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Initial Education of Future Secondary Mathematics Teachers in Spain

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RESUMEN DEL CONTENIDO DE TESIS DOCTORAL

1.- Título de la Tesis	
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RESUMEN (en español)

El propósito de esta tesis doctoral es analizar los programas de formación inicial para el futuro profesorado de matemáticas en Educación Secundaria en España, donde la investigación es aún escasa. En 2008, España participó, junto con otros 16 países, en el TEDS-M (Teacher Education and Development Study in Mathematics), primer estudio comparativo internacional sobre la formación inicial del futuro profesorado de matemáticas de Educación Primaria y primeros cursos de Secundaria. Sin embargo, la participación española se limitó a futuros maestros debido a las dificultades encontradas a la hora de contactar y recoger datos de futuros profesores en Educación Secundaria. Otros estudios desarrollados en el contexto español se fundamentan en los conocimientos y experiencias de los propios autores sobre la organización y el desarrollo de los programas de formación inicial docente, o bien se limitan al análisis de datos recogidos en una o dos universidades. Así, esta investigación se considera pionera en España.

Esta investigación parte de una comparativa internacional sobre los programas de formación inicial para el futuro profesorado de Educación Secundaria, seguida de una descripción detallada de la situación española, centrada en la especialidad de matemáticas. Este enfoque permite identificar las similitudes y diferencias entre los distintos países, además de algunos puntos débiles del sistema español, como el limitado bagaje matemático de los estudiantes matriculados en un programa de formación inicial para el futuro profesorado de matemáticas en Educación Secundaria, o la falta de un marco común a nivel nacional que establezca las competencias que deben ser adquiridas durante la formación inicial. Ambos factores se abordan a lo largo de esta memoria.

El segundo paso de esta investigación reside en la conceptualización de los conocimientos y competencias del futuro profesorado de matemáticas en Educación Secundaria. En primer lugar, se desarrolla un marco de treinta y tres competencias a partir de una revisión de la literatura sobre modelos teóricos existentes y marcos de competencias disponibles. Dicho marco es posteriormente validado mediante un proceso de consulta a expertos.

La disposición de un marco de competencias proporciona los fundamentos necesarios para medir tanto conocimientos como competencias docentes. Por consiguiente, se proponen medidas y escalas con un alto índice de fiabilidad para la evaluación del conocimiento y las competencias del futuro profesorado de matemáticas en Educación Secundaria. Los instrumentos diseñados en investigaciones previas permiten analizar un número limitado de competencias. En esta tesis doctoral se describe un instrumento para la recogida de datos que incluye un amplio conjunto de conocimientos matemáticos y competencias docentes.

A continuación, este instrumento se utiliza en un estudio a nivel nacional, en el que participan profesores de matemáticas en formación, formadores de profesores de matemáticas, tutores de prácticas, y profesores de matemáticas recién graduados de diferentes universidades españolas. Los resultados confirman la hipótesis de que los programas de formación inicial en España son moderadamente ecaces, y revelan bajos niveles de desarrollo y adquisición de

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competencias docentes.

Esta memoria concluye con la descripción de una intervención cuyo objetivo es explorar el impacto del uso de video-clips en los programas de formación inicial docente como herramienta para potenciar el desarrollo de competencias. Los resultados muestran el potencial de esta estrategia didáctica para proporcionar al futuro profesorado la oportunidad de experimentar distintas dimensiones de la práctica docente.

RESUMEN (en Inglés)

This dissertation aims at gaining insight into initial education programs for future secondary mathematics teachers in Spain, where nationwide empirical research is scarce. In 2008, Spain participated, along with 16 other countries, in the Teacher Education and Development Study in Mathematics (TEDS-M), an international comparative study which examined how different countries prepare future teachers to teach mathematics in primary and lower-secondary education. However, the Spanish participation in the study was limited to future teachers at primary education due to difficulties in collecting data from dispersed and dicult-to-reach future teachers at secondary education level. Additional studies, set up in the Spanish context, are based on the professional experiences and knowledge of their authors as responsible for the organization and development of initial teacher education programs, or are limited to data collected from one or two universities. In this sense, this research is considered pioneering in Spain.

The starting point of this dissertation lies in an international comparison of initial education programs for future teachers at secondary education, followed by an in-depth description of the Spanish situation, focusing on the mathematics specialty. This approach helps to identify significant similarities and differences between countries and, in particular, to reveal two major signs of weakness within the Spanish context: the narrow mathematical background of the students enrolled in an initial education program for future secondary mathematics teachers, and the lack of a common nationwide framework establishing the competences to be mastered by the time the student teachers graduate. Both factors are tackled throughout the present dissertation.

A second step in this research resides in the attempt to conceptualize future secondary mathematics teachers' subject-matter knowledge and competences. To this end, a comprehensive framework of thirty-three competences is first developed by means of a literature review of existing theoretical models and available competence frameworks, and subsequently validated through an expert panel consultation process.

The disposition of a competence framework provides a strong foundation in order to measure teaching knowledge and competences. Reliable measures and scales are therefore suggested for the assessment of the subject-matter knowledge and competences of future secondary mathematics teachers in Spain. Although previous research has already adopted valid direct and indirect measurement methods, these are often limited to a small number of competences. In this dissertation, a research instrument scoping a wide range of mathematical knowledge domains and teaching competences is described.

This instrument is subsequently used in a nationwide survey, involving mathematics student teachers, mathematics teacher educators, mentors, and recently graduate mathematics teachers from different Spanish universities. The results evidence the hypothesis that initial education programs in Spain are moderately effective in order to prepare future secondary mathematics teachers for the profession, but reveal critical competences hardly pursued and attained during initial teacher education.

This dissertation concludes with the description of an intervention, which aims at exploring the impact of using video-vignettes in initial teacher education programs as an alternative to enhance the development of teaching competences. The findings document the potential of simulation-based activities to provide future teachers with the opportunity to experience dimensions of simulated practice reality.

