Training in the Primary Education Teacher Degree in STEM disciplines: Analysis before its reform in Spain

Formación en el Grado de Educación Primaria en las disciplinas STEM: Análisis ante su reforma en España

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Abstract

The new Law of Education in Spain, known as LOMLOE, includes for the first time the STEM competence with its own entity, among other changes. Accordingly, a reform of the curricula of the Primary Education Teacher Degrees is proposed, for which a deep and global analysis of this initial training is essential. Thus, the objectives that guided this study included the following: *i)* to compare the distribution of credits among STEM disciplines and their didactics; *ii)* to check whether scientific-mathematical or didactic content predominates; *iii)* to analyse the contents of Technology and Engineering; and *iv)* to compare these aspects between public and private universities. To that end, the study plans of the 37 public and 22 private universities that offered the Primary Education Teacher Degree in the 2020-2021 academic year were analysed. The teaching guides of the 342 compulsory subjects of the associated disciplines were evaluated, considering their contents and their timing, and a descriptive and inferential study was carried out. The results show that public universities allocate more credits to training in STEM disciplines, especially to the disciplinary content of mathematics and science, while there is a significant dispersion in the data. In public universities there is a major focus on disciplinary content, especially in science. Regarding technology, the contents are specific to Information and Communication Technologies, and not to technology understood from the STEM perspective. In addition, engineering and the global STEM approach itself are absent. This analysis reveals the need to renew the curricula with contents that are more adapted to what the LOMLOE demands and, above all, explicitly including aspects of technology and engineering with a STEM approach.

Keywords: STEM, LOMLOE, pre-service primary teacher training, science, mathematics, technology, engineering, public universities, private universities

Resumen

La nueva Ley de Educación, conocida como LOMLOE, incluye entre otros cambios y por vez primera la competencia STEM con entidad propia. En consonancia, se propone una reforma de los planes de estudio de los Grados de Magisterio en Educación Primaria, para lo cual resulta indispensable un análisis profundo y global de dicha formación inicial. En este estudio se abordan los siguientes objetivos: *i)* comparar la distribución de créditos en las disciplinas STEM y sus didácticas; *ii)* comprobar si predominan los contenidos científico-matemáticos o los didácticos; *iii)* analizar los contenidos de Tecnología e Ingeniería; *iv)* comparar estos aspectos entre universidades públicas y privadas. Para ello, se revisan los planes de estudios de las 37 universidades públicas y 22 privadas que ofertan el Grado de Magisterio en Educación Primaria en el curso 2020-2021. Se analizan las guías docentes de las 342 asignaturas obligatorias de las disciplinas relacionadas, atendiendo a sus contenidos y a su temporalización, y se realiza un estudio descriptivo e inferencial. Los resultados muestran que las universidades públicas dedican más créditos a la formación en las disciplinas STEM, especialmente a los contenidos disciplinares de matemáticas y ciencias, existiendo una importante dispersión en los datos. En las universidades públicas, los contenidos disciplinares predominan sobre los didácticos, especialmente en ciencias. En cuanto a la tecnología, los contenidos son propios de las llamadas Tecnologías de la Información y la Comunicación, y no de la tecnología entendida desde STEM. Por su parte, la ingeniería y el propio enfoque global STEM están ausentes. Este análisis revela la necesidad de renovar los planes de estudio con contenidos adaptados a lo que demanda la LOMLOE, fundamentalmente, incluyendo aspectos de tecnología e ingeniería desde una perspectiva STEM.

Palabras clave: STEM, LOMLOE, formación inicial de maestros, ciencias, matemáticas, tecnología, ingeniería, universidades públicas, universidades privadas

Introduction

The international expansion of the STEM educational approach (acronym for Science, Technology, Engineering, and Mathematics) has been unstoppable since its conception in the United States in the 1990s. Nowadays, its influence is evident in most educational contexts across the globe (Belbase et al., 2021). Although there is no clear conceptualisation of STEM, Moore et al. (2014) define STEM education as “an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems” (p.38). On this basis, there are different perspectives on integration in STEM, ranging from those that advocate for the fusion of all disciplines through transdisciplinary problems (Costantino, 2018) to others that emphasise the uniqueness of each subject while acknowledging its epistemic complementarity (Simarro & Couso, 2021). In addition, in recent years, there has also been a demand for the integration of Arts and Humanities into this approach (which could become STEAM), to unify convergent and divergent thinking and promote more inclusive academic and professional identities (Aguilera & Ortiz-Revilla, 2021).

The Spanish prospective report titled “Spain 2050” (Ministry of the Presidency, 2021) highlights the importance of increased training in STEM areas. Therefore, the new Education Law, recently approved and known as LOMLOE, introduces the STEM competence for the first time (mathematical competence and competence in science, technology, and engineering), which “involves understanding the world using scientific methods, mathematical thinking and representation, technology, and engineering methods to transform the environment in a committed, responsible, and sustainable way” (Royal Decree 157/2022, p.24406). Moreover, this key competence is associated with five operational descriptors in both Primary and Secondary Education.

With the introduction of this new legal framework, the Ministry of Education has also proposed updating Primary Education Teacher Degrees (MEFP, 2022a), given the critical role of teachers' practice in promoting scientific literacy. Therefore, if the aim is to improve teacher training for the development of the STEM competence, a prior analysis of initial training in the various STEM disciplines in Primary Education Teacher Degrees is required. Although there are several studies for each discipline, a joint analysis such as the one proposed in this paper has not been conducted yet.

Furthermore, a proper analysis should include private universities, as they represent a high percentage of students in Spain, specifically 26.6% in the 2020/21 academic year (MEFP, 2022b). Previous studies that have analysed the overall curriculum, i.e., the distribution of credits between basic, disciplinary, and didactic subjects, field experiences, and the final degree project, have not found significant differences with public universities (Sánchez-Urán, 2019). However, each

Received: 02/08/2022 Accepted: 02/04/2023

university decides how to distribute the credits of each module in the different subjects and what content to include. This has been criticised, as these decisions are sometimes based on the trajectory of each faculty or the interests of the departments, rather than on the benefit of the students (Imbernón & Colén, 2014). Moreover, 30 out of the total 240 ECTS of the bachelor's degree are designated as electives and are normally devoted to elective courses or majors.

Training in STEM disciplines

According to the "Teacher Education and Development Study in Mathematics" (INEE, 2012), primary preservice teachers lack mathematical knowledge and skills, leading to decreased confidence, motivation, enjoyment, and sense of the subject's usefulness (Nortes Checa & Nortes Martínez-Artero, 2013). These deficiencies are attributed in part to inadequacies in their previous training and, potentially, to an overemphasis on operational thinking (Socas, 2011). Similar conclusions can be drawn from science education. As such, various national (Martínez-Borreguero et al., 2022) and international authors (Appleton, 2003) have found that future primary school teachers often have inadequate scientific knowledge, alternative conceptions similar to those of school-age pupils, and a rigid understanding of science, which hinders exploration and positive attitudes towards the subject (Porlán et al., 2010).

On the other hand, there is a broad consensus regarding the indispensability of adequate Pedagogical Content Knowledge (PCK hereafter) in both Mathematics and Science, since this element is essential to represent or transform disciplinary knowledge in such a way that students can understand it (Shulman, 1987). In both disciplines, PCK is assumed to comprise knowledge of curricula, students' understanding of these subjects, teaching methods, assessment strategies, as well as orientations towards teaching (Cortés et al., 2012; Naya- Riveiro et al., 2021). In Mathematics, both national and foreign authors (Cardetti & Truxaw, 2014; Naya-Riveiro et al., 2021) highlight the deficiencies in university training regarding mathematical knowledge for teaching. The situation is similarly unsatisfactory in Science, where Cañal (2008) and Toma et al. (2017) analysed the design of inquiry-based teaching units by primary preservice teachers and identified their difficulties in integrating conceptual and procedural knowledge, promoting student reflection, and providing adequate scaffolding.

