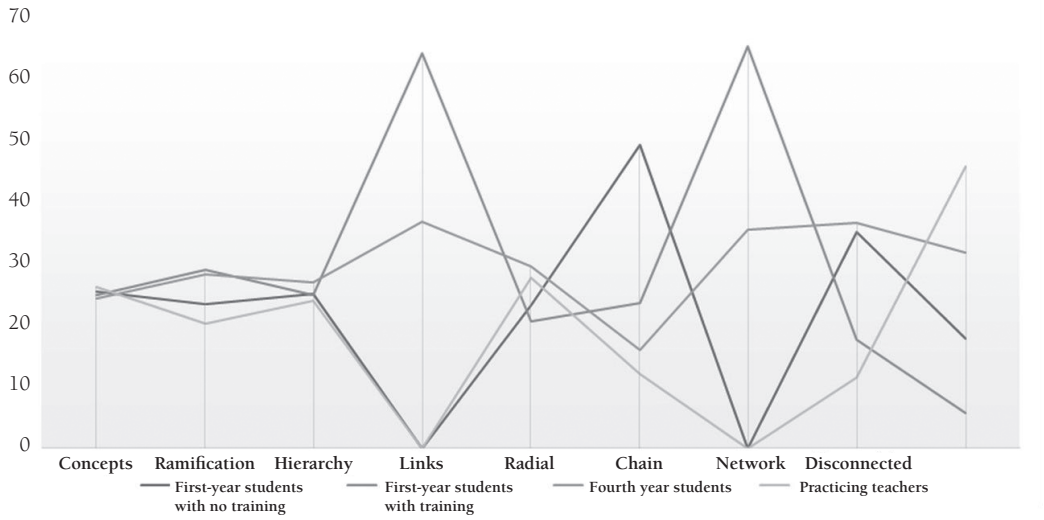
Table 2 shows a preliminary outline of the results, comparing the mean frequency of each mode of concept map. For each mode, the highest mean is shown.

Table 2. Comparison of means for each mode of concept map

		Mathematical mean of frequency for each mode by groups			
	Modes	**First-years with training**	**First-years with no training**	**Fourth-years**	**Practising teachers**
Structure	Concepts	24.53	26.36	22.09	**26.45**
	Ramifications	3.68	**5.03**	4.17	3.34
	Hierarchies	1.91	**2.09**	1.92	1.92
	Links	0	**0.08**	0.04	0
	Radial	0.69	0.68	0.83	**0.87**
	Chain	**0.31**	0.16	0.09	0.08
	Network	0	**0.16**	0.08	0
	Disconnected	**0.15**	0.09	**0.15**	0.05
	Unbalanced	0.15	0.05	0.25	**0.39**
Semantic	Static prop.	3.72	**4.44**	4.06	4.21
	Dynamic prop.	0.01	**1.53**	0.13	0.11
	Repeated prop.	**0.65**	0.46	0.34	0.05
	Sentences	0.11	0.23	0.45	**0.61**
	Examples	**2.26**	1.92	0.43	0.63
Relations	Skeleton	0.92	0.79	**0.98**	0.89
	Feeding	0.83	**0.84**	0.68	0.55
	Locomotion	0.26	0.19	**0.39**	0.21
	Reproduction	**0.71**	0.56	0.64	0.55
	Habitat	0.33	**0.54**	0.34	0.24
	Covering	0.03	**0.12**	0.11	0.11

Figure 3 shows the results obtained after performing an χ^2 homogeneity test on the structural components of the concept maps of each of the four groups.

Figure 3. Comparison of concept map structure between groups



The most important finding was that the maps by the first-year students with no training, the fourth-year students and the practising teachers were similar in structure, while those by the first-year students with training differed considerably (Table 3).

