# STEM Education and Primary Teacher Training in Spain[1]

# Educación STEM y formación del profesorado de Primaria en España

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Elena Castro-Rodríguez
Ana B. Montoro
*Universidad de Granada*

**Abstract**

STEM education has been characterised by a number of models since it was initially introduced. That diversity notwithstanding, a literature review conducted on the occasion of this study identified three characteristics consistently found in all: problem solving, application to real-life situations, and interdisciplinarity. This study explored the possibility of implementing STEM education that adheres to the primary education pre-service training curriculum in Spain. Pursuit of that objective entailed ascertaining the presence of STEM characteristics in the syllabi for 236 core or requisite subjects dealing with STEM areas (science, technology, enginerering, mathematics) delivered in Spanish public universities. The findings showed that the guides for subjects in the mathematics and science areas in place in most universities envisage all three characteristics, with problem solving the one most frequently mentioned in the four curricular elements addressed in the guides (learning expectation, content, methodology and assessment). The conclusion drawn is that STEM education could be adopted on the multidisciplinary level, in which each subject would have its own objectives but with tasks introduced under a common theme.

*Keywords*: STEM, primary teacher training, syllabus analysis, university education, educational innovation

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**Resumen**

Desde sus inicios, la educación STEM ha sido caracterizada a través de distintos modelos. A pesar de esta diversidad, encontramos tres características comunes en la literatura especializada —resolución de problemas, aplicación de contenidos en situaciones reales e interdisciplinariedad—. En este trabajo indagamos hasta qué punto es posible implementar una Educación STEM que se ciña al plan de formación inicial de maestros de Educación Primaria vigente en España. Para ello, hemos realizado un análisis de documentos, en base a las tres características propias de la educación STEM, de las 236 guías docentes de las asignaturas de carácter básico u obligatorio relacionadas con las áreas STEM de las universidades públicas españolas. Los resultados muestran que la mayoría de las universidades contemplan en sus guías docentes del área de Matemáticas y Ciencias Experimentales estas tres características, siendo la resolución de problemas la que mayor presencia tiene en todos los niveles curriculares de las guías (expectativas de aprendizaje, contenidos, metodología y evaluación). Concluimos que, la inclusión de la educación STEM podría ser posible a través de una integración a nivel multidisciplinar, donde cada asignatura tiene sus propios objetivos pero se introducen tareas a través de un tema común.

*Palabras clave*: STEM, formación de docentes de primaria, análisis de documentos curriculares, Educación Universitaria, innovación educativa

## Introduction

The nineteen nineties saw the advent in the United States of a movement, a legacy of the educational reforms prompted by the Sputnik crisis, that pursues a holistic approach to science, technology, engineering, and mathematics (STEM). Beyond the political and economic situation that induced it, the movement soon spilled over into education in response to the social need to prepare citizens for the new challenges arising with the twenty-first century. The know-how, skill and abilities associated with a crosswise command of STEM disciplines are sought in nearly all industries and have become part of people's daily lives (Bergsten & Frejd, 2019; Mpofu, 2020). That educational movement evolved into a separate entity: STEM education, which aims to help students prepare for those changes and respond to the growing demand for STEM area expertise.

STEM education, understood as an educational approach that fosters the integration of scientific, technological, engineering, and mathematics contents to solve real-world problems, is deemed a complex process (Martín-Páez, Aguilera, Perales-Palacios, & Vílchez-González, 2019). Researcher and educator concern to improve that approach has grown in step with the demand for STEM skills (English, 2016). In countries such as the United States and Singapore the idea of instituting STEM education has been envisaged for decades. Very few teachers know how to practise it in the classroom, however (Kelley & Knowles, 2016), particularly when they themselves entertain a narrow idea of what STEM education entails (Dare, Ring-Whalen, & Roehrig, 2019). These new instructional challenges call for pre-service training tailored to twenty-first century demands (Hernández, 2011).

Teacher training for STEM education is a fairly new area of research. A few studies have been conducted to analyse the efficacy of proposals for science (e.g., Alan, Zengin, & Kececi, 2019), secondary mathematics (e.g., Bergsten & Frejd, 2019) and primary (e.g., Bergsten & Frejd, 2019) teacher training curricula. In Alan et al.'s (2019) quasi-experimental study, students who attended science class for which integrated STEM proposals had been designed improved their problem-solving skills substantially. Bergsten and Frejd (2019) observed that in a brief training course on STEM education, the future mathematics teachers participating proved able to integrate STEM discipline contents with richly designed proposals in which modelling and inquired-based learning were essential elements. Most of their proposals included the use of information and communication technologies (ICT) as tools for developing twenty-first century skills. A number also envisaged creativity, problem solving and decision making as skills related to a way of thinking. In their research on primary school teachers, Bartels et al. (2019) reported that most of the proposals designed were contextualised around the science classes for which they were asked to plan, design, build, test, and collect data and included the integration of at least two disciplines, although most included three or four. At the same time, other more limited visions of what is entailed in integrated technology were also observed.