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Summary

This dissertation aims at gaining insight into initial education programs for future secondary mathematics teachers in Spain, where nationwide empirical research is scarce. In 2008, Spain participated, along with 16 other countries, in the Teacher Education and Development Study in Mathematics (TEDS-M), an international comparative study which examined how different countries prepare future teachers to teach mathematics in primary and lower-secondary education. However, the Spanish participation in the study was limited to future teachers at primary education due to difficulties in collecting data from dispersed and difficult-to-reach future teachers at secondary education level. Additional studies, set up in the Spanish context, are based on the professional experiences and knowledge of their authors as responsible for the organization and development of initial teacher education programs, or are limited to data collected from one or two universities. In this sense, this research is considered pioneering in Spain.

The starting point of this dissertation lies in an international comparison of initial education programs for future teachers at secondary education, followed by an in-depth description of the Spanish situation, focusing on the mathematics specialty. This approach helps to identify significant similarities and differences between countries and, in particular, to reveal two major signs of weakness within the Spanish context: the narrow mathematical background of the students enrolled in an initial education program for future secondary mathematics teachers, and the lack of a common nationwide framework establishing the competences to be mastered by the time the student teachers graduate. Both factors are tackled throughout the present dissertation.

A second step in this research resides in the attempt to conceptualize future secondary mathematics teachers' subject-matter knowledge and competences. To this end, a comprehensive framework of thirty-three competences is first developed by means of a

literature review of existing theoretical models and available competence frameworks, and subsequently validated through an expert panel consultation process.

The disposition of a competence framework provides a strong foundation in order to measure teaching knowledge and competences. Reliable measures and scales are therefore suggested for the assessment of the subject-matter knowledge and competences of future secondary mathematics teachers in Spain. Although previous research has already adopted valid direct and indirect measurement methods, these are often limited to a small number of competences. In this dissertation, a research instrument scoping a wide range of mathematical knowledge domains and teaching competences is described.

This instrument is subsequently used in a nationwide survey, involving mathematics student teachers, mathematics teacher educators, mentors, and recently graduate mathematics teachers from different Spanish universities. The results evidence the hypothesis that initial education programs in Spain are moderately effective in order to prepare future secondary mathematics teachers for the profession, but reveal critical competences hardly pursued and attained during initial teacher education.

This dissertation concludes with the description of an intervention, which aims at exploring the impact of using video-vignettes in initial teacher education programs as an alternative to enhance the development of teaching competences. The findings document the potential of simulation-based activities to provide future teachers with the opportunity to experience dimensions of simulated practice reality.

The relevance of this dissertation is theoretical, empirical and practical in nature. The theoretical relevance is reflected in the development and validation of a competence framework for future secondary mathematics teachers. This framework can be adapted for use in subsequent studies, whether in other specialties or countries. Besides, this dissertation contributes to the scientific literature through the disposal of validated instruments. From an empirical point of view, this research provides accurate data sets on factors related to the initial education of future secondary mathematics teachers in Spain. This dissertation is also relevant for the educational practice and policy. The findings of the nationwide survey attempt to inform policymakers and educational leaders about the urgent need to reformulate some aspects of initial education programs for future secondary mathematics teachers in Spain. In particular, the developed intervention leaves at teacher educators disposal an effective learning strategy to foster the acquisition of teaching competences during initial teacher education.

Resumen

El propósito de esta tesis doctoral es analizar los programas de formación inicial para el futuro profesorado de matemáticas en Educación Secundaria en España, donde la investigación es aún escasa. En 2008, España participó, junto con otros 16 países, en el TEDS-M (Teacher Education and Development Study in Mathematics), primer estudio comparativo internacional sobre la formación inicial del futuro profesorado de matemáticas de Educación Primaria y primeros cursos de Secundaria. Sin embargo, la participación española se limitó a futuros maestros debido a las dificultades encontradas a la hora de contactar y recoger datos de futuros profesores en Educación Secundaria. Otros estudios desarrollados en el contexto español se fundamentan en los conocimientos y experiencias de los propios autores sobre la organización y el desarrollo de los programas de formación inicial docente, o bien se limitan al análisis de datos recogidos en una o dos universidades. Así, esta investigación se considera pionera en España.

Esta investigación parte de una comparativa internacional sobre los programas de formación inicial para el futuro profesorado de Educación Secundaria, seguida de una descripción detallada de la situación española, centrada en la especialidad de matemáticas. Este enfoque permite identificar las similitudes y diferencias entre los distintos países, además de algunos puntos débiles del sistema español, como el limitado bagaje matemático de los estudiantes matriculados en un programa de formación inicial para el futuro profesorado de matemáticas en Educación Secundaria, o la falta de un marco común a nivel nacional que establezca las competencias que deben ser adquiridas durante la formación inicial. Ambos factores se abordan a lo largo de esta memoria.

El segundo paso de esta investigación reside en la conceptualización de los conocimientos y competencias del futuro profesorado de matemáticas en Educación Secundaria. En primer lugar, se desarrolla un marco de treinta y tres competencias a partir de una revisión de la

literatura sobre modelos teóricos existentes y marcos de competencias disponibles. Dicho marco es posteriormente validado mediante un proceso de consulta a expertos.

La disposición de un marco de competencias proporciona los fundamentos necesarios para medir tanto conocimientos como competencias docentes. Por consiguiente, se proponen medidas y escalas con un alto índice de fiabilidad para la evaluación del conocimiento y las competencias del futuro profesorado de matemáticas en Educación Secundaria. Los instrumentos diseñados en investigaciones previas permiten analizar un número limitado de competencias. En esta tesis doctoral se describe un instrumento para la recogida de datos que incluye un amplio conjunto de conocimientos matemáticos y competencias docentes.

A continuación, este instrumento se utiliza en un estudio a nivel nacional, en el que participan profesores de matemáticas en formación, formadores de profesores de matemáticas, tutores de prácticas, y profesores de matemáticas recién graduados de diferentes universidades españolas. Los resultados confirman la hipótesis de que los programas de formación inicial en España son moderadamente eficaces, y revelan bajos niveles de desarrollo y adquisición de competencias docentes.