Table 3. Values used for the χ^2 test on the data resulting from the structural analysis

Modes	Groups	*n*	*M*	n_{esp}	χ^2(n)	$\sum\chi^2$
Concepts	1ºSWT	3084	26.36	3100.09	0.08354	2.77469
	4ºS	1171	22.09	1199.09	0.65849	
	Teachers	1005	26.45	960.81	2.03266	
Ramifications	1ºSWT	588	5.03	551.65	2.39501	13.97675
	4ºS	221	4.17	213.38	0.27241	
	Teachers	127	3.34	170.97	11.30933	
Hierarchies	1ºSWT	245	2.09	247.54	0.02598	0.61477
	4ºS	102	1.92	95.75	0.40856	
	Teachers	73	1.92	76.72	0.18023	
Links	1ºSWT	9	0.08	6.48	0.99714	3.10169
	4ºS	2	0.04	2.51	0.10276	
	Teachers	0	0	2.01	2.00919	
Radial	1ºSWT	79	0.68	91.94	1.82173	2.71388
	4ºS	44	0.83	35.56	2.00179	
	Teachers	33	0.87	28.49	0.71209	

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Table 3. Values used for the χ^2 test on the data resulting from the structural analysis (cont.)

Modes	Groups	*n*	*M*	n_{esp}	χ^2(n)	$\sum\chi^2$
Chain	1ºSWT	19	0.16	15.91	0.59884	1.57235
	4ºS	5	0.09	6.16	0.21676	
	Teachers	3	0.08	4.93	0.75675	
Network	1ºSWT	19	0.16	13.56	2.18672	6.68278
	4ºS	4	0.08	5.24	0.29478	
	Teachers	0	0	4.21	4.20125	
Disconnected	1ºSWT	10	0.09	11.79	0.27104	3.61572
	4ºS	8	0.15	4.56	2.59651	
	Teachers	2	0.05	3.65	0.74817	
Unbalanced	1ºSWT	6	0.05	20.03	9.83515	25.82936
	4ºS	13	0.25	7.75	3.55494	
	Teachers	15	0.39	6.21	12.43927	
	TOTAL	-	-	-	-	60.88199

First-year students with training showed more ramifications than the other groups, thereby indicating that their maps were more complex and better-developed.

The χ^2 test showed that the concept maps by the fourth-year students and those by the practising teachers were similar in their use of radial and chain structures. Also, the test showed that there were differences in the layout of the chain, disconnected and unbalanced types between first-year students with training, fourth-year students and practising teachers. The maps by the first-year students with training were very rarely unbalanced or disconnected, in contrast to those by the fourth-year students, who created the same number of disconnected maps as first-year students with no training. The first-year students with training drew maps with more crossed links and network structures, and less with radial or chain structures. The disconnections in the first-year students' maps diminished by almost half after receiving training, and the number of unbalanced maps also fell by almost 65%.

Figure 4 shows the mean obtained from the homogeneity tests of each of the different modes in the semantic analysis (Table 4).

The maps by the first-year students with no training, the fourth-year students and the practising teachers were different in their use of sentences, examples and repeated propositions. Those of the first-year students with training, fourth-year students and practising teachers were similar in the numbers of static propositions, although the first years with training used them more. This latter group was significantly different in their use of dynamic propositions (utility, survival, origins and extinction, habits, care, rights, living conditions, social implications, respect, food chains, relationships with humans, empathy, curiosities, etc.). The "sentences" mode showed a rising tendency, from the first years through the fourth-years to the practising teachers. The "examples" and "repeated propositions" were more prevalent among first years with no training, falling by 29% and 15% respectively among first-years with training, and finally to almost zero among in-service teachers.