The foregoing review revealed that although research has identified the possibility of including STEM education in training curricula and attested to educators' ability to draft an educational design for STEM disciplines, such proposed designs are questionable because they do


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not always cover all four areas or they focus on one only, broaching the others as mere context or tools to perform the task (Bartels et al., 2019; Bergsten & Frejd, 2019). Their specificity stands as evidence of the need to revise teacher training globally (Bogdan & García-Carmona, 2021). Research along those lines also highlights the need for studies on improving teacher training in respects associated with STEM education (Kelley & Knowles, 2016), in primary school pre-service training in particular, where future teachers face substantial challenges in and hold unfavourable attitudes toward the areas of science and mathematics (Casis, Rico, & Castro, 2017).

Under those circumstances, the question that arises is whether it is possible to institute STEM education in Spain's existing pre-service training for primary school teachers. The study discussed below was not broached from the perspective of assessment, for the implementation of STEM education is not one of the aims of the training programme. The focus was on STEM education rather than more recent approaches such as STEAM because it has been more fully developed in theory and in practice (García-Carmona, 2020). At the same time, whilst one of the primary arguments to justify such more recent proposals is their furtherance of creativity and innovation, both pursuits are inherent in scientific-technological disciplines (Aguilera et al., 2021; García-Carmona, 2020).

## Characterising STEM education

From the outset, the literature has interpreted STEM education from different perspectives. Some authors describe it as problem solving based on scientific and mathematical ideas and procedures that integrate strategies applied in enginerering and the use of technology (Shaughnessy, 2013). Other experts note that it aims to view all STEM disciplines as a single coherent entity taught through the integrated and coordinated solving of real-world problems (Aguilera et al., 2021). In light of such diversity experts such as Bybee (2013), Dare (2019), Mpofu (2020), or Martín-Páez et al. (2019) categorise the several ways STEM education has been broached in research and the literature. All four authors identified the following approaches.


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The first advocates for teaching the disciplines separately, either as different subjects or as different units in the same subject (Bybee, 2013). This traditional approach, which addresses the content of each area individually, furthers instruction disconnected from real life and may preclude an integrated focus (Martín-Páez et al., 2019; Mpofu, 2020). It also necessitates the presence of all four areas in school curricula, whereas enginerering is excluded from Primary Education.

The second model combines two or three disciplines but fails to integrate all four. The areas integrated may be deemed a new core discipline dealt with in depth and in connection with other STEM areas. Some authors (Dare et al., 2019; Martín-Páez et al., 2019) nonetheless believe that this risks excluding some of the disciplines or emphasising or envisioning them as mere tools or context.

In the third approach some one of the STEM disciplines, normally enginerering or technology, is integrated into the instruction of the other three. Bybee (2013) contends that such a perspective constitutes a first step toward integration.

A final integrated model includes the knowledge and skills characteristic of all the areas in a single instructive experience. The inference is that the teachers entrusted with delivery must have a command of all the areas to enable students to acquire competencies with which to understand and confront real-world problems. This model embodies the interdisciplinary significance of STEM education, combining the content of all in the same unit of a given single subject. It also eludes the drawbacks of teaching the areas separately by mirroring the interdisciplinary nature of real-life problems while enhancing students' learning experience (Martín-Páez et al., 2019; Mpofu, 2020).

In this study one of the essential characteristics for deeming STEM education to be in place was the integration of the four areas, for otherwise it would be scantly distinguishable from earlier educational proposals such as Science, Technology, and Society (STS). Inasmuch as such integration is among the major challenges posed by STEM education (Bogdan & García-Carmona, 2021; Dare et al., 2019), some authors define several levels (Aguilera et al., 2021; English, 2016). On the first, the disciplinary level, content is learned separately for each discipline. On the second or multidisciplinary level, each discipline has its own aims, although they are introduced via the same task under a common topic and the interarea connections are explicitly identified. In some cases, the disciplines may be unevenly weighted. On the third or interdisciplinary level, the aims involve several disciplines. The highest or transdisciplinary level involves aims pertaining to all disciplines and is geared to solving real-world problems.