Although there is widespread recognition of the need to improve the scientific-mathematical and didactic knowledge of future teachers, there is no consensus on whether the didactic component should follow conceptual knowledge per se or whether both should be addressed simultaneously (Amat et al., 2022). In fact, tensions arise between what could be described as a more scientific approach and a more didactic one, and doubts persist on how to bring the two together (García-Barros, 2016). On the one hand, the lack of conceptual knowledge hinders PCK development (Cañal, 2008; Martínez-Borreguero et al., 2022). On the other hand, an isolated or consecutive treatment of the two approaches makes their integration difficult and carries the risk that future teachers will reproduce teaching models that are far removed from social constructivism, where content is not articulated in learning situations connected to the ideas and culture of the students (García-Barros, 2016; Porlán et al., 2010).

Similarly, there is ongoing debate regarding the relative emphasis placed on disciplinary and didactic knowledge in teacher training curricula. In their analysis of the current regulation of Primary Education Teacher Degrees, Pro-Bueno et al. (2022) indicate that "it seems that legislators have placed greater emphasis on the learning of scientific knowledge", and add that "while acknowledging its importance, the curricular proposal is clearly improvable as it prioritises what a teacher should know about science over how to teach it" (p.192). From our point of view, the same conclusion can be drawn when examining the mathematical competences established for future teachers by this law. Accordingly, inservice primary school teachers demand didactic-pedagogical training to a greater extent than strictly disciplinary training (Manso & Garrido-Martos, 2021), despite the aforementioned problems with their scientific-mathematical background.

Received: 02/08/2022 Accepted: 02/04/2023

Regarding the other two STEM disciplines, Technology and Engineering, the debate is also open. Defining technology and differentiating it from engineering is a complex issue (Cavanagh & Trotter, 2008) that varies from country to country (Yata et al., 2020). Some authors even suggest that the two disciplines are so closely linked that they should be taught together (Barak, 2013). However, there is a general consensus that, within the STEM framework, Engineering should focus on solving real-world problems by exploring solutions, developing prototypes, and testing their feasibility, while prioritising the processes and products created (Simarro & Couso, 2021). In fact, several methodologies that follow this approach have been proposed, such as *Design-based Learning* and *Design Thinking*.

On the other hand, Technology within STEM is considered to be the set of tools –often digital– that are used during scientific, mathematical, or engineering practices, or the product developed through these processes. In this respect, some authors state that Technology should not be considered a discipline and should not be included in the STEM acronym alongside Science, Mathematics, and Engineering (McComas & Burgin, 2020). In addition, Technology is not only specific to these fields, but also to social sciences, arts, or technical crafts (Costantino, 2018). With this complexity in mind, this study also analyses the presence of Engineering and Technology in the curricula of the Primary Education Teacher Degrees and assesses whether they are really aligned with their conception in STEM education.

Research questions

As a useful element of debate about curricular changes in the context of the LOMLOE, this work analyses the initial training of primary school teachers in the different STEM disciplines. Specifically, the following research questions regarding the compulsory training in the Spanish Primary Education Teacher Degrees are addressed:

P.1. How many ECTS credits are assigned to scientific-mathematical areas and disciplines?

P.2. Which is the predominant content: scientific-mathematical or didactic?

P.3. Are Technology and Engineering approached from a STEM perspective?

P.4. Are there differences in credits and content between public and private universities?

Understanding the approaches and timing assigned to these areas and disciplines will help promote reflection to articulate curriculum plans that contribute to STEM teacher education.

Method

A cross-sectional statistical study has been conducted based on data collected from the curricula of Spanish universities.

Sample

The study sample comprises the Primary Education Teacher Degree programs at the 37 public universities and 22 private universities in Spain that offered this training during the 2020-2021 academic year.

The curricula were reviewed using the information available on the universities' websites. For this study, all compulsory subjects with STEM content were selected. This selection consisted of 342 subjects, 225 from public universities and 117 from private universities.

The teaching guides for these subjects were then analysed, which include information on scopes, content, competences, methodology, timing, and assessment.

Received: 02/08/2022 Accepted: 02/04/2023

Procedure

To answer the *first two research questions*, the contents and timing of the subjects in the sample were identified based on the teaching guides. According to the most frequent division, the contents were classified into: Mathematics, Physics, Chemistry, Biology, Geology, Didactics of Mathematics, and Didactics of Science.

For the calculation of credits assigned to the contents, the timing indicated in the teaching guides was considered. If this was not explicitly identified, the credits were distributed proportionally to the number of content descriptors.

There are subjects solely dedicated to mathematical or scientific content (sometimes incorporating more than one scientific discipline), subjects dealing entirely with their didactics (curriculum, epistemology, methodologies and strategies, resources, assessment, etc.), and mixed subjects, where the credit count follows the aforementioned guidelines. Some subjects about didactics make use of certain scientific-mathematical concepts and models, but the ultimate aim is to illustrate methodological or didactic approaches. In such cases, credits were linked to didactics.

There are some contents whose categorisation to a certain discipline is not always obvious. In such cases, we followed a criterion consistent with the Primary Education curriculum. For instance, the specific contents of Astronomy (Universe, Solar System, Moon, etc.) were not considered in the analysis, as they are part of the Social Sciences in Primary Education and, therefore, in many universities they are also included in subjects about Geography, a discipline that has been excluded in this study and in the STEM disciplines. Conversely, regarding contents about nutrition and health, which are included in the Natural Sciences curriculum in Primary Education, they were assigned to Biology as it is the most related discipline of those established for the analysis.

The allocation of credits was carried out independently by two members of the research team. Discrepancies were discussed and resolved by agreement with the intermediation of a third researcher. Finally, the results were presented using descriptive statistical parameters.

To analyse the difference in the credits assigned to disciplinary and didactic content in each university, the parameter ε was defined, both for mathematics (ε_M) and science (ε_S), as follows:

$$\varepsilon = \frac{CR_{DID} - CR_{DIS}}{CR_{DID} + CR_{DIS}} \quad (1)$$

Here, ε represents the relative difference between the credits assigned to didactics (CR_{DID}) and to disciplinary content (CR_{DIS}). In particular, $\varepsilon = 0$ indicates an equal distribution between the two, while $\varepsilon > 0$ reveals more emphasis on didactics and $\varepsilon < 0$ on disciplinary content. Extreme values correspond to universities that allocate all their credits to didactic content ($\varepsilon = 1$) or disciplinary content ($\varepsilon = -1$). In addition, we conducted a cluster analysis of these parameters to explore potential groups of universities based on the prevalence of disciplinary or didactic content. The analysis aims to identify groups that are as homogeneous as possible while being different from each other. Various distance algorithms and group formation methods were tested to select those that made sense for the research. In particular, the Euclidean distance method and clustering using the Cutree algorithm (R Core Team, 2018) were chosen.

To address the *third research question*, we reviewed the contents of teaching guides for compulsory subjects dedicated specifically to Technology, analysing their coherence with a STEM approach (Moore et al., 2014). In addition, we checked for explicit references to STEM and specific Engineering content in the overall curriculum (Simarro & Couso, 2021).