Figure 4. Comparison by groups of the semantic components of the concept maps

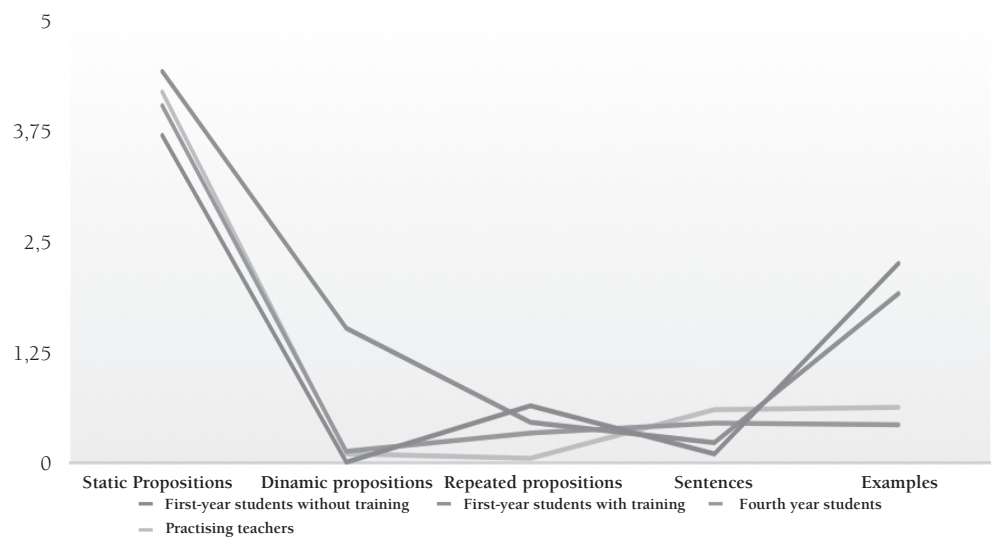
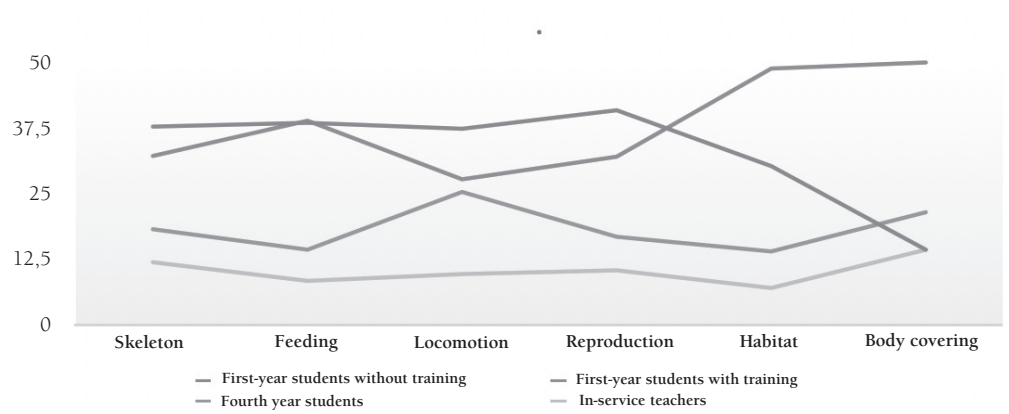


Table 4. Values used for applying the χ^2 test to the data from the semantic analysis

Modes	Groups	*n*	*M*	n_{esp}	χ^2(n)	$\sum\chi^2$
Static propositions	1ºSNT	435	3.72	461.80	0.62471	1.79592
	4ºS	215	4.06	201.35	0.92537	
	Teachers	160	4.21	153.85	0.24584	
Dynamic propositions	1ºSNT	1	0.01	3.05	1.37787	1.74333
	4ºS	7	0.13	6.67	0.01633	
	Teachers	4	0.11	2.98	0.34913	
Repeated propositions	1ºSNT	76	0.65	63.76	2.34971	17.70535
	4ºS	18	0.34	21.37	0.53281	
	Teachers	2	0.05	11.86	8.19727	
Sentences	1ºSNT	12	0.11	36.11	16.10141	43.09418
	4ºS	27	0.45	13.14	8.98370	
	Teachers	24	0.61	9.75	18.00907	
Examples	1ºSNT	265	2.26	190.97	28.69241	74.50376
	4ºS	23	0.43	69.47	31.08284	
	Teachers	24	0.63	51.56	14.72851	
	TOTAL	-		-	-	138.8425

Regarding the degree of homogeneity of the static-classifying propositions, the χ^2 test revealed close similarity between all groups in their inclusion of relationships linked to the categories of skeleton, feeding habits, reproduction, habitat, locomotion and body covering (Figure 5)

Figure 5. Comparison of frequency of static-classifying propositions for the four groups (percentages of the total)



This finding reflects a similar concept structure, which did not change after not specific SMK training (Table 5).

Table 5. Values used for the χ^2 test performed on the data on semantic relationships

Modes	Groups	*n*	*M*	n_{esp}	χ^2(n)	$\sum\chi^2$
Skeleton	1ºSNT	108	0.92	112.19	0.15614	0.67353
	4ºS	52	0.98	51.75	0.00117	
	Teachers	34	0.89	30.06	0.51622	
Feeding	1ºSNT	97	0.83	89.05	0.70894	1.68126
	4ºS	36	0.68	41.08	0.62891	
	Teachers	21	0.55	23.86	0.34341	
Locomotion	1ºSNT	31	0.26	34.69	0.39382	2.13268
	4ºS	21	0.39	10.01	1.55789	
	Teachers	8	0.21	9.29	0.18097	
Reproduction	1ºSNT	83	0.71	79.81	0.12816	0.35024
	4ºS	34	0.64	36.81	0.21521	
	Teachers	21	0.55	21.38	0.00687	
Habitat	1ºSNT	39	0.33	38.16	0.01822	0.17416
	4ºS	18	0.34	17.61	0.00877	
	Teachers	9	0.24	10.23	0.14717	
Body covering	1ºSNT	4	0.03	8.09	2.07217	4.99088
	4ºS	6	0.11	3.73	1.37383	
	Teachers	4	0.10	2.17	1.54488	
	TOTAL	-		-	-	10.00275