Although significant progress has been made to date, no consensus has been reached on a common characterisation of or model for STEM education nor how to put it in practice (Bogdan & García-Carmona, 2021). Nonetheless, the present review, in line with the criticism levelled at the models, revealed three basic characteristics that must be present in STEM education, referred to hereafter as 'STEM characteristics': (i) inclusion of a real-world problem; (ii) interdisciplinarity or interconnection among the STEM areas; and (iii) development of problem-solving skills (Aguilera et al., 2021; Bybee, 2013; Fomunyam, 2020; Kennedy & Odell, 2014)

## Official documents on primary school teacher pre-service training in Spain

Primary school teacher pe-service training has evolved over the last few decades due to the introduction of the Bologna Process and the need to adapt university courses to European Higher Education Area standards. That has entailed substantial change, such as lengthening course time by a full year and adopting a skills-based curricular approach. The new curricular design is laid down in a number of official nation, institution and department scale documents, drafted to different levels of detail (Rico, Gómez, & Cañadas, 2014).

The nationwide guidelines establish the number of university credits required and their distribution across different training units: academic (learning and personality development; educational processes and contexts; society, family, and classroom), disciplinary (teaching and learning experimental science; social science; mathematics; languages; music, plastic and visual arts; physical education), and practical (classroom practice and bachelor's dissertation). These guidelines likewise describe the skills that must be acquired by future teachers, as specified by the Ministry of Education and Science (MEC).

On the institutional scale, universities particularise the nationwide guidelines in the course memorandum, which includes curricular design and structure and the descriptors and credits assigned to each subject.

Universities are free to design their own curricula, subject to compliance with nationwide stipulations (Rico et al., 2014).

On the final and most specific or individual scale, the respective university departments are entrusted with fleshing out the subjects included in the national and institutional documents. Known as syllabi, these official documents serve as a reference for professors delivering the subject and their students, for they contain general information on the subject (number of ECTS credits, nature, semester, department, professors in charge, bibliography). They also address essential planning details, which may be arranged around the four basic curricular elements proposed by Tyler (1986): learning expectations, content, methodology and assessment (Rico, 2013).

This study focuses on the most detailed or department scale documents, the syllabi, to answer the question: can STEM education be introduced in Spain's existing primary education pre-service training curriculum? The two objectives posed to respond to that question were:

- To describe the presence of STEM areas in the curriculum for the official university degree that qualifies students to practise as primary education teachers in Spain.
- To identify the presence of STEM education characteristics (problem solving, real-world situations and interdisciplinarity) in Spanish public universities' syllabi for STEM area-related subjects delivered in connection with the aforementioned degree.

## Method

The document analysis (Bowen, 2009) covered the 236 syllabi for STEM area-related subjects defined by Spanish public universities as core or requisite subjects[2] to earn official university qualification to practise as primary education teacher ('Grado en Maestro de Educación Primaria' or 'Grado de Educación primaria' [Primary Teacher or Primary Education Graduate]). All the syllabi analysed were in effect in academic year 2020/2021. Of the 236 core or requisite subjects delivered by the 39

(2) Subjects that all students must pass to earn their degree.


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Spanish public universities offering the degree, 113 addressed Didactic of Mathematics, 101 Didactic of Experimental Science, and 22 ICTs[3].

## Categories

The categories applied in the present analysis were built around two dimensions: STEM characteristics and curricular elements. STEM characteristics were drawn from the features described in STEM education definitions and models:

- Problem solving. A problem is understood to be a task or challenge and that some investigation to determine the procedure applied to determine the solution, which is not known at the outset. This category therefore involves developing problem-solving skills rather than engaging in theoretical considerations associated with the idea such as identification of or distinctions between types of problems (arithmetic, educational, dispute settlement…).
- Application of real-life situations or inclusion of a real-world context. Allusions to the application of content learnt to daily or real-life situations. This category does not cover the content itself such as probability or magnitudes in mathematics, for instance, or the human body or the earth in experimental science.
- Interdisciplinarity. References to one or several STEM areas other than the one associated with the syllabus. This category had in tun to be subdivided into two subcategories due to the large number of references to ICTs: ICT usage (mentions of this matter in a non-ICT subject syllabus) and other STEM areas (mentions of a STEM area other than the area at hand and of ICTs, or explicit reference to interdisciplinarity).

The second dimension, curricular elements, refers to syllabus structure and includes the categories deemed essential in the curriculum and classroom planning (Rico, 2013; Tyler, 1986):

(3) The intention here is not to equate ICTs with technology, but rather identify them as part of that category. They were consequently deemed to form part of the ICT rather than the technology area.


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- Learning expectations. Targets that establish learning priorities, defined in syllabi in terms of skills, learning objectives or learning outcomes.
- Content. References that organise knowledge in terms of ideas, procedures or attitudes. In syllabi they appear as subject content or topics.
- Methodology. Strategies, actions, teaching techniques, tasks or necessary materials that together define how the subject will be delivered.
- Assessment. Guidelines, systems or techniques whose purpose is to identify what students have learned.