Finally, to answer the *fourth research question*, which has a cross-sectional nature, and to make a comparison between public and private universities, the non-parametric Mann-Whitney U test was carried out to determine whether there are statistically significant differences ($p < 0.05$) in the

Received: 02/08/2022 Accepted: 02/04/2023

distribution of credits. This choice was based on the previous application of the Shapiro-Wilk test, which allowed us to rule out the normality of the distributions.

For all research questions, calculation of statistical parameters, cluster analysis and hypotheses tests were carried out using the open-source software R (R Core Team, 2018).

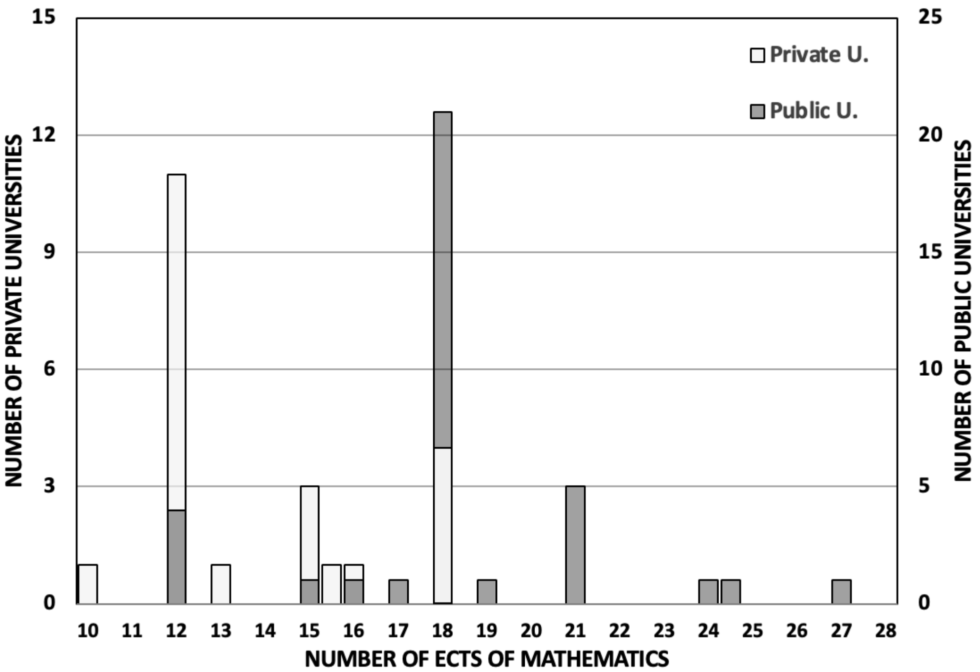
Results

The results are presented in three sections following the first three research questions. The last question is addressed across all sections.

Distribution of credits in scientific-mathematical disciplines

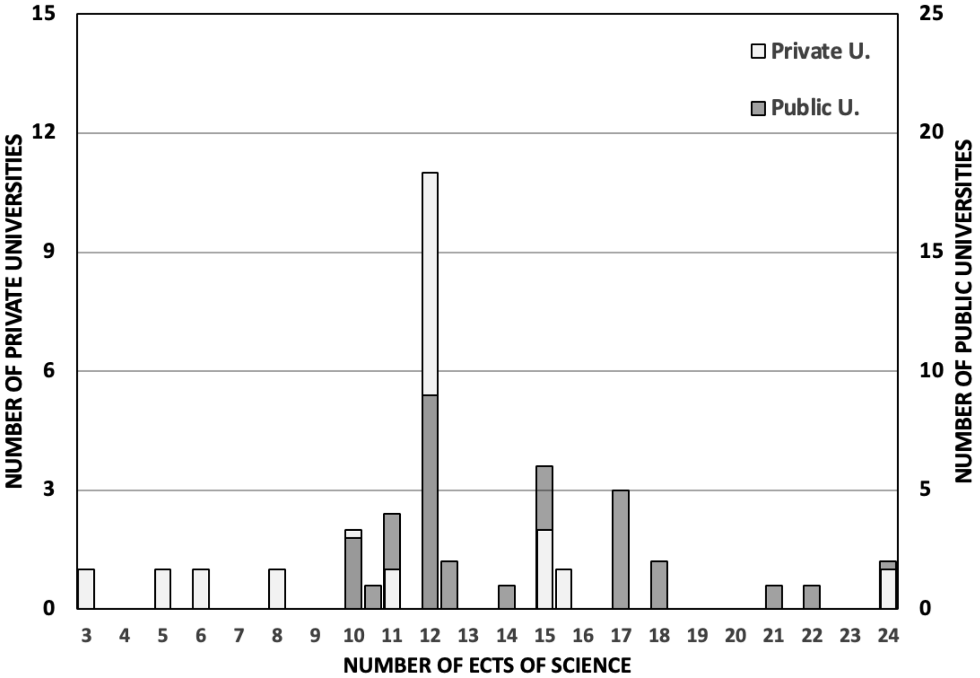
The total ECTS credits allocated to Mathematics and Science in the curricula (including their disciplinary and didactic contents) are shown in Graph I, and the descriptive statistics in Table I. Firstly, the dispersion of the results is striking, with some universities allocating little more than 10 credits to Mathematics and 5 to Science, while others allocate up to 25 credits to each. This dispersion is greater in Science than in Mathematics ($\sigma = 4.2$ vs. $\sigma = 3.6$). Secondly, there is a significant difference between universities, with public universities allocating 31.9% more credits to Mathematics ($U = 694.0$, $p = 2.40e\text{-}06$) and 24.1% more to Science ($U = 559.5$, $p = 0.0149$).

GRAPH I. Distribution of ECTS credits allocated to Mathematics (top) and Science (bottom), including their disciplinary and didactic contents, in public and private universities



Source: compiled by the authors based on the study plans

Received: 02/08/2022 Accepted: 02/04/2023



Source: compiled by the authors based on the study plans

TABLE I. ECTS credits allocated to Mathematics and Science, including their disciplinary and didactic contents

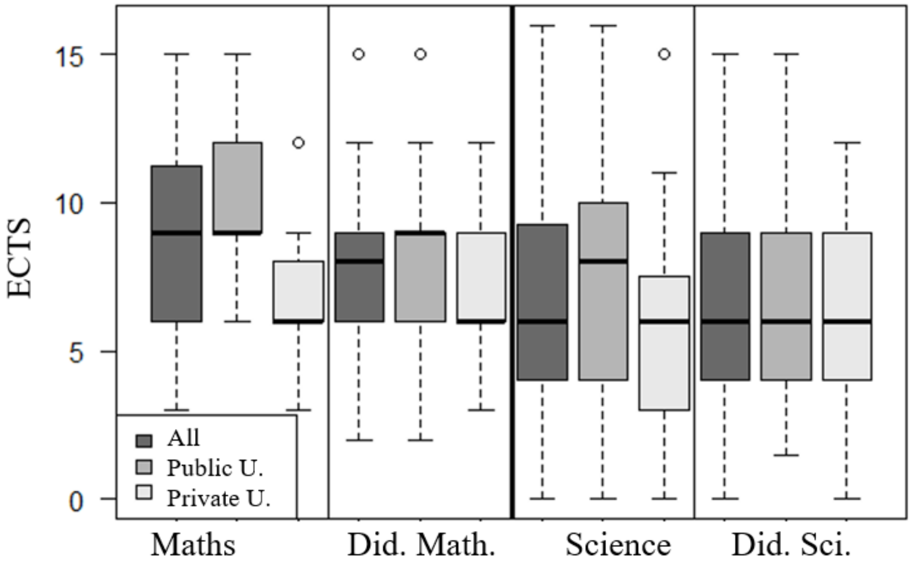
	PUBLIC UNIVERSITIES		PRIVATE UNIVERSITIES		ALL THE UNIVERSITIES	
	Mean	**Standard deviation**	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Mathematics	18.2	3.2	13.8	2.5	16.6	3.6
Science	14.4	3.8	11.6	4.1	13.4	4.2
Mathematics + Science	32.6	4.6	25.4	5.9	29.9	6.2

Source: compiled by the authors based on the study plans

Graph II illustrates the distribution of ECTS credits assigned to disciplinary and didactic content for Mathematics and Science in both types of universities. The results indicate a statistically significant difference in the disciplinary credits for Mathematics (U = 681.5, p = 1.04e-05) and, although relevant, not significant for Science (U = 531.5, p = 0.0510), with public universities assigning more credits to these subjects. Therefore, the fundamental difference between universities is essentially due to the difference in time allocated to disciplinary content. Regarding the ECTS assigned to didactics, the difference between types of universities is not significant.