Esta memoria concluye con la descripción de una intervención cuyo objetivo es explorar el impacto del uso de video-clips en los programas de formación inicial docente como herramienta para potenciar el desarrollo de competencias. Los resultados muestran el potencial de esta estrategia didáctica para proporcionar al futuro profesorado la oportunidad de experimentar distintas dimensiones de la práctica docente.

La relevancia de esta tesis es de carácter teórico, empírico y práctico. La relevancia teórica se refleja en el desarrollo y validación de un marco de competencias para el futuro profesorado de matemáticas en Educación Secundaria. Este marco puede ser adaptado para su uso en futuros estudios, ya sea en otras especialidades o países. Además, esta investigación pone a disposición de la comunidad científica instrumentos validados. Desde un punto de vista empírico, esta investigación proporciona datos y resultados sobre el conocimiento y las competencias del futuro profesorado de matemáticas en Educación Secundaria en España. Esta investigación es a su vez de gran relevancia para la práctica y la política educativa. Los resultados pretenden informar a los responsables de la política educativa sobre la urgente necesidad de reformular algunos aspectos del sistema de formación inicial para el futuro profesorado de matemáticas en Educación Secundaria en España. En particular, la intervención desarrollada pone a disposición de los formadores de profesores una estrategia eficaz para fomentar la adquisición de competencias.

Samenvatting

Doel van dit proefschrift is het analyseren van initiële opleidingsprogramma's voor toekomstige secundaire wiskunde leraren in Spanje. Empirisch onderzoek bij deze doelgroep is schaars. In 2008 heeft Spanje samen met 16 andere landen deelgenomen aan de TEDS-M, de eerste internationale vergelijkende studie die onderzocht hoe verschillende landen toekomstige leraren voorbereiden om wiskunde in het basis en middelbaar onderwijs aan te leren. De Spaanse deelname aan de studie bleef echter beperkt tot basisonderwijs leraren door moeilijkheden bij het verzamelen van gegevens bij toekomstige leraren secundair onderwijs. Andere beschikbare Spaanse studies zijn gebaseerd op de professionele ervaring en kennis van auteurs – als verantwoordelijke voor de organisatie en ontwikkeling van initiële lerarenopleidingen – of op beperkt gegevens, verzameld bij studenten uit een of twee universiteiten. In dit opzicht is het onderzoek voorgesteld in dit proefschrift zeker innovatief voor de Spaanse context.

Uitgangspunt van dit proefschrift is een internationale vergelijking van de initiële opleidingsprogramma's voor toekomstige secundaire leraren. Dit wordt gevolgd door een diepgaande beschrijving van de Spaanse situatie, gericht op de opleiding van leraren wiskunde. Deze aanpak helpt bij het identificeren van overeenkomsten en verschillen tussen landen en vooral twee belangrijke zwakke punten in de Spaanse context: de beperkte wiskundige achtergrond van studentleerkrachten die zich inschrijven voor het opleidingsprogramma voor toekomstige secundaire wiskunde leraren, en het ontbreken van een gemeenschappelijk nationaal kader dat bepaalt welke competenties moeten verwerven zijn na die de initiële opleiding. Allebei worden aangepakt in dit proefschrift.

Een tweede stap in dit onderzoek ligt in de poging om de kennis en competenties van toekomstige secundaire wiskunde leraren te identificeren. Daarvoor is een omvattend kader van drieëndertig lerarencompetenties ontwikkeld. Dit gebeurde op basis van een literatuuronderzoek van beschikbare theoretische modellen en beschikbare competentie overzichten. Dit nieuwe competentiemodel is vervolgens gevalideerd.

Het opstelling van dit competentiekader biedt een sterke basis om die competenties te evalueren. Er worden betrouwbare aanpakken voorgesteld voor de beoordeling van competenties bij toekomstige secundaire wiskunde leraren in Spanje. Hoewel eerder onderzoek reeds directe en indirecte meetmethoden voorstelt, bleven deze vaak beperkt tot een klein aantal competenties. In het proefschrift wordt een instrument voorgesteld om een breed scala aan lerarencompetenties voor wiskunde in kaart te brengen.

Dit instrument wordt vervolgens gebruikt – in een nationaal onderzoek – bij toekomstige wiskunde leraren, wiskunde lerarenopleiders, mentoren, en recent afgestudeerd wiskunde leraren uit verschillende Spaanse universiteiten. De resultaten bevestigen de hypothese dat initiële opleidingsprogramma's in Spanje matig effectief zijn in de voorbereiding van toekomstige secundaire wiskunde leraren voor het lerarenberoep. De resultaten tonen ook aan hoe bepaalde competenties nauwelijks nagestreefd en bereikt worden tijdens de initiële lerarenopleiding.

Het laatste onderzoek in het proefschrift is de beschrijving van een interventie, gebaseerd op het gebruik van videovignetten in een initiële lerarenopleiding, als alternatieve aanpak om een de complexe competentie "feedback" geven te ontwikkelen. De onderzoeksresultaten tonen het potentieel aan van deze klinische simulatie-aanpak om toekomstige leraren de volle complexiteit van de onderwijspraktijk in relatie tot deze competentie te ervaren.

De relevantie van het proefschrift is theoretisch, empirisch en praktisch. De theoretische relevantie wordt weerspiegeld in de ontwikkeling en validatie van een competentiekader voor toekomstige secundaire wiskunde leraren. Dit kader kan worden aangepast voor latere studies, in andere specialisaties of in andere landen. Daarnaast draagt deze proefschrift bij tot de wetenschappelijke literatuur door de aanpak bij het valideren van instrumenten. Er is nu een empirische basis beschikbaar die nauwkeurige gegevens en resultaten oplevert m.b.t. de competenties van secundair wiskunde studentleerkrachten in Spanje. Dit proefschrift is ook relevant voor de onderwijspraktijk en het onderwijsbeleid. De resultaten informeren beleidsmakers en onderwijsverantwoordelijken over de dringende noodzaak om aspecten van de initiële opleidingsprogramma's voor toekomstige secundaire wiskunde leraren in Spanje te herformuleren. Naast aandacht voor een bredere kijk op de lerarencompetenties toont het interventie onderzoek aan hoe alternatieve aanpakken effectief kunnen zijn voor het verwerven van competenties tijdens een initiële lerarenopleiding.