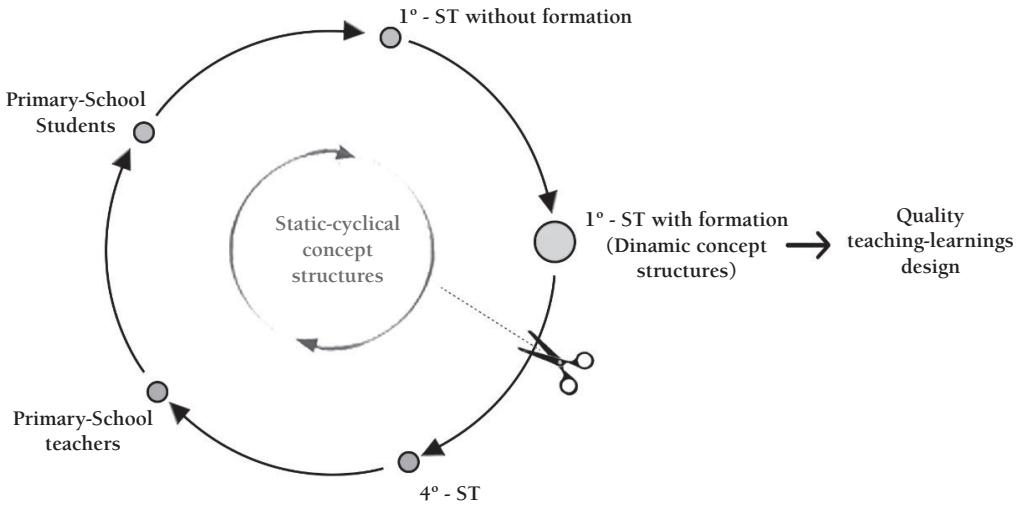
The results of this study show that preservice and practising teachers, without specific training in SMK, produce very poor concept maps. From the conceptual structure reflected in their concept maps, it is difficult to construct didactic designs that allow them to go beyond mere rote

learning (Mayer, 2002). With the overdose of static-classificatory propositions about types of animals according to their physical attributes, feeding, or reproduction, etc., with which students' minds are overloaded, the possibilities for them to use the knowledge in a way that is not merely replicative are reduced. This conceptual structure reduces the possibilities for an interpretative and critical use that allows them to ask why, how, what for, under what conditions, what needs, etc., animals have. With the endless list of classifications of animals, in some cases disconnected and unbalanced, with a radial or chain structure, little can be done to achieve learning about animals that is not merely rote learning. For all these reasons, the possibilities of transferring what is learnt, of becoming aware of and developing a certain empathy towards what is learnt are reduced. Definitely, with this type of content, there are few possibilities for creation, and many for the accumulation of isolated ideas about classifications of animals into amphibians, reptiles, mammals, omnivores, viviparous, etc., reducing the possibilities for students to feel that they are somewhat protagonists of their own learning. Even if teachers plan to use methodologies of enquiry, discovery, etc., in the development of their Primary class, they will find it difficult to do so if they use the conceptual and semantic structure of the content shown in the concept maps analysed in this study. Only the preservice teacher's group with specific training on SMK improve their knowledge structure on "Animals", showing a richer structure capable of being the basis for a meaningful and deep didactic design. This group shows maps with a greater number of networked conceptual structures through cross-linking, and a better balance between static and dynamic propositions. This will allow access to knowledge how animals are, but also a connection to aspects of animals' lives such as their needs, living conditions, responsibilities towards animals, etc.