GRAPH II. ECTS credits allocated to Mathematics, Science (including Biology, Physics, Chemistry, and Geology) and their respective Didactics, in public and private universities

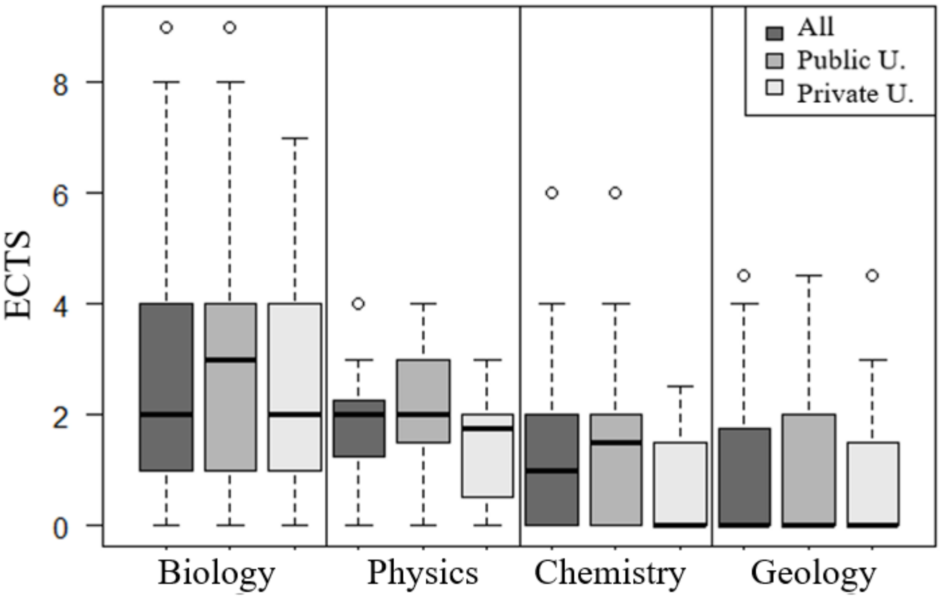
Received: 02/08/2022 Accepted: 02/04/2023



Source: compiled by the authors based on the teaching guides

Finally, Graph III shows the results divided by disciplinary content: Biology, Physics, Chemistry, and Geology. The difference is evident, with the highest weight for Biology, followed by Physics, and quite low for Chemistry and Geology. This gradation aligns with the weight of these disciplines in the Primary Education curriculum. The disparity between types of universities is again evident, with public universities having a greater teaching load. On the other hand, it is remarkable that at least 50% of both public and private universities do not devote any time at all to Geology, nor to Chemistry in the case of private universities. There are no significant differences between the types of universities in any discipline.

GRAPH III. ECTS credits allocated to Biology, Physics, Chemistry, and Geology in public and private universities



Source: compiled by the authors based on the teaching guides

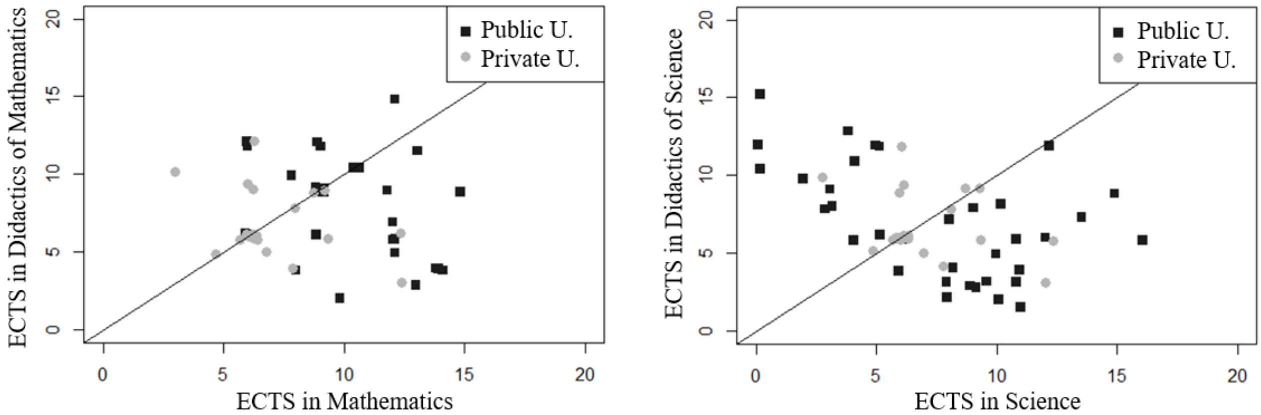
Scientific-mathematical training vs. didactic training

Firstly, the number of credits assigned by each university to scientific-mathematical disciplinary content and to didactic content is analysed. Graph IV displays Mathematics and Science separately;

Received: 02/08/2022 Accepted: 02/04/2023

the straight line represents an equal distribution between both contents, with universities with more didactic credits at the top and those with more disciplinary credits at the bottom. Once again, a wide dispersion in teaching loads can be observed, with a greater dispersion in Science. When comparing disciplinary and didactic credits in public universities, a statistically significant difference is obtained in Mathematics (U = 930.0, p = 0.0062), with a predominance of disciplinary content, but not in Science (U = 740.0, p = 0.5506). In private universities, there are no significant differences between the two domains.

GRAPH IV. ECTS credits allocated in each university to didactic versus disciplinary content, in Mathematics (left) and Science (right)