Contents

CHAPTER 1

General introduction

This preliminary chapter presents an overview of the content of this dissertation. The first section introduces the reader to the field of initial teacher education, which is the main topic of this research. In particular, two of the most frequently investigated factors related to initial teacher education and their relevance to student achievement are summarized, namely future teachers' subject-matter content knowledge and future teachers' competences. This is followed by an in-depth description of the research context and problem in which this dissertation is embedded. The focus of attention is on the Spanish situation and, in particular, on secondary mathematics teacher education. The third section presents the main research aim, together with the specific research objectives. This is followed by a detailed description of the research design, outlining the different studies together with a brief explanation of each methodological approach. This introductory chapter concludes with an overview of the dissertation.

1.1 Introduction

Research exploring factors that might influence student achievement identifies teachers as one of the most powerful predictors of performance (Greenwald, Hedges, & Laine, 1996; Hattie, 2009; Rowan, Correnti, & Miller, 2002). But there is no doubt that all teachers are not alike. Theories about the essential qualities of a good teacher point at the multilevel nature of teachers' professional identity (Korthagen, 2004). This author distinguished between six layers summarized in *the onion model*: environment, behavior, competences, beliefs, identity, and personal mission (see Figure 1.1). The higher the alignment of these layers, the better teachers will function within an educational environment. The development of the different layers is strongly influenced by initial teacher education (Korthagen 2004), which is the core of this research.

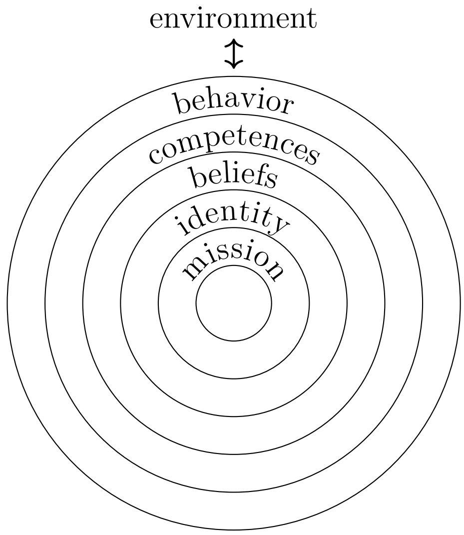

Figure 1.1. The onion model of Korthagen (2004).

Initial teacher education refers to the process by which future teachers acquire the knowledge, attitudes, behaviors and skills necessary to perform effectively as teachers. It is commonly provided through initial teacher education programs: under- or post-graduate courses in higher education that lead to the qualification to teach. The students enrolled in an accredited initial teacher education program are generally denominated future teachers, prospective teachers, student teachers, or pre-service teachers. Initial teacher education programs commonly involve a theoretical and a practical component. The university staff members responsible for instructing the student teachers during the theoretical component are usually referred to as teacher educators. Whereas the school teachers responsible for supervising and guiding the student teachers during the field experience are broadly named mentors. Initial teacher education must be viewed as the starting point of teachers' professional development (OECD, 2014).

Previous research studies have provided empirical evidence about how initial education influences the nature of the teaching practices of future teachers (Bramald, Hardman, & Leat, 1995; Darling-Hammond, Hammerness, Grossman, Rust, & Shulman, 2005). As a consequence, other researchers indicate that initial teacher education correlates significantly with student achievement (Darling-Hammond, 2000; Greenwald et al., 1996). On the other hand, meta-analytic studies report an insignificant effect size (around 0.10) of initial teacher education programs on subsequent student learning outcomes (Glazerman, Mayer, & Decker, 2006; Hattie, 2009; Wideen, Mayer-Smith, & Moon, 1998). In this sense, Hattie (2009) states that the familiar saying "the best part of initial teacher education was the practical" explains the limited impact of initial education programs.

None the less, the quality of initial teacher education programs has been frequently questioned. A long-standing issue is the lack of consensus about the curriculum of initial teacher education programs. This means, as claimed by Hattie (2009, p. 109), that "there is no standard approach to where and how teachers should be prepared". Some authors describe the world of initial teacher education as "unruly and disordered" (Levine, 2006, p. 109) and blame policymakers and educational leaders for ignoring and underestimating this low-quality problem (see also Sparks, 2004).

So far, the literature agrees on some common considerations and concerns that should be taken into account for the design of initial teacher education programs:

- **The recruitment systems** of initial teacher education programs should select competent candidates with the relevant beliefs and attitudes, such as commitment, confidence, initiative, leadership, respect, among others (Bokdam, van den Ende, & Broek, 2014; OECD, 2005). This is crucial because teachers' emotions and instructional behavior significantly predict students' emotions (Becker, Goetz, Morger, & Ranellucci, 2014).

- **The content of initial teacher education programs** should be determined by the demands of the competences that future teachers need for real classrooms (Levine, 2006). The research community coincides that this content significantly influences future teachers' readiness for the job (Darling-Hammond et al., 2005) and largely explains the overall quality of initial teacher education (Bokdam et al., 2014).

- **The gap between theory and practice** should be reduced by a close, successful partnership between universities and schools with a shared conception of teaching (Darling-Hammond, 2006; Korthagen & Kessels, 1999). Allen and Wright (2013) highlight that this theory-practice binary is doubtless complex, but necessary to assure future teachers' readiness for the job. Other authors explain that linking theory and practice reduces the false expectations of student teachers about the profession (Struyven & Vanthournout, 2014) and avoids the initial shock that occurs between initial teacher education and the reality of the workplace (Caspersen & Raaen, 2014; Stokking, Leenders, De Jong, & Van Tartwijk, 2003).