The foregoing categories, drawn deductively from the literature, were submitted to experts in the field for their evaluation, and more specifically to three area researchers with ample experience in the area.

## Data analysis

The data were analysed by two stages. In the first, references in the documents were coded in keeping with the categories defined with MAXQDA software. A deductive process was deployed because the categories to be coded were formulated on theoretical grounds (Fraenkel, Wallen, & Hyun, 2011). For instance, the skill defined as 'Posing and solving daily life problems' was coded under all three categories: learning expectations, problem solving and application of real-life situations.

Five per cent of the syllabi was first coded separately by the two researchers. Table I gives the number of analytical units consistently coded with the same code (a), along with the number coded by only one of the two researchers (b and c). The likelihood of coding an analytical unit with a random code is minimal in this type of documents, since all pieces of information not chosen can in fact be deemed to have been agreed on. MAXQDA calculated a kappa index of 0.944 with 95% agreement between coders.

**TABLE I.** Inter-coder agreement

| | | **Coder 1** | | |
|---|---|---|---|---|
| | | **0** | **1** | |
| **Coder 2** | **0** | a = 231 | b = 3 | 234 |
| | **1** | c = 7 | 0 | 7 |
| | | 238 | 3 | 241 |

Source: author formulation

The non-agreements were reviewed and a consensus was reached for coding the remaining documents. Given the optimal consistency attained, the remaining documents were coded by only one of the researchers.

In the second stage, undertaken after all the data were coded, the frequency tables and statistical descriptors for the categories were calculated by STEM area. That exercise was followed by the formulation of concurrence tables and relationship matrices between STEM characteristics and curricular elements. An inter-code relationship matrix is a visual representation of the intersections of two codes in any given mention (Graph I). The matrix gives the number of mentions where any two specific codes were assigned for all possible combinations of pairs of codes. The size of the symbols at the points where the two members of each pair intersect is proportional to the number of mentions coded with that pair. A cluster analysis was then conducted, establishing the STEM characteristics as the criteria for defining document clusters. More specifically, simple matching was used as similarity measure. That method uses the frequency of code occurrence in a document (which is only included in the calculation if it has been assigned a code) and defines inter-attribute similarity as the number of matches divided by the total number of attributes.

## Results

The results are described in the three subsections that follow. The first discusses the overall presence of STEM areas in the course, in reply to the first research objective. The second and third subsections address the


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second research objective. The second focuses on the STEM characteristics found in STEM area-related subjects and curricular elements, whilst the cluster analysis findings are set out and cluster characteristics are described in the third.

## Presence of STEM areas in primary education pre-service training

Further to the analysis of the 2020/2021 syllabi, only two of the four STEM areas were present as explicit subjects in the official curriculum for a degree in primary education. The review also showed mathematics and experimental science to clearly prevail over ICT in terms of the total number of requisite subjects defined in all 39 university courses, given in Table II along with the descriptive statistics for the number of subjects and credits per university assigned to each area.

**TABLE II.** Statistical descriptors for number of subjects and credits assigned to STEM areas in the curricula for primary education courses delivered by Spanish public universities

| | No. of subjects | | | | | | No. of credits | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | Min | Max | Me | | σ | N | Min | Max | Me | | σ |
| **Mathematics** | 113 | 2 | 4 | 3 | 2.90 | 0.502 | 711 | 12 | 24 | 18 | 18.154 | 2.368 |
| **Experimental Science** | 102 | 2 | 5 | 2 | 2.56 | 0.754 | 598 | 12 | 24 | 15 | 15.679 | 3.617 |
| **ICT** | 22 | 0 | 2 | 1 | 0.54 | 4.582 | 120 | 0 | 12 | 3 | 3.077 | 6.235 |

Note: N= total; Min=minimum; Max=maximum; Me= median; =mean; σ=standard deviation
Source: author formulation

In the academic year reviewed, mathematics, the most predominant area, accounted for a total of 113 core or requisite subjects and a median of 3, ranging from 2 in some institutions to 4 in others. A median of 18 ECTS was assigned to each subject, with a minimum of 12 and a maximum of 24. On the whole, the courses were designed to further future teachers' acquisition of two types of competence: basic mathematical skills such as problem solving or the organisation and interpretation of information; and skills related to mathematics teaching and learning such as 'familiarity with the mathematics curriculum' or 'conveying and assessing curricular content with suitable educational resources and fostering students' acquisition of skills' (MEC, 2007, p. 53750). The subject matter was observed to be organised in one of two ways: (i) via subjects focusing primarily on understanding mathematics and others dealing separately with content delivery; or (ii) combining the two types of skills in all subjects, each dealing with a given area of mathematics (Table III).