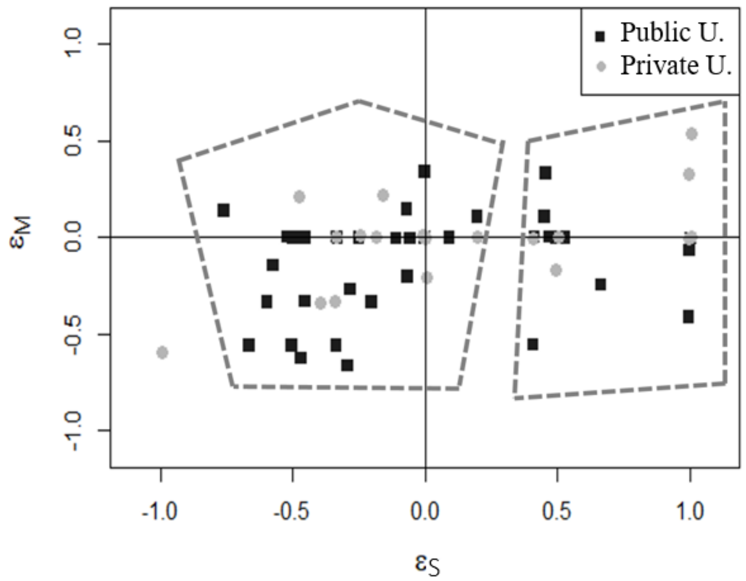


Source: compiled by the authors based on the teaching guides

To illustrate the dominant formative role of each institution, Graph V shows jointly the results of the ε parameter for Mathematics and Science, while Table II provides a distribution of the parameter values. In Mathematics, there are no extreme cases with 0 ECTS for either content. The most common situation in both types of universities exhibits an equal distribution between disciplinary and didactic content ($\varepsilon_M = 0$), although there are many public universities where the more disciplinary approach dominates ($\varepsilon_M < 0$). On the other hand, there are more contrasting trends in Science, as most universities opt for one approach over the other, with the disciplinary content approach dominating ($\varepsilon_S < 0$). The case of the Universitat Abat Oliba CEU is noteworthy, as training is exclusively oriented towards disciplinary content ($\varepsilon_S = -1$). Conversely, in institutions such as Alfonso X el Sabio, Autònoma de Barcelona, La Laguna, Mondragón, Oberta de Catalunya, Vic, and Zaragoza, training is entirely centred on didactics ($\varepsilon_S = 1$). It is important to note that this last approach does not necessarily imply a lack of attention to disciplinary content in the subjects, which could be approached from the perspective of teaching and learning (school models, evolution of students' previous ideas, design of inquiry-based activities, etc.).

GRAPH V. Parameter ε for Mathematics and Science of the universities analysed. The groups identified in the cluster analysis are indicated

Received: 02/08/2022 Accepted: 02/04/2023



Source: compiled by the authors

TABLE II. Distribution of the values of the parameter ε for Mathematics and Science in the universities analysed

	MATHEMATICS (ε_M)			SCIENCE (ε_S)		
	<0	**0**	**>0**	**<0**	**0**	**>0**
Public Universities	15 (40.5%)	16 (43.2%)	6 (16.2%)	21 (56.8%)	3 (8.1%)	13 (35.1%)
Private Universities	5 (22.7%)	13 (59.1%)	4 (18.2%)	8 (36.4%)	6 (27.3%)	8 (36.4%)

Source: compiled by the authors

Graph V also shows the cluster analysis, which divides the sample into two major groups: $\varepsilon_S < 0.3$, comprising 26 public and 14 private universities (70.3% and 63.6%, respectively), and $\varepsilon_S > 0.3$, comprising 11 public and 7 private universities (29.7% and 31.8%, respectively). As a third group, Universitat Abat Oliba CEU appears separately due to its distinct approach. Therefore, the differentiation of university profiles is based on the model assumed for Science and its Didactics (horizontal axis), rather than on the model for Mathematics and its Didactics (vertical axis). While most universities prioritise explicit training in the disciplinary content of Science, a smaller group proposes to structure teacher training around its didactics.

To complement this view, Table III distributes the 298 Mathematics and Science subjects according to whether they address disciplinary or didactic content, or both. As such, it can be observed that public universities predominantly adopt a mixed approach for both disciplines, while private universities exhibit greater diversity.

TABLE III. Subjects with a disciplinary-only, didactic-only, or mixed approach to content

	MATHEMATICS			SCIENCE		
	Disciplinary contents	**Mixed contents**	**Didactic contents**	**Disciplinary contents**	**Mixed contents**	**Didactic contents**
Public Universities	18 (16.8%)	74 (69.2%)	15 (14.0%)	21 (22.8%)	43 (46.7%)	28 (30.4%)
Private Universities	14 (26.4%)	23 (43.4%)	16 (30.2%)	15 (32.6%)	13 (28.3%)	18 (39.1%)

Source: compiled by the authors based on the teaching guides

Another interesting aspect to analyse is whether disciplinary training comes before, begins in the same year as didactics, or comes after it. The results are shown in Table IV, excluding the universities already mentioned which only teach disciplinary or didactic content in the case of

Received: 02/08/2022 Accepted: 02/04/2023

Science. The data reveal that, in both Mathematics and Science, very few universities teach didactics before disciplinary content. The majority of universities start teaching both in the same academic year.

TABLE IV. Distribution of the universities according to whether disciplinary training is prior to (G1), begins in the same year (G2) or is subsequent (G3) to didactic training

	MATHEMATICS			**SCIENCE**		
	G1	**G2**	**G3**	**G1**	**G2**	**G3**
Public Universities	14 (37.8%)	22 (59.5%)	1 (2.7%)	10 (27.0%)	22 (59.5%)	2 (5.4%)
Private Universities	9 (40.9%)	13 (59.1%)	0 (0.0%)	10 (45.5%)	8 (36.4%)	0 (0.0%)

Source: compiled by the authors based on the study plans

Finally, Graph VI shows the distribution of Science and Mathematics subjects throughout the Primary Education Teacher Degree. It is shown that most of them are concentrated in the 2nd and 3rd years, with fewer subjects offered in the first year (which typically focuses on the basic training module) and in the fourth year (which is largely devoted to electives). No relevant differences were found between types of universities in this part of the analysis.

GRAPH VI. Distribution of the universities based on when they begin (vertical) and end (horizontal) teaching the contents of the disciplines indicated

PUBLIC UNIVERSITIES

Mathematics

Year	1º	2º	3º	4º
1º	2	6	7	1
2º		3	10	8
3º			0	0
4º				0

Didactics of Mathematics

Year	1º	2º	3º	4º
1º	0	1	6	2
2º		3	12	6
3º			3	3
4º				1

Science

Year	1º	2º	3º	4º
1º	2	1	1	0
2º		9	7	1
3º			7	6
4º				0

Didactics of Science

Year	1º	2º	3º	4º
1º	0	0	1	0
2º		2	9	5
3º			12	6
4º				2

PRIVATE UNIVERSITIES

Mathematics

Year	1º	2º	3º	4º
1º	3	1	1	1
2º		9	4	0
3º			1	2
4º				0

Didactics of Mathematics

Year	1º	2º	3º	4º
1º	0	1	0	1
2º		6	5	0
3º			7	1
4º				1

Science

Year	1º	2º	3º	4º
1º	3	1	0	0
2º		3	3	0
3º			6	2
4º				0

Didactics of Science

Year	1º	2º	3º	4º
1º	0	0	0	0
2º		2	4	0
3º			9	3
4º				3

Source: compiled by the authors based on the study plans

Technology and Engineering in the Primary Education Teacher Degree

Received: 02/08/2022 Accepted: 02/04/2023

Out of the total of 59 universities analysed, 44 of them have a specific compulsory subject whose title or contents mainly focus on the field of Technology. In almost all cases, these subjects carry 6 ECTS credits (88.6%). Their year distribution is as follows: 28 (63.6%) are taken in the first year, 13 (29.5%) in the second year, and 3 (6.8%) in the third or fourth year.

To analyse the role of Technology in these degrees, the contents declared in the teaching guides of these 44 subjects were reviewed. In this case, no relevant differences were found between public and private universities, so the results were grouped together.

As shown in Table V, the contents related to search for information and use of Internet resources, as well as those oriented towards the design of activities, are particularly remarkable. In addition, various tools (videos, virtual reality, video games, simulations, virtual laboratories, etc.) are addressed, sometimes in relation to some active methodologies (inquiry, project-based learning, gamification, etc.) or integrative approaches (such as Science, Technology and Society, STS).