- **The existence of well-defined standards of teaching competences** should be a requirement for initial teacher education programs (Levine, 2006). Teaching standards reflect a professional agreement on the competences student teachers are expected to attain throughout initial education (Kleinhenz & Ingvarson, 2007). Consequently, they serve as a guide for initial teacher education programs' definition and assessment (Darling-Hammond, 2006).

- **The preparation of teacher educators** matters, but is often overlooked (Koster & Korthagen, 2001). The quality and the effectiveness of initial teacher education largely depends on the competences and expertise of teacher educators (Buchberger, Campos, Kallos, & Stephenson, 2000). In this sense, previous studies conclude with the need for an investment in the quality of teacher educators (Korthagen, 2010). This call has been already addressed by some researchers who attempted to set out the quality requirements that are needed for teacher educators (Koster, Brekelmans, Korthagen, & Wubbels, 2005).

A deficient initial teacher education system may lead to short- and long-term negative consequences for future teachers and, as a result, for the educational system as a whole. For instance, a number of findings in the academic literature identified different factors that contribute to high dropout rates during initial teacher education or at the start of the career, such as the inevitable shock that occurs between initial teacher education and the reality of the workplace (Caspersen & Raaen, 2014; Stokking et al., 2003), the excessively naive and idealistic expectations of future teachers about teaching (Hong, 2010; Stokking et al., 2003), or student teachers' low levels of self-efficacy for the teaching practice (Klassen & Chiu, 2011). As an outcome, in the last years, the high proportions of dropout have resulted in a shortage of teachers in many countries (Cochran-Smith, 2004). The former factors should be considered a responsibility of initial teacher education programs.

In this dissertation, considerably more emphasis is laid on two additional elements related to initial teacher education, namely future teachers' subject-matter content knowledge and future teachers' competences. Both components underpinned the theoretical background of this research. Therefore, both concepts are briefly introduced to the reader within this introductory chapter.

1.1.1 Future teachers' subject-matter content knowledge

According to Shulman (1986), a conceptual analysis of teachers' knowledge should necessarily be based on a framework for classifying the domains and categories of such knowledge. In his attempt to develop a more coherent framework for teachers' knowledge, Shulman differentiates between one particular domain, namely *content knowledge*, and some other categories within it, labeled *subject-matter content knowledge*, *pedagogical content knowledge*, and *curricular knowledge*. Shulman (1986, p. 9) refers to "the amount and organization of knowledge per se in the mind of the teacher" as *content knowledge*. Undoubtedly, the content knowledge necessary to teach the different subject-matter areas vary from one to another. This is why Shulman (1986) introduces the notion of *subject-matter content knowledge*, which implies understanding the concepts, theories and structures of the subject-matter.

In general, research stresses that teaching requires strong subject-matter content knowledge (Osana, Lacroix, Tucker, & Desrosiers, 2006; Rowan et al., 2002). The consequences of teachers lacking a comprehensive base of subject-matter content knowledge can be negative for students, who can receive incorrect information and, as a result, develop misconceptions about the subject-matter content (Koehler & Mishra, 2009). However, there has been a long debate about the impact of such knowledge on student achievement. On the one hand, several large-scale studies demonstrated that teachers' subject-matter content knowledge significantly influences students' outcomes (Hill, Rowan, & Ball, 2005; Rowan, Chiang, & Miller, 1997). On the other hand, previous meta-analysis on the topic found a very low effect size: d=0.12 (Ahn & Choi, 2004) or d=0.09 (Hattie, 2009)[1].

A number of studies have succeeded in the attempt to conceptualize the subject-matter content knowledge necessary for teaching (Ball & McDiarmid, 1990; Kennedy, 1990). These authors categorize the subject-matter content knowledge of teachers in three different dimensions. On the one hand, Ball and McDiarmid (1990) distinguish between: the *substantive knowledge of the subject*, which includes specific

[1] d = effect size.

information, ideas, and topics to be known; the *knowledge about the subject*, which refers to the understandings about the subject; and the *dispositions toward the subject.* On the other hand, Kennedy (1990) differentiates between: the *content of the subject*, which includes the facts, concepts, or principles that have been gathered through the history; the *organization and structure of the content*, which refers to the relationships among facts and ideas; and the *methods of inquiry.* Both, the substantive knowledge and the content of the subject refer to the same notion of knowledge, while the other dimensions differ. In general, research highlights that the subject-matter content knowledge of future teachers might be influenced by a number of factors, such as their pedagogical preferences and academic tasks management, the specific discipline they will teach (Kennedy, 1990), their expectations about teaching and learning (Ball, 1991), or the attitudes of their students towards the subject (Ball & McDiarmid, 1990).

This exploration of the subject-matter content knowledge of future teachers commonly distinguishes between generalist and specialist teachers. Generalist teachers are usually qualified to teach all, or almost all, subjects in the curriculum, as opposed to specialist teachers who usually major one or two different subjects, such as chemistry, history, or mathematics. Generalist teachers commonly teach in primary education, while specialist teachers do it at secondary education level. A shared assumption is that, for any specific domain, the subject-matter content knowledge of specialist teachers should be deeper as compared to the one of generalist teachers. Specialist teachers generally acquire their subject-matter content knowledge before they start initial teacher education. In addition to the previous distinction, a seldom discussed question is whether a future specialist teacher should acquire the same knowledge as a future chemist, historian, or mathematician (Ball & McDiarmid, 1990; Kennedy, 1990). No answer to this question has been agreed upon. It is still a critical issue to determine whether teachers need to know more, or as much as they will teach, and whether such knowledge should differ from the one of other practitioners in view of, for instance, social norms, the relationship of a subject to social issues, or the value of the subject to the everyday life.