**TABLE III.** Examples of the distribution of credits for requisite subjects in the areas of mathematics and experimental science

| | **Mathematics** | **Experimental Science** |
|---|---|---|
| **University of Las Palmas de Gran Canaria** | Mathematics and Didactics of Mathematics I (6 ECTS) [numbers and algebra] | Didactics of Natural science, Health, Biodiversity, and Environment (6 ECTS) |
| | Mathematics and Didactics of Mathematics II (7 ECTS) [measurement and geometry] | Didactics of Physics, Chemistry, Geology, and Environmental (7.5 ECTS). |
| | Mathematics and Didactics of Mathematics III (6 ECTS) [statistics and probability] | |
| **University of Granada** | Basic Mathematics for Primary Education (9 ECTS) | Didactics of Experimental Science I (9 ECTS) [physics, chemistry, and geology] |
| | Teaching and Learning Mathematics in Primary School (6 ECTS) | Didactics of Experimental Science II (6 ECTS) [biology] |
| | Curricular Design and Development for Teaching Primary Education Mathematics (7 ECTS) | |

Source: author formulation

A total of 102 experimental science requisite subjects were identified, with a median of 2 subjects and 15 ECTS. However, data ranged from 2 to 5 subjects, which correspond to 12-24 ECTS. As with mathematics, training in this area was observed to be geared to understanding scientific content such as 'the basic principles and fundamental laws of experimental science' (MEC, 2007, p. 53749) and to acquiring the ability to 'convey and assess curricular content with suitable teaching resources


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and further students' acquisition of basic competencies (MEC, 2007, p. 53749). The syllabi for academic year 2020/2021 fostered both types of knowledge, organised along the lines of the discipline involved (physics, chemistry, biology, geology), although some subjects focused on an understanding of scientific content only.

No specific subjects were identified in the technology area and only 20 universities established as requisites subjects dealing specifically with ICTs. That notwithstanding, further to the national guidelines, one of the 12 general competencies students were to acquire to earn their degree was 'an understanding and classroom application of information and communication technologies' (MEC, 2007, p. 53749). The syllabi for the mathematics and experimental science areas therefore frequently carried references to working with ICTs or software. Explicit references to technology were also observed (such as: 'energy in the social and technological surrounds' and 'science and technological development; technology and social development') in some of the syllabi for experimental science subjects, in particular those focusing on physics.

Not a single subject dealing exclusively with enginerering was identified, nor was any explicit reference to that area observed in any of the syllabi reviewed.

## Presence of STEM characteristics in syllabi

Problem solving was the STEM characteristic most frequently found in the syllabi (Table IV).

**TABLE IV.** Statistical descriptors for STEM statistics

| | Mean | Standard deviation | Median | Minimum | Maximum |
|---|---|---|---|---|---|
| **Problem solving** | 3.43 | 1.03 | 3 | 0 | 14 |
| **Real-life situations** | 2.02 | 0.94 | 1 | 0 | 10 |
| **Other STEM areas** | 1.82 | 0.81 | 2 | 0 | 9 |
| **ICT usage** | 1.45 | 1.25 | 1 | 0 | 14 |

Source: author formulation

Problem solving was also the STEM characteristic observed to prevail in all the curricular elements (Graph I), whilst application to real-life situations was found primarily in the first two elements (learning expectations and content). The element with highest frequency of references to interdisciplinarity, in turn, was learning expectations. As a rule, in the syllabi analysed, content, methodology, and assessment focused on subject organisational details, which would explain the low frequency of STEM characteristics under those headings.

**GRAPH I.** STEM characteristic / curricular element matrix

| | Expectations | Content | Methodology | Assessment |
|---|---|---|---|---|
| Problem solving | 397 | 117 | 182 | 108 |
| Real-life situations | 317 | 103 | 22 | 29 |
| Other STEM areas | 373 | 29 | 7 | 8 |
| ICT usage | 222 | 49 | 53 | 7 |

Source: author formulation

## Problem solving

Problem solving was the characteristic with greatest presence in the syllabi analysed (Table IV), identified up to 14 times in one. That finding is reasonable, given the existence of mathematics subjects specifically devoted to such skills, as in the subject 'Problem solving and mathematical connections' delivered at the University of Almería. Although references were found in all areas, problem solving was significantly greater in mathematics than in the other two (Table V).

**TABLE V.** Presence of problem solving in curricular elements by STEM area-related subject

| | Expectations | Content | Methodology | Assessment | Total |
|---|---|---|---|---|---|
| **Mathematics (N=113)** | 227 | 93 | 116 | 79 | 515 |
| **Experimental Science (N=102)** | 154 | 21 | 62 | 25 | 262 |
| **ICTs (N=22)** | 12 | 2 | 4 | 4 | 22 |

Source: author formulation


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In line with national guidelines (MEC, 2007), which in 2020/2021 stipulated the general competency for the science area to be 'posing and solving science-related problems in daily life' (p. 53749) and for mathematics to be 'posing and solving problems associated with daily life' (p. 53759), those skills were included in most of the syllabi as learning expectations. In some cases, however, they were particularised as part of a given discipline in one of the two areas (numbers, geometry; biology, environmental education…) or no reference was made to daily life.