TABLE V. Frequency of the contents declared in the teaching guides of the subjects dedicated to Technology

Contents	Frequency		Contents	Frequency
Internet	44 (100.0%)		STS	9 (20.5%)
Web Resources	43 (97.8%)		SCORM	9 (20.5%)
Methodologies	24 (55.5%)		Programming	7 (15.9%)
Design of Activities	20 (45.5%)		Virtual Reality	6 (13.6%)
Curriculum	15 (34.1%)		Robotics	5 (11.3%)
Videos	12 (27.3%)		Video Games	4 (9.1%)
Epistemology	11 (25.0%)		Virtual Laboratories	3 (6.8%)
VLE	11 (25.0%)		Scratch	2 (4.5%)
Assessment	10 (22.7%)		Simulations	2 (4.5%)

Source: compiled by the authors based on the teaching guides

Virtual Learning Environments (VLE) and e-Learning concepts (such as SCORM, an acronym for *Shareable Content Object Reference Model*, a standard for standardising virtual learning content) also appear in a relevant way in Table V. Thereafter it is concluded that the concept of technology that future teachers may acquire is closely linked to that of Information and Communication Technologies (ICT), although some new elements related to digitalisation are beginning to appear.

Finally, Table V includes some contents related to Technology in STEM education, such as robotics or programming, albeit to a lesser extent. These contents appear similarly in public universities, such as A Coruña, Girona, Illes Balears, and Rey Juan Carlos, and other private universities, such as Ramón Llull, Internacional de Catalunya, or Vic. It is worth mentioning the unique case of the European University of Madrid, which has a 4 ECTS subject called “Introduction to Programming”.

Regarding Engineering, no references to specific concepts of this discipline, such as engineering design, prototyping, or computational thinking, were found in the set of compulsory subjects analysed, except for the aforementioned subject at the European University. Accordingly, specific methodologies such as *Design-based Learning* or *Design Thinking* are absent in the teaching guides. It is therefore clearly concluded that this discipline is not included in the compulsory training of future teachers.

Finally, it is worth noting that, surprisingly, references to STEM or STEAM have only been found in the teaching guides of two private universities: Internacional de La Rioja and Mondragón. In fact, in the latter there is a subject entitled “STEAM in Primary Education”, although it seems to

Received: 02/08/2022 Accepted: 02/04/2023

include content related to the teaching of language and mathematics and the use of associated technological tools.

Discussion

The aim of this study is to analyse STEM education in Primary Education Teacher Degrees in Spain (in terms of timing and approaches) as a point of debate about its adequacy for achieving STEM education goals. Firstly, it has been found that there is no STEM training understood in a global way (Moore et al., 2014). There are no compulsory subjects related to this approach, and there is no mention of it in the teaching guides for Science, Mathematics and Technology subjects either, with a few exceptions. This result contradicts the objectives of the LOMLOE and is surprising, given the ubiquity of the acronym in the specialised literature (Toma & García-Carmona, 2021), and reflects the slowness or resistance to transferring the results of educational research to the classroom, also at university (Carr et al., 2012).

Analysing each discipline, the findings are similar in Mathematics and Science in terms of the most relevant aspects. Firstly, there is a wide dispersion in the ECTS credits allocated to these disciplines, which agrees with other studies on public universities (Castro-Rodríguez & Montoro, 2021; García-Barros, 2016; Naya-Riveiro et al., 2021) and private universities (Nolla et al., 2021). Furthermore, it has been found that the difference between types of universities is essentially due to the lesser amount of time dedicated to disciplinary content in private universities, and not so much to the time spent in didactic content. In general, these values are below the recommendations of the *White Paper* on Primary Education Teacher Degrees (ANECA, 2005, p.201), which suggests a minimum of 20 ECTS for Mathematics (Naya-Riveiro et al., 2021) and a higher teaching load than those obtained for Science. In fact, this poor training is associated with the lack of confidence and insecurity that primary school teachers experience when teaching these disciplines (García-Ruiz & Sánchez, 2006; Jarvis & Pell, 2004).

Another issue for debate in the degree reforms will be the distribution of credits among scientific disciplines, especially when this load can be distributed among different departments. Here it has been observed that the contents of the teaching guides reflect a distribution consistent with the presence of these disciplines in the Primary Education curriculum, with greater weight given to Biology, and then to Physics. On the other hand, there is a scarce presence of Geology and, especially in private universities, of Chemistry. The scientific content covered in each discipline can be consulted in García-Barros (2016).

Another important decision is whether to focus the training more on disciplinary content or on didactic content. It has been found that in most universities there is an equal distribution between both domains in Mathematics. Still, where this is not the case, it is almost always due to an excess of disciplinary content, which is much more pronounced in public universities. The result is similar to that of other studies (Naya-Riveiro et al., 2021), although this work provides the differentiating nuance of identifying the specific content and its ECTS timing. In Science, public universities seem to be more polarised between the two domains, with a greater emphasis on disciplinary content, while private universities maintain a better balance between the two. In this respect, Cortés et al. (2012) found that, at the beginning of their training, primary preservice teachers place greater importance on disciplinary content; however, as they progress through the degree program (and complete field experiences), the value given to didactic content increases.

Beyond content, there is a rich controversy between those who advocate for disciplinary and didactic content to be addressed consecutively or simultaneously. On the one hand, it is argued that deficient disciplinary training can hinder the construction of PCK (Cañal, 2008; Martínez-Borreguero, 2022) and that the relevance of students' prior ideas and conceptual errors is not

Received: 02/08/2022 Accepted: 02/04/2023

sufficiently addressed (Porlán et al., 2010). However, consecutive approaches can make it difficult to integrate bot domains (García-Barros, 2016) and design contextualised learning situations that activate and mobilise essential knowledge, enabling the adoption of future teaching roles and promoting metacognition (Dignath & Büttner, 2008). Our study has revealed that Mathematics has a higher prevalence of subjects in which both disciplinary and didactic contents are taught in an interrelated manner. This is also the case in Science, although less markedly so, which has been severely criticised (García-Barros, 2016). In both cases, didactic content is hardly ever taught before disciplinary content. In fact, there are only a few universities where either subject is taught in the final year, which could help to link this knowledge with the final field experiences, where students can really put into practice their previous learning in the degree and integrate both disciplinary and didactic domains (Naya-Riveiro et al., 2021).

With regards to Engineering, our study has shown that it is left out of the curricula of the Primary Education Teacher Degrees, as has been noted by other authors (Castro-Rodríguez & Montoro, 2021). There are no concepts such as engineering design, process optimisation, or computational thinking. Nor are there any references to methodologies associated with this approach, such as *Design-based Learning* or *Design Thinking*. This absence is not surprising, since this type of content was included for the first time in the Spanish Primary Education curriculum with the recent LOMLOE. Even so, this does not guarantee its rapid and effective inclusion in the classroom. In fact, in other countries, the transfer of engineering content to the classroom has proven to be costly, despite curricular support (Carr et al., 2012).

Finally, Technology is addressed in most degree programs through specific compulsory subjects. The approach for Technology is generally focused on ICT (search for information and resources, digital tools, etc.), which seems coherent with the specific competences established in the *White Paper* on Primary Education Teacher Degrees, i.e., "Ability to use and incorporate information and communication technologies appropriately in teaching-learning activities" (ANECA, 2015, p.90). Even so, following Gewerc and Montero (2015), it can be criticised that the notion of technology is limited to an instrumental perspective. In fact, in the STEM approach, technology is not exclusively associated with ICT, but is more of a tool or result of solving real-world problems that are viewed from a global perspective in Mathematics, Science, and/or Engineering. In this regard, some teaching guides –typically related to Physics– refer to technological devices associated with simple machines or electromagnets, but once again, not from a true STEM perspective. From our perspective, it would be advisable to genuinely interrelate Engineering and Technology with Science and Mathematics, to address the design and construction of technological devices that solve real-world problems and satisfy social needs: waste separation, medical applications, space exploration, etc. (Simarro & Couso, 2021).