Previous research on the measurement of future teachers' subject-matter content knowledge has employed a number of different data collection instruments, such as structured open interviews with questions about teachers' underlying knowledge or sources of their knowledge, concept mapping assignments for understanding how teachers store and use the knowledge they possess for teaching, detailed observations about how teachers link their knowledge with practice, scores on subject-matter content exams, or the nature of teachers' bachelor degree (Ben-Peretz, 2011; Kennedy, 1990; Meijer, Verloop, & Beijaard, 1999; Nixon, Campbell, & Luft, 2016). Some authors criticize that the latter requirement does not assure that a person understands and is able to explain the subject-matter (Diamond, Maerten-Rivera, Rohrer, & Lee, 2013; Goldhaber & Brewer, 2000).

This dissertation focuses on the conceptualization and measurement of future secondary mathematics teachers' subject-matter content knowledge. To this end, a number of comprehensive and empirically supported theoretical models about teachers' knowledge (Ball, Thames, & Phelps, 2008; Carrillo, Climent, Contreras, & Muñoz-Catalán, 2013; Godino, 2009; Koehler & Mishra, 2009; Shulman, 1986, 1987) were taken into account (see Chapter 3 for a detailed description).

1.1.2 Future teachers' competences

The concept of competence in teaching refers to the combination of knowledge, skills and attitudes that enables teachers to develop effective teaching practice at multiple levels: the individual teacher, the school environment, the educational system, the educational authorities, and beyond. According to this definition, teaching competences are interrelated to each other and should be viewed as a whole. An effective teacher cannot be characterized in terms of isolated competences.

The existence of comprehensive and structured competence frameworks in initial teacher education programs has important practical implications. Competences define which knowledge, skills and attitudes student teachers should achieve and strengthen during their initial education. They can therefore be employed as reference points for developing initial teacher education programs and guiding curriculum development (Erebus International, 2008; Morris, Hiebert, & Spitzer, 2009). Besides, they are useful to set clear short- and long-term goals for teachers' learning and professional growth (Kleinhenz & Ingvarson, 2007; Tigelaar, Dolmans, Wolfhagen, & van der Vleuten, 2004), and – together with benchmark levels – serve as measures to assess the quality of teaching (European Commission, 2013).

Worldwide, initial teacher education institutions struggle to define core teaching competences in view of the accreditation of initial education programs and resulting diplomas. The research community coincides with the fact that competences should be coherent, contextualized, flexible, measurable, and up-to-date (Mohamed, Valcke, & De Wever, 2016; Tigelaar et al., 2004). However, there is hardly any international consensus about which competences student teachers should master after completing their initial education.

In order to determine whether a student teacher is ready and competent to teach, it is essential to implement practical measures to assess the acquisition and development of teaching competences. The literature stresses such measures are relevant in order to foster teachers' awareness about their own competences, enhance teaching quality and excellence, and develop timely interventions to improve teaching (European Commission, 2013). However, up to now, no systematic tool has been developed. Previous research on the assessment of teachers' competences can be divided into studies using indirect measures and studies using more direct measures. In the case of indirect measures, the assessment of teachers' competences has been mainly based on teachers' self-assessment (Alkharusi, Kazem, & Al-Musawai, 2011; Mohamed et al., 2016). In the case of direct assessment, the measurement of teachers' competences has been based on the analysis of directly performed and observed actions. Some frequently used instruments are written teaching portfolios (Klenowski, 2000), video recordings (Hatch, Shuttleworth, Jaffee, & Marri, 2016), and/or clinical simulations (Dotger, Masingila, Bearkland, & Dotger, 2015). Having said that striking discrepancies are known to exist between the competences observed through indirect measures and the competences reflected in direct measures. Indirect measures, such as teachers' self-assessment, rely on individuals' self-reports, self-evaluations or self-perceptions, while direct measures, such as video recordings or clinical simulations, provide performed-based evidence of teaching through observation techniques (Admiraal et al., 2014). Both types of measures present advantages and disadvantages. Direct measures are usually more expensive, time consuming, and difficult to implement in large samples. In contrast, indirect measures suffer from validity problems as individuals can overestimate or underestimate someone's competences or be aware of social desirable answers (Zlatkin-Troitschanskaiaa, Shavelsonb, & Kuhn, 2015).

In the research carried out in the context of this dissertation, a multi-actor perspective to analyze the perception of student teachers, teacher educators, mentors, and recently graduate teachers about the extent to which professional teaching competences are pursued and attained during initial education programs was first adopted. This approach allowed to identify critical competences weakly pursued and/or attained during the theoretical and practical component of initial teacher education programs. This evoked the design, implementation and assessment of a competence development intervention. In particular, the extent to which video-vignettes are an effective tool for the development of a specific teaching competence during initial education programs – namely *giving and seeking constructive, purposeful and timely feedback to/from students, their families, and colleagues* – was explored.

1.2 Research context and problem

In Spain, initial teacher education has been in the spotlight for a long while. The not outstanding results of Spanish students in national and international assessments, such as the Program for International Student Assessment (PISA) or the Trends in Mathematics and Science Study (TIMSS), have pointed at the low quality of the initial education of future secondary teachers as one of the main causes (Rico, 2004). Previous research in the field has identified different shortcomings that can be classified as follows:

- **Heterogeneity.** There is considerable variability among the different autonomous communities and universities regarding the organization, the structure, the admission requirements, the tuition fees, and the number of student teachers admitted by each university every academic year (Palarea, 2011; Viñao, 2013). This heterogeneity is wider within the private sector. Given that teachers can develop their teaching career in any of the different Spanish autonomous communities, it seems appropriate to establish homogeneous criteria in the curricular and organizational aspects related to initial teacher education.
- **Disconnected structure.** Student teachers perceive a notable lack of coordination between the theoretical and the practical modules and subjects (Santos & Lorenzo, 2015; Vilches & Gil-Pérez, 2010). In general, the content of initial teacher education programs is considered to be too theoretical in relation to the practice (Comisión de Educación del CEMat, 2011; Gutiérrez, 2011; Valdés & Bolívar, 2014). Researchers stress the need for careful advance planning, articulation, and evaluation of the initial education provided to future teachers.
- **Limited competences.** On the one hand, there is a low level of attainment of general competences. Serrano and Pontes (2015) analyzed the level of competence

acquired by 353 secondary student teachers during their initial education. The results show a moderate level of satisfaction. This finding is consistent with results from previous studies on this topic (Buendía et al., 2011; García, Pascual, & Fombona, 2011). On the other hand, there is no specific competence framework for future secondary specialist teachers (Comisión de Educación del CEMat, 2011; Font, 2013). In this sense, it is also requisite to design and implement instruments for the definition and assessment of such competences.