Conclusions

From the discussion of these results, two conclusions can be drawn that reflect the ineffectiveness of teacher training programmes in terms of SMK training. The first is that the conceptual structure reflected in the concept maps of most preservice and practising teachers reflects a very limited knowledge of CK (structure and semantics), which will make it difficult to connect with adequate PCK (facilitating the use, transfer and connection of the knowledge to be learnt with the life and interests of the students). Only when future teachers receive specific training on SMK, they show a richer and more elaborated conceptual structure that will serve as a basis for meaningful learning. Secondly, the knowledge structure of preservice and practising teachers is cyclical, repetitive and similar, from first year preservice teachers to fourth year and practising teachers. There is no conceptual change in the knowledge structure of preservice and practising teachers. The future teachers of the primary education degree (without specific SMK training), who are taking the subject of General Didactics, will teach Primary Education students on the basis of the conceptual structure reflected in these analysed concept maps. These Primary Education pupils may eventually become preservice teachers in the Degree of Primary Education in the future, and they will repeat this same structure learned at school to think, feel and act on the subject of "Animals", thus closing this vicious circle for training and for the construction of mental structures. Only students in the course of General Didactics in the Degree of Primary Education, with specific training in SMK, show differences in the conceptual structure. Therefore, this specific training in SMK should be powerful enough to interrupt and break with the static and memorised conceptual structure assimilated in the teacher training programmes (Figure 6).

Figure 6. Participants' static-cyclical concept structures



One cause of the problem in our context may be the scant interest in SMK shown by the Spanish teaching tradition and in most Spanish teacher training courses. The SMK is forgotten (missing paradigm) (Shulman 1987) and discredited. Perhaps this disregard for the SMK can continue to be considered an option, leaving it in the background, without giving it the importance it deserves. Contradictorily, it can even continue to be identified as counterproductive for having received excessive attention in teacher training, as Bolívar (2009) indicates: "It is not that we have forgotten the paradigm (the "missing paradigm") of subject knowledge, as Shulman writes of the North-American context, and that we should reassess content and how it is taught, but on the contrary that this has had almost exclusive prevalence in teacher training" (p. 95).

Shulman (2015) found that SMK was more highly developed in teacher training in "China, Germany, Norway, the Netherlands, Australia, Brazil and Israel, in addition to California and Massachusetts" (p. 13). Grossman *et al.* (1989) note that "researchers and teacher educators have been slow to recognise the powerful influence that subject knowledge, or lack of subject knowledge, has on teaching. Therefore, once aware of its centrality, teacher educators should stimulate the connection between didactic action and content in actual teacher education practice" (p. 20).

To paraphrase Shulman (2015), it seems that in Spain SMK has not been adopted as the "chosen son" in teacher training. Based on the evidence of this study, we may legitimately ask if didactic attention to SMK can still be seen as optional; if it is technically responsible to reduce it to secondary importance and continue associating it with traditional or conservative teacher education; and, in short, if the epistemologically and politically correct line, associated with the collective ego identified with the deweyan tradition or with a biased form of criticism, is capable of making the change towards what seems to be better practice in teacher training.

Although decades apart, the quote from Grossman *et al.* (1989), is still valid today, and numerous investigations confirm the importance of the SMK (Gousenghim, 2017; Levin, 2018; Schmidt *et*

al., 2020). Therefore, this work strongly advocates giving the CK and the PCK the attention it deserves and giving it the priority place it currently occupies associated with the movement of basic practices for teacher training (Grossman, 2018; Kavanagh *et al.,* 2019; McGrew *et al.,* 2018). Perhaps the perspective from which the SMK has been considered in the Spanish context has been exclusively rote and representational, a perspective that must be rejected without a doubt, as Bolívar (2008) points out, or as the current Spanish educational law LOMLOE points out. But it would be a serious mistake to reject SMK and its associated development for the benefits of developing conceptual and semantic memory (Klimesch, 2015; Novak, 2010). Therefore, it is necessary to give it the prominence it deserves and keep it in mind from its two dimensions, CK and PCK. This will allow future teachers to be trained in the necessary skills to make didactic designs that allow the development of the conceptual structure of the students, and to be able to achieve the desired significant and deep learning that all quality teaching seeks.