Conclusions

This study examines jointly the initial training of primary school teachers in STEM disciplines in both public and private universities. From this research, we can conclude that nowadays undergraduate programs do not include STEM training with a global approach in their compulsory itineraries. Engineering is absent from the curricula, and Technology is usually approached from an ICT-centred perspective, far removed from its conception in STEM education.

In addition, the number of ECTS credits in Science and Mathematics is below the recommendations established in the *White Paper* on Primary Education Teacher Degrees (ANECA, 2005, p.201), particularly in private universities. However, their relative weight does seem to be in line with the teaching load of the disciplines in Primary Education (Mathematics, Biology, Physics, Chemistry, and Geology, in that order).

Received: 02/08/2022 Accepted: 02/04/2023

Furthermore, there are important differences between the relevance given by universities to disciplinary and didactic content, especially in the case of Science, which is a very hot debate. In this line, it can be seen that there is a predominance of subjects that simultaneously combine both contents, although this interrelation is weaker in Science than in Mathematics.

This study is highly relevant at this moment given the renewed importance of the so-called STEM competence since the approval of the LOMLOE. This context requires an update in the curricula of the Primary Education Teacher Degrees, which Spanish universities will soon have to address. For this purpose, the review, analysis, and comparison presented in this study are undoubtedly valuable and highlight the need to specifically include Technology and Engineering aspects with a STEM perspective, without compromising the time devoted to Mathematics and Science, which is already less than recommended.

The limitations of the study presented may arise from the fact that information on the contents and their timing in ECTS credits was derived from the teaching guides, and not from the real activities implemented by the trainers. This can lead to biases in the results, due to tensions between planned and executed training (Porlán et al., 2010). Moreover, like other research approaches, analysing teaching guides involves adopting criteria that may differ from the actual timing of STEM training content. In addition, the analysis was restricted to compulsory training, ignoring elective subjects which, although they are not linked to the general profile of graduates, provide a suitable space to focus on the didactic aspects of STEM disciplines (Naya-Riveiro et al., 2021) and their interaction during problem-solving.

For this reason, in future work, we propose to study elective subjects by analysing the teaching guides related to STEM. Another future line of research could be to investigate whether the conclusions presented here hold true for Double Degrees, whose variety is wide and where it is not always easy to combine the syllabuses of the degrees involved. Surveys to teacher trainers would also provide a complementary view that would undoubtedly contribute to the debate on the best way to reform the curricula of the Primary Education Teacher Degrees.

Acknowledgements

To Irene González Muñoz and Cristina Rodríguez Mayordomo, beneficiaries of a collaboration grant from the Spanish Ministry of Education and Vocational Training during the 2020-2021 academic year, for their assistance in data collection for this study.

Bibliographical references

Aguilera, D., & Ortiz-Revilla, J. (2021). STEM vs. STEAM education and student creativity: A systematic literature review. *Education Sciences, 11*, 331. https://doi.org/10.3390/educsci11070331

Amat, A., Martínez-Chico, M., & Jiménez-Liso, M. R. (2022). Formación de maestras por implementación de secuencias en su propio contexto de aula: red sistémica para el análisis de las entrevistas pre-post. [Teacher training by implementing instructional sequence in Primary School teachers' classroom context: systemic network for analyzing pre-post interviews]. *Revista Interuniversitaria de Formación del Profesorado*, *97*(36.1), 35–56. https://doi.org/10.47553/rifop.v97i36.1.91928

Received: 02/08/2022 Accepted: 02/04/2023

ANECA (2005). *Libro Blanco. Título de Grado en Magisterio. Volumen 1*. Agencia Nacional de Evaluación de la Calidad y Acreditación. https://www.aneca.es/documents/20123/63950/libroblanco_jun05_magisterio1.pdf/bd7fdceb-075e-6256-b769-f89502fec8aa?t=1654601800472

Appleton, K. (2003) How do beginning primary school teachers cope with science? Toward an understanding of science teaching practice. *Research in Science Education*, *33*(1), 1–25. https://doi.org/10.1023/A:1023666618800

Barak, M. (2013). Teaching engineering and technology: cognitive, knowledge and problem-solving taxonomies. *Journal of Engineering, Design and Technology*, *11*(3), 316–333. https://doi.org/10.1108/JEDT-04-2012-0020

Belbase, S., Mainali, B. R., Kasemsukpipat, W., Tairab, H., Gochoo, M., & Jarrah, A. (2021). At the dawn of science, technology, engineering, arts, and mathematics (STEAM) education: prospects, priorities, processes, and problems. *International Journal of Mathematical Education in Science and Technology*. https://doi.org/1.1080/0020739X.2021.1922943

Brunsell, E. (2012). The engineering design process. En E. Brunsell (Ed.), *Integrating engineering and science in your classroom* (pp. 3–5). NSTA Press.

Cañal, P. (2008). ¿Cómo orientar la formación inicial del profesorado de primaria en didáctica de las ciencias experimentales? En M.R. Jiménez-Liso (Ed.), C*iencias para el mundo contemporáneo y formación del profesorado en Didáctica de las Ciencias Experimentales* (pp. 256–263). Universidad de Almería.

Cardetti, F., & Truxaw, M. P. (2014). Toward improving the mathematics preparation of elementary preservice teachers. *School Science and Mathematics*, *114*(1), 1–9. https://doi.org/10.1111/ssm.12047

Carr, R. L., Bennett IV, L. D., & Strobel, J. (2012). Engineering in the K-12 STEM standards of the 50 U.S. states: An analysis of presence and extent. *Journal of Engineering Education*, *101*(3), 539–564. https://doi.org/10.1002/j.2168-9830.2012.tb00061.x

Castro-Rodríguez, E., & Montoro, A. B. (2021). Educación STEM y formación del profesorado de Primaria en España. [STEM Education and Primary Teacher Training in Spain]. *Revista de Educación*, *393*, 353–378. https://doi.org/10.4438/1988-592X-RE-2021-393-497

Cavanagh, S., & Trotter, A. (2008). Where's the "T" in STEM. *Education Week*, *27*(30), 17–19.