- **Narrow subject-matter content knowledge.** Assuming that student teachers enter initial education with sound subject-matter content knowledge is probably one of the major problems (Font, 2013). López, Miralles, and Viader (2013) tested the mathematical knowledge of 33 secondary mathematics student teachers at the beginning of their initial education program. The results show a lack of subject-matter content knowledge. This wrong assumption might negatively influence the achievement of the professional competences required to become an effective teacher (Comisión de Educación del CEMat, 2011).

- **Gap between universities and secondary education schools.** So far, the connection between universities and secondary education schools has been loose (Santos & Lorenzo, 2015; Valle & Manso, 2011). This link must be reinforced in order to provide future teachers a model of quality learning. Mentors supporting field experiences in secondary education schools should work together with teacher educators and contribute to the organization of initial education programs (Comisión de Educación del CEMat, 2011).

- **Inexperienced teacher educators.** The knowledge and experience of Spanish teacher educators have been constantly questioned (Santos & Lorenzo, 2015; Viñao, 2013). Researchers criticize the fact that the main criterion for selecting teacher educators has been, in many cases, the availability of teaching credits, instead of their career profile (Gutiérrez, 2011, Vilches & Gil-Pérez, 2010). Therefore, a significant proportion of teacher educators has none experience in secondary education (Valdés & Bolívar, 2014).

- **Unrewarded mentors.** Previous studies point at the absence of an effective system for mentors (Gutiérrez, 2011; Viñao, 2013). On the one hand, the current selection of mentors does not prioritize their professional experience (Comisión de Educación del CEMat, 2011). In this sense, some authors question the preparation of mentors to support student teachers during the field experience (Valdés & Bolívar, 2014). On the other hand, many mentors have refused such role by considering that the reward was limited to a mere academic certification (Santos & Lorenzo, 2015).

- **Inadequate assessment system.** The assessment of initial teacher education has a two-fold purpose. On the one hand, to verify that student teachers have acquired the competences to perform as effective teachers. On the other hand, to evaluate and improve the quality of the program itself. For the latter, each Spanish university designs its own initial teacher education program. Each curriculum proposal is then verified by the internal quality assurance system of each university and by an external authority: the ANECA (Spanish acronym for Agencia Nacional de Evaluación de la Calidad y Acreditación). As a consequence, regional differences arise from this curriculum development and assessment system (Rico et al., 2003). Additional evaluation processes are also needed in order to fulfill the primary purpose of initial teacher education assessment, i.e., the acquisition level of teaching competences. To this end, Rico et al. (2003) suggest a model based on three dimensions: the relevance, the efficacy, and the efficiency of initial teacher education programs.

- **Negative expectations.** Overall, student teachers feel disappointed about the initial teacher education system in Spain (Muñiz-Rodríguez, Alonso, Rodríguez-Muñiz, & Valcke, 2016a; Serrano & Pontes, 2015; Zagalaz, Manrique, Granados, Sánchez, & de Mesa, 2015). They believe that their bachelor degree is sufficient to enter into the teaching profession, and that the compulsory nature of initial teacher education delays with one year their opportunity to access the labor market.

Despite the previous troubling weaknesses, the literature emphasizes the professionalizing nature of initial education programs for future secondary teachers as the most significant achievement in initial teacher education in Spain (Santos & Lorenzo, 2015; Valdés & Bolívar, 2014).

Building on the aforementioned shortcomings, this dissertation aims at analyzing initial teacher education programs, focusing on secondary mathematics teacher education. This specific focus was inspired by a number of additional facts. Worldwide, there is a growing concern about mathematics education. Mathematics is linked to the critical STEM (Science, Technology, Engineering, and Mathematics) domain for which research asks to pay more attention to (Kelley & Knowles, 2016; Marginson, Tytler, Freeman, & Roberts, 2013). Consequently, the role of teachers is considered to be important in this context. Besides, the results of previous research studies reveal that mathematics and science teachers are more likely to quit teaching in order to pursue other careers (Borman & Dowling, 2008; Henke, Zahn, & Caroll, 2001). This dissertation addresses this specific call and attempts to overcome the perceived deficiencies of initial education programs for future secondary mathematics teachers in Spain.

1.3 Research objectives

Building on the above theoretical background and taking into account the mentioned research problem, the main aim of this dissertation is to gain insight into the nature and the quality of initial education programs for future secondary mathematics teachers in Spain. More specifically, to analyze the competences and knowledge that future secondary mathematics teachers acquire during their initial education. This general purpose was covered by five specific research objectives that guided the different studies of this research:

- **Research objective 1 (RO1).** To identify the principal strengths and weaknesses of initial education programs for future secondary mathematics teachers in Spain.
- **Research objective 2 (RO2).** To develop and validate a competence framework for secondary mathematics student teachers in Spain.
- **Research objective 3 (RO3).** To design and validate an instrument to assess the knowledge and competences of future secondary mathematics teachers.
- **Research objective 4 (RO4).** To assess the knowledge and competences of future secondary mathematics teachers in Spain.
- **Research objective 5 (RO5).** To design, implement and evaluate an intervention to enhance the development of a specific teaching competence – *giving constructive, purposeful and timely feedback* – during an initial education program.

In order to achieve these research objectives, different methodological approaches were adopted. The following section outlines the research design of this dissertation.