Problem solving was also found to constitute part of the content or as a topic. Under ICTs, the University of the Basque Country's subject 'Information and communication technologies in primary education' contained a chapter on 'Solving conceptual problems with digital media', although tat skill was more frequently observed in mathematics syllabi (Table V).

Methodology included practical lessons devoted to problem solving to illustrate the academic theory involved. In some cases, reference was observed to PBL (problem-based learning) in conjunction with other methodologies.

Under assessment, problem solving was most often included in exams calling for students to solve problems, such as in the stipulation that 'tests will contain questions on academic knowledge as well as problems similar to the ones addressed in the classroom', set out in the University of León's subject 'Experimental science teaching and learning I'. Problem solving was normally deemed to be one of the classroom activities performed throughout the school year liable to assessment.

## Real-life situations

Application to real-life situations was not very heavily present in the 2020/2021 syllabi, with over half containing only one or no references (Table IV). As the matrix in Graph I shows, this characteristic was found nearly exclusively under learning expectations (in connection with posing and solving problems associated with daily life) and content. As explained earlier, content was deemed to embrace real-life situations only when reference was made to its application to daily life, with chapters such as 'Chemistry and daily life' in the University of Seville's subject 'Fundamentals of the science of matter' or 'Uses and contexts of natural numbers' in the University of Cordoba's subject 'Mathematics'. This characteristic was essentially absent from methodology and assessment in the syllabi analysed.

Its weight by area (Table VI) was found to be similar in mathematics and experimental science, although slightly greater in the latter, whereas mention was practically notional only in ICT subjects.

**TABLE VI.** Presence of real-life situations in curricular elements by area

| | Expectations | Content | Methodology | Assessment | Total |
|---|---|---|---|---|---|
| **Mathematics (N=113)** | 147 | 53 | 9 | 12 | 221 |
| **Experimental Science (N=102)** | 166 | 48 | 12 | 16 | 242 |
| **ICTs (N=22)** | 4 | 2 | 1 | 1 | 10 |

Source: author formulation

## Interdisciplinarity

Means of two references to the subcategory other STEM areas and of 1.45 to ICT usage were observed in the syllabi reviewed (Table IV). Nearly all the references to the former subcategory were found under learning expectations (Graph I), given the definition in the national guidelines of the skills: 'esteeming the relationship between mathematics and science as one of the mainstays of scientific thinking' (p. 53750) in mathematics; and 'recognising the interconnections among science, society and technological development and the respective civilian behaviours in pursuit of a sustainable future' (p. 53749) in experimental science as course aims. Unsurprisingly, then, references to this characteristic in the syllabi were found most frequently in connection with learning expectations. One notable finding was the inclusion of the item 'STEAM in experimental science education, fundamentals and classroom experiences' under the topic 'Science, technology and society' in Rovira i Virgili University's subject 'Teaching and learning experimental science'.

References to the second subcategory, ICT usage, in the syllabi analysed stressed the importance of future teachers' user-level command


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of such technologies as well as of their acquaintance with specific ICT resources for teaching mathematics and Science and their ability to use and include them in teaching proposals. In contrast to the subcategory on other STEM areas, here the curricular elements content and methodology accounted for the greater number of mentions to ICT usage. Examples include the chapter on 'ICTs in mathematics teaching-learning' in the University of La Laguna's subject 'Teaching numeracy and probability in statistics' or under methodology, the recommendation to 'furthering the use of ICTs' in the University of Valladolid's subject 'Teaching the experimental science curriculum'.

The inter-area differences observed are set out in Table VII. References to ICT usage were more frequent in the mathematics than in experimental science syllabi, whereas the relationship to other STEM areas carried greater weight in Science. The ICT syllabi, in turn, carried practically no reference to interdisciplinarity. That notwithstanding, the difference between areas was narrower in that subcategory.