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Resumen

El conocimiento de la materia en la formación del profesorado de Educación Primaria

INTRODUCCIÓN. En el artículo se cuestiona un problema básico de la didáctica: la relevancia del conocimiento de la materia como requisito de calidad en la formación del profesorado. El conocimiento de la materia se asume como necesario para facilitar el aprendizaje y la educación del alumnado desde la enseñanza. Concretamente, se entiende como requisito para que los docentes puedan realizar diseños y desarrollos didácticos que faciliten experiencias de aprendizaje significativas y fortalezcan la estructura conceptual de su alumnado. El objetivo de la investigación es conocer si los futuros profesores de Educación Primaria y los docentes de Primaria en ejercicio disponen de un adecuado conocimiento de la materia de enseñanza. MÉTODO. Para dar respuesta al objetivo, se examina el tipo y organización de su conocimiento a través de mapas conceptuales, evaluando las producciones con rúbricas estructurales y semánticas validadas. RESULTADOS. Los resultados muestran que, en general, el profesorado posee una organización del conocimiento de la materia muy pobre, con un débil potencial didáctico. DISCUSIÓN. Asimismo, los datos indican que existen diferencias poco significativas entre los mapas conceptuales de los profesores en formación y los realizados por los docentes en ejercicio, lo que refleja una estructura de conocimiento similar y cíclica. Las conclusiones inciden en el poco efecto formativo que, en general, producen los programas de formación del profesorado para la adquisición del conocimiento de la materia, comprendido

como un requisito didáctico esencial para la formación básica del profesorado y para el desarrollo de una enseñanza de calidad.

Palabras clave: *Formación del profesorado, Conocimientos básicos para la enseñanza, Conocimiento pedagógico del contenido, Eficacia del profesorado.*

Résumé

Connaissance des matières dans la formation des enseignants de l'enseignement primaire

INTRODUCTION. L'article s'interroge sur un problème fondamental de la didactique : la pertinence de la connaissance des matières en tant qu'exigence de qualité dans la formation des enseignants. La connaissance des matières est supposée être nécessaire pour faciliter l'apprentissage des élèves et dans la formation à l'enseignement. Plus précisément, il est une exigence pour les enseignants d'être en mesure d'effectuer des conceptions et des développements didactiques qui facilitent des expériences d'apprentissage significatives et renforcent la structure conceptuelle de leurs élèves. L'objectif de la recherche est de déterminer si les futurs enseignants du primaire et les enseignants du primaire en exercice ont une connaissance adéquate de la matière enseignée. **MÉTHODE**. Afin de répondre à l'objectif, le type et l'organisation des connaissances sont examinés au moyen de cartes conceptuelles en évaluant les productions à l'aide de rubriques structurelles et sémantiques validées. **RÉSULTATS**. Les résultats montrent qu'en général les enseignants ont une très mauvaise organisation de leurs connaissances avec un faible potentiel didactique. **DISCUSSION**. Les données indiquent également qu'il existe des différences insignifiantes entre les cartes conceptuelles des enseignants en formation et celles des enseignants en exercice, reflétant une structure de connaissances similaire et cyclique. Les conclusions soulignent l'impact formatif généralement faible des programmes de formation des enseignants sur l'acquisition de connaissances disciplinaires, même si elles sont considérées comme une exigence didactique essentielle pour la formation basique des enseignants et pour le développement d'un enseignement de qualité.

Mots-clés *: Formation des enseignants, Base de connaissances pour l'enseignement, Connaissance du contenu pédagogique, Efficacité des enseignants.*

Perfil de los autores

Cristina Moral Santaella

Profesora titular de la Universidad del Departamento de Didáctica y Organización Escolar de la Facultad de Educación de la Universidad de Granada. Perteneciente a las redes de investigación sobre mejora de la educación, justicia social y liderazgo educativo de directores y profesores RILME, ISSPP, ISLDN e ISTL.
ORCID: https://orcid.org/0000-0002-7302-165X
E-mail: cmoral@ugr.es

Agustín de la Herrán Gascón (autor de contacto)

Profesor titular del Departamento de Pedagogía de la Universidad Autónoma de Madrid (UAM). Promotor del enfoque radical e inclusivo de la Pedagogía y de la Didáctica General. Director del grupo de investigación "Pedagogía, formación y conciencia".
ORCID: https://orcid.org/0000-0001-9156-6971
E-mail: agustin.delaherran@uam.es
Dirección para la correspondencia. Departamento de Pedagogía, Facultad de Formación de Profesorado y Educación, Universidad Autónoma de Madrid. Campus de Cantoblanco. Ctra. de Colmenar Viejo, km 15,500. 28049 Madrid.