1.4 Research design

In order to fulfill the previous research objectives, the research design outlined in Table 1.1 was followed. Both qualitative and quantitative methods were used.

The research objective 1 (RO1) was first dealt by means of a literature review of initial teacher education programs in a set of countries. Next, the analysis of the Spanish situation was performed using a document analysis technique (Bowen, 2009) based on the curricula and underlying policy documents of the different initial education programs for future secondary mathematics teachers offered in Spain. These documents were obtained from two different sources: universities websites and the RUCT (Spanish acronym for Registro de Universidades, Centros y Títulos) created by the Spanish Ministry of Education, Culture and Sport. Content and descriptive analyses were performed. The results of this study (labeled study 1) provided avenues for the subsequent studies.

In order to achieve the research objective 2 (RO2), two research methods were combined: a document analysis (Bowen, 2009) and the Delphi method (Linstone & Turoff, 1975). First, an in-depth literature review of the existing theoretical models about the knowledge and competences of a mathematics teacher was conducted. Next, a document analysis of available competence frameworks at the international level was carried out. As a result, a comprehensive list of competences was drawn up. These competences were compared looking for commonalities and differences, and classified by related domains, following a content analysis technique and using Weft QDA©, an open-source tool for the analysis of textual data. Next, the validation process was tackled through an expert panel consultation technique: the Delphi method. Experts (n=31) were invited to express their opinion about the priority nature and formulation of the competences through an online questionnaire. The results of this study (labeled study 2) were used in the subsequent studies of this dissertation.

The research objective 3 (RO3) was achieved conducting a pilot study based on a survey design (labeled study 3). An online questionnaire was completed by recently graduate mathematics teachers (n=51) from an initial education program in Spain. Psychometric and descriptive analyses were performed using SPSS® (version 24). The results of the psychometric analysis supported the validity of the instrument in view of the following study (labeled study 4).

Table 1.1. Overview of the research objectives, research design, and outputs of this dissertation.

Research objective	Research method and data collection	Sample (size) and time frame	Data analysis technique	Output (study)
RO1. To identify the principal strengths and weaknesses of initial education programs for future secondary mathematics teachers in Spain	Literature review Document analysis	Initial education programs curricula and policy documents (n=50) July – December 2014	Content analysis Descriptive analysis	Chapter 2 (study 1)
RO2. To develop and validate a competence framework for secondary mathematics student teachers in Spain	Document analysis Delphi method Online questionnaire	Experts (n=31) April – July 2015	Content analysis Descriptive analysis	Chapter 3 (study 2)
RO3. To design and validate an instrument to assess the knowledge and competences of future secondary mathematics teachers	Pilot study Survey design Online questionnaire	Graduate teachers (n=51) October – December 2015	Psychometric analysis Descriptive analysis	Chapter 4 (study 3)
RO4. To assess the knowledge and competences of future secondary mathematics teachers in Spain	CIPO model Survey design Online questionnaire	Student teachers (n_1=95) Teacher educators (n_2=95) Mentors (n_3=96) Graduate teachers (n_4=29) February – May 2016	Descriptive analysis Inferential analysis	Chapter 5 (study 4)
RO5. To design, implement and evaluate an intervention to enhance the development of teaching competences during an initial education program	Pre-test/Post-test Online assignment Online questionnaire	Student teachers (n=14) March 2017	Content analysis Descriptive analysis	Chapter 6 (study 5)

In view of the research objective 4 (RO4), a research design building on the CIPO model (Scheerens, 1990, 2015) was followed. A nationwide survey was carried out, adopting a multi-actor perspective. Data were gathered through an online questionnaire completed by mathematics student teachers (n_1=95), mathematics teacher educators (n_2=95), mentors (n_3=96), and recently graduate mathematics teachers (n_4=29). Descriptive and inferential analyses were performed using SPSS® (version 24), focusing on the identification of critical competences. The results of this study (labeled study 4) helped identifying a critical competence currently hardly pursued, and consequently attained, during initial teacher education, namely *provide and seek constructive, purposeful and timely feedback to/from students, their families, and colleagues*. This finding led to the concluding study (labeled study 5) of this dissertation.

As to the research objective 5 (RO5), a competence development intervention with a pre-test/post-test design was performed (labeled study 5). Two data collection instruments were administered before and after the training: a competence development assignment – building on Bloom's revised taxonomy levels (Anderson & Krathwohl, 2001) and feedback components (Hattie & Timperley, 2007) – and a self-efficacy questionnaire (Bandura, 1986). Secondary mathematics student teachers (n=14) participated in this study. Content and descriptive analyses were done using Weft QDA🅭 and SPSS® (version 24). The results reflect a clear and positive impact of the intervention on the development of teaching competences.

In this dissertation, considerable emphasis was laid on the online approach. On the one hand, data collection for studies 2, 3, and 4 was done through an online survey. For each study, a questionnaire was individually administered via email and implemented through LimeSurvey®, an open-source software for online questionnaire design, delivery and administration. On the other hand, study 5 took place in an online environment. Each participant was provided with one computer, internet connection, and headphones. The competence development assignment was available on EDpuzzle®, an open-source web application for online video-questionnaire design, delivery, administration, and visualization. The online approach was extremely convenient taking into account the context of this research. Spain is a relatively extensive country with a substantial number of universities offering an initial education program for future secondary mathematics teachers. These universities are geographically spread around the country. Online surveys are cost-efficient and demand less effort to administer and analyze (Fricker, 2008). They do not require the physical presence of participants, who can chose in a flexible way the time and place to take part in the study.

1.5 Overview of the dissertation

This dissertation is structured into seven chapters (see Figure 1.2). All chapters – except Chapter 1 and Chapter 7 – have been published or submitted for publication in journals listed in the ISI Web of Knowledge (see Academic output). The five intermediate chapters – Chapter 2 to Chapter 6 – are directly related to a specific research study. Therefore, they are presented following the same structure: introduction, theoretical framework, methodology, results, and discussion.