**TABLE VII.** Presence of interdisciplinarity and use of ICTs in curricular elements by area

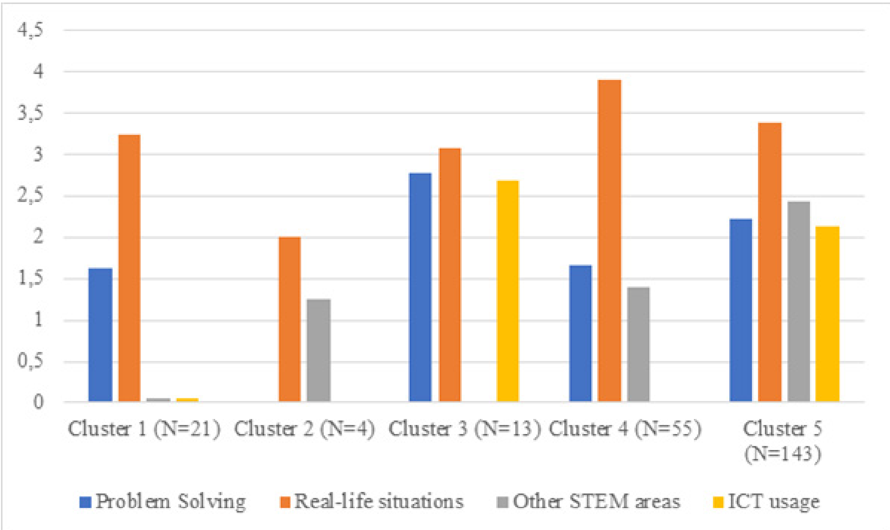
| | | Expectations | Content | Methodology | Assessment | Total |
|---|---|---|---|---|---|---|
| **Other STEM areas** | **Mathematics (N=113)** | 175 | 5 | 4 | 2 | 186 |
| | **Experimental Science (N=102)** | 192 | 24 | 3 | 6 | 224 |
| | **ICTs (N=22)** | 6 | 0 | 0 | 1 | 7 |
| **ICT usage** | **Mathematics (N=113)** | 133 | 36 | 32 | 5 | 207 |
| | **Experimental Science (N=102)** | 89 | 13 | 21 | 1 | 124 |
| | **ICTs (N=22)** | - | - | - | - | - |

Source: author formulation

## Cluster analysis of syllabi by STEM characteristic

As discussed in the preceding section, globally speaking the syllabi reviewed contained references to all three STEM characteristics (problem solving, real-life situations, interdisciplinarity (sub-divided into ICT usage and relations with other STEM areas). Not all the syllabi mentioned all three categories, however. Cluster analysis was conducted to identify similarities among the syllabi in terms of the STEM characteristics present. Inasmuch as the use of MAXQDA software entails pre-defining the clustering method and number of clusters because the tool does not deploy hierarchical methods, the analysis involved was conducted by adding a new cluster until the next one generated was the result of the division of a minority cluster. That procedure ultimately yielded the five clusters depicted in Graph II, which shows the number of syllabi in each cluster and the mean number of references to each STEM characteristic.

**GRAPH II.** Syllabi clustered by STEM characteristic




Source: author formulation

The 21 syllabi in the first cluster contained references primarily to problem solving and application to real-life situations. Cluster 2, the smallest of the five, consisted in just four syllabi characterised by the presence of references only to real-life situations and other STEM areas. The third comprised 13 syllabi in which the prevailing characteristic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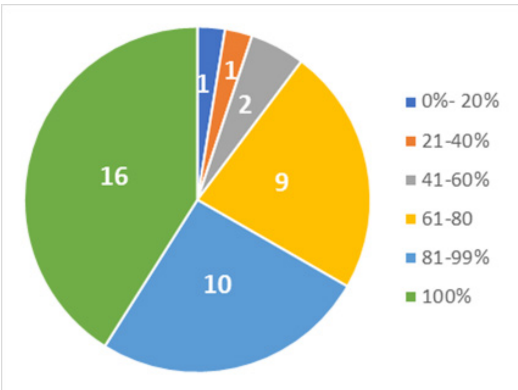
was the absence of inter-relationships between STEM areas, whilst the characteristic lacking in the 55 guides in the fourth cluster was ICT usage. In contrast, all four STEM characteristics were present in the fifth and largest cluster, with 143 guides. In other words, the syllabi in clusters 4 and 5 contained references to the three STEM characteristics analysed: problem solving, application to real-life situations, and interdisciplinarity. Whilst mathematics syllabi were observed to prevail in the third cluster, characterised by the absence of the characteristic other STEM areas, the number of those and science syllabi was similar in the other three. ICT subject syllabi were evenly distributed in the first and fourth clusters.

Once the clusters containing syllabi with references to all the STEM characteristics were identified (clusters 4 and 5), the percentage of each university's syllabi exhibiting those characteristics was found. As Graph III shows, in 16 of a total of 39 Spanish public universities 100 % of the syllabi contained references to all three STEM characteristics; in 10 universities the three characteristics were found in 81% to 99% of the documents; a percentage of 20 % was recorded for one university only. In other words, all the syllabi published by 40 % of the universities mentioned all the STEM characteristics defined here, whilst in approximately 12 % of the universities fewer than half of the syllabi in place contained such references. Nonetheless, all the universities had at least one syllabus in which all three characteristics were mentioned.