Cortés, A. L., Gándara, M., Calvo, J. M., Martínez-Peña, B., Ibarra, J., Arlegui, J., & Gil-Quílez, M.J. (2012). Expectativas, necesidades y oportunidades de los maestros en formación ante la enseñanza de las ciencias en la Educación Primaria. [Expectations, needs and opportunities of pre-service teachers in view of science teaching in Primary Education]. *Enseñanza de las Ciencias*, *30*(3), 155–176. https://doi.org/10.5565/rev/ec/v30n3.597

Costantino, T. (2018). STEAM by another name: Transdisciplinary practice in art and design education. *Arts Education Policy Review*, *119*(2), 100–106. https://doi.org/10.1080/10632913.2017.1292973

Dignath, C., & Büttner, G. (2008). Components of fostering self-regulated learning among students. A meta-analysis on intervention studies at primary and secondary school level. *Metacognition and Learning*, *3*(3), 231–264. https://doi.org/10.1007/s11409-008-9029-x

García-Barros, S. (2016). Conocimiento científico Conocimiento didáctico. Una tensión permanente en la formación docente. [Science knowledge and Education knowledge. A continuous strain in teachers' education]. *Campo Abierto*, *35*(1), 31–44. https://mascvuex.unex.es/revistas/index.php/campoabierto/article/view/2825

García-Ruiz, M., & Sánchez, B. (2006). Las actitudes relacionadas con las Ciencias Naturales y sus repercusiones en la práctica docente de profesores de primaria. *Perfiles Educativos*, *114*, 61–89. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0185-26982006000400004&lng=es&nrm=iso

Gewerc, A., & Montero, L. (2015). Conocimiento profesional y competencia digital en la formación del profesorado. El caso del Grado de Maestro en Educación Primaria. [Professional

Received: 02/08/2022 Accepted: 02/04/2023

knowledge and digital competency in teacher education. The case of Elementary Teacher Education Degree]. *Revista Latinoamericana de Tecnología Educativa*, *14*(1), 31–43. https://doi.org/10.17398/1695-288X.14.1.31

INEE (2012). *TEDS-M. Estudio internacional sobre la formación en matemáticas de los maestros. Informe español*. Instituto Nacional de Evaluación Educativa. https://sede.educacion.gob.es/publiventa/d/15408/19/00

Imbernón, F., & Colén, M. T. (2014). Los vaivenes de la formación inicial del profesorado. Una reforma siempre inacabada. *Tendencias Pedagógicas, 24,* 265–284. https://revistas.uam.es/tendenciaspedagogicas/article/view/2106

Jarvis, T., & Pell, A. (2004). Primary teachers' changing attitudes and cognition during a two-year science in-service programme and their effect on pupils. *International Journal of Science Education*, *26*(14), 1787–1811. https://doi.org/10.1080/0950069042000243763

Manso, J., & Garrido-Martos, R. (2021). Formación inicial y acceso a la profesión: qué demandan los docentes. [Initial training and access to the profession: teachers' demands]. *Revista de Educación*, *393*, 293–319. https://doi.org/ 10.4438/1988-592X-RE-2021-393-494

Martínez-Borreguero, G., Naranjo, F. L., & Mateos, M. (2022). Cognitive and emotional development of STEM skills in primary school teacher training through practical work. *Education Sciences*, *12*, 470. https://doi.org/10.3390/educsci12070470

McComas, W. F., & Burgin, S. R. (2020). A critique of "STEM" education. *Science & Education*, *29*(4), 805–829. https://doi.org/10.1007/s11191-020-00138-2

MEFP (2022a). *24 propuestas de reforma para la mejora de la formación docente*. Ministerio de Educación y Formación Profesional. https//educagob.educacionyfp.gob.es/comunidad-educativa/profesorado/propuesta-reforma.html

MEFP (2022b). *Estadísticas de la Educación*. Ministerio de Educación y Formación Profesional. https://www.educacionyfp.gob.es/servicios-al-ciudadano/estadisticas.html

Ministerio de la Presidencia (2021). *España 2050: Fundamentos y propuestas para una Estrategia Nacional de Largo Plazo.* https://www.lamoncloa.gob.es/presidente/actividades/Documents/2021/200521-Estrategia_Espana_2050.pdf

Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A, & Stohlmann, M. S. (2014). A framework for quality K-12 engineering education: research and development. *Journal of Pre-College Engineering Education Research*, *4*(1), 2. https://doi.org/10.7771/2157-9288.1069

Naya-Riveiro, M. C., Gómez-Sánchez, T. F., Rumbo, M. B., & Segade, M. E. (2021). Estudio interregional comparado de la educación matemática en la formación inicial del profesorado de Educación Primaria. [Comparative interregional study of mathematical education for preservice primary teachers]. *RELIME. Revista Latinoamericana de Investigación en Matemática Educativa*, *24*(2), 207–233. https://doi.org/10.12802/relime.21.2424

Nolla, Á., Muñoz, R., Cerisola, A., & Fernández, B. (2021). La formación inicial de los maestros en matemáticas y su didáctica. [Initial teacher training in elementary mathematics and its didactics]. *Revista Interuniversitaria de Formación del Profesorado*, *96*(35.1), 185–208. https://doi.org/10.47553/rifop.v96i35.1.85882

Nortes Checa, A., & Nortes Martínez-Artero, R. (2013). Formación inicial de maestros: Un estudio en el dominio de las matemáticas. [Primary school teachers' initial training: A study in math domain]. *Profesorado, Revista de Currículum y Formación del Profesorado*, *17*(3), 185–200. https://revistaseug.ugr.es/index.php/profesorado/article/view/19684

Porlán, R., Martín del Pozo, R., Rivero, A., Harres, J., Azcárate, P., & Pizzato, M. (2010). El cambio del profesorado de ciencias I: marco teórico y formativo. [Science teacher change I: Theoretical and teacher education framework]. *Enseñanza de las Ciencias*, *28*(1), 31–46. https://doi.org/10.5565/rev/ensciencias.3619

Received: 02/08/2022 Accepted: 02/04/2023

Pro-Bueno, A., Pro-Chereguini, C., & Cantó, J. (2022). Cinco problemas en la formación de maestros y maestras para enseñar ciencias en Educación Primaria. [Five problems in training teachers to teach science in Primary Education]. *Revista Interuniversitaria de Formación del Profesorado, 97*(36.1), 185–202. https://doi.org/10.47553/rifop.v97i36.1.92510

R Core Team (2018). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.Rproject.org/

Real Decreto 157/2022, de 1 de marzo, por el que se establecen la ordenación y las enseñanzas mínimas de la Educación Primaria. *Boletín Oficial del Estado, 52*, de 2 de marzo de 2022. https://www.boe.es/boe/dias/2022/03/02/pdfs/BOE-A-2022-3296.pdf

Sánchez-Urán, L. (2019). La formación inicial de los maestros de Educación Primaria en España: universidades y planes de estudios. En J. Manso (Ed.), *La formación inicial del profesorado en España* (pp. 12–30). Ministerio de Educación y Formación Profesional.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1–23. https://doi.org/10.17763/haer.57.1.j463w79r56455411

Simarro, C., & Couso, D. (2021). Engineering practices as a framework for STEM education: a proposal based on epistemic nuances. *International Journal of STEM Education, 8*, 53. https://doi.org/10.1186/s40594-021-00310-2

Socas, M. M. (2011). Aprendizaje y enseñanza de las Matemáticas en Educación Primaria. Buenas prácticas. *Educatio Siglo XXI*, *29*(2), 199–224. https://revistas.um.es/educatio/article/view/133031

Toma, R. B., & García-Carmona, A. (2021). «De STEM nos gusta todo menos STEM». Análisis crítico de una tendencia educativa de moda. [«Of STEM we like everything but STEM». A critical analysis of a buzzing educational trend]. *Enseñanza de las Ciencias*, *39*(1), 65–80. https://doi.org/10.5565/rev/ensciencias.3093

Toma, R. B., Greca, I. M., & Meneses-Villagrá, J. A. (2017). Dificultades de maestros en formación inicial para diseñar unidades didácticas siguiendo la metodología de indagación. [Elementary pre-service teachers' difficulties for designing science-teaching units by inquiry]. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, *14*(2), 442–457. http://dx.doi.org/10.25267/Rev_Eureka_ensen_divulg_cienc.2017.v14.i2.11

Yata, C., Ohtani, T., & Isobe, M. (2020). Conceptual framework of STEM based on Japanese subject principles. *International Journal of STEM Education*, *7*(12). https://doi.org/10.1186/s40594-020-00205-8

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Received: 02/08/2022 Accepted: 02/04/2023