**GRAPH III.** Distribution of universities by percentage of experimental science, mathematics, and ICT syllabi containing references to all three STEM characteristics




Source: author formulation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## Discussion and conclusions

This study aimed to ascertain whether the present primary education curriculum in Spain can accommodate STEM education. The first of the two objectives for that purpose was to describe the STEM areas present in official university degrees qualifying for teaching primary school in Spain. A second aim was to identify the presence of STEM education characteristics (problem solving, real-life situations and interdisciplinarity) in the syllabi for STEM area-related subjects delivered by Spanish public universities.

The only two STEM areas to which subjects were explicitly devoted in the 2020/2021 curriculum were mathematics and experimental science, for they were the only two defined as requisites under the item on course breakdown by discipline in the national guidelines (MEC, 2007). The aforementioned guidelines defined neither the number of subjects nor the credits to be accorded each area, but only the total credits (100 ECTS) assigned to the disciplinary training unit. Hence the wide scatter observed around the median number of subjects (3 in mathematics and 2 in science) and mean number of credits (18 in mathematics and 15 in experimental science) assigned by the universities analysed. No specific core or requisite subjects were found for enginerering or technology, although the syllabi for mathematics and experimental science subjects contained references to technology and ICTs. Only 20 universities delivered core or requisite subjects specifically focusing on ICTs, however, even though one of the twelve general skills to be mastered by future teachers during pre-service training is 'understanding and applying information and communication technologies in the classroom' (MEC, 2007, p. 53748). The explanation for these findings may lie in the structure of the official curriculum for Primary Education (Ministerio de Educación Cultura y Deporte, 2014), which makes no mention of enginerering, includes technology under a nature science unit entitled 'Technology, objects and machines' (p. 17) and defines only two subjects, nature science and mathematics.

In connection with the second objective, of the three STEM characteristics identified (problem solving, application to real-life situations, and interdisciplinarity), only the first was observed to be present in all four curricular elements (learning expectations, content, methodology and assessment). The others were found primarily in connection with learning expectations, although also on occasion in other elements as well.

The national guidelines proved to address interdisciplinarity, in turn, via the inclusion of 'familiarity with primary education curricular areas and their interrelationships' as one of general skills demanded of pre-service training teachers. Since that characteristic was mentioned under the curricular element learning expectations only, however, the question that arises is whether it actually forms part of pre-service teacher training. In other words, the doubt harboured is whether the syllabi are overly brief in this respect, focusing more intensely on organisational details such as types of activity or marking criteria. Over half the syllabi analysed contained all three STEM characteristics, which were likewise present in nearly all (80 % or over) the guides in place in 26 of the 39 public universities offering a degree in primary education. Admittedly, however, those guides do not necessarily mirror classroom realities and are often too pithy to furnish sufficient information.

In connection with the integration of STEM disciplines in primary education training, Aguilera et al. (2021) recommend that in multidisciplinary proposals each discipline should be introduced with its own objectives but all around a common topic, in which the professor not only describes possible social impact but explicitly relates the disciplines to one another. The present findings suggest the possibility of implementing such experiences in teacher training as it stands. Any such proposal would be most effectively rolled out if, as described by Bartels et al. (2019), the experimental science and mathematics departments cooperate in its design and inclusion and make an effort to understand what is involved in enginerering and accommodate that discipline in their suggestions. Rising to that challenge entails providing lifelong training for the teaching staff delivering the subjects in question. All post-secondary levels are deemed to be in need of substantial curricular reform, which should include a certain degree of STEM competence that today's students are lacking. That said, on occasion STEM educational proposals may be deemed to entail a partial vision of technology, often confined to references to ICT usage only (García-Carmona, 2020). As noted in earlier studies (Bartels et al., 2019), any potential institution of STEM education as part of the primary education curriculum should eschew that misguided approach and define technology in all its depth and breadth.

The conclusion drawn is that inasmuch as the absence of academic staff collaboration is one of the obstacles to the adoption of STEM teaching sequences (Margot & Kettler, 2019), such reluctance should be overcome and STEM experiences included in primary school teachers' pre-service training to prepare them to confront twenty-first century challenges. Teachers would be very unlikely to implement such teaching without the necessary prior training. The present study aims to take a first step in that direction by showing that STEM education proposals are compatible with the primary education curriculum in place in Spain.

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**Contact address:** Ana B. Montoro. Universidad de Granada, Facultad de Ciencias de la Educación, departamento de Didáctica de la Matemática. Calle Prof. Vicente Callao, s/n. Facultad de Ciencias de la Educación, 18011, Granada, España. E-mail: amontoro@ugr.es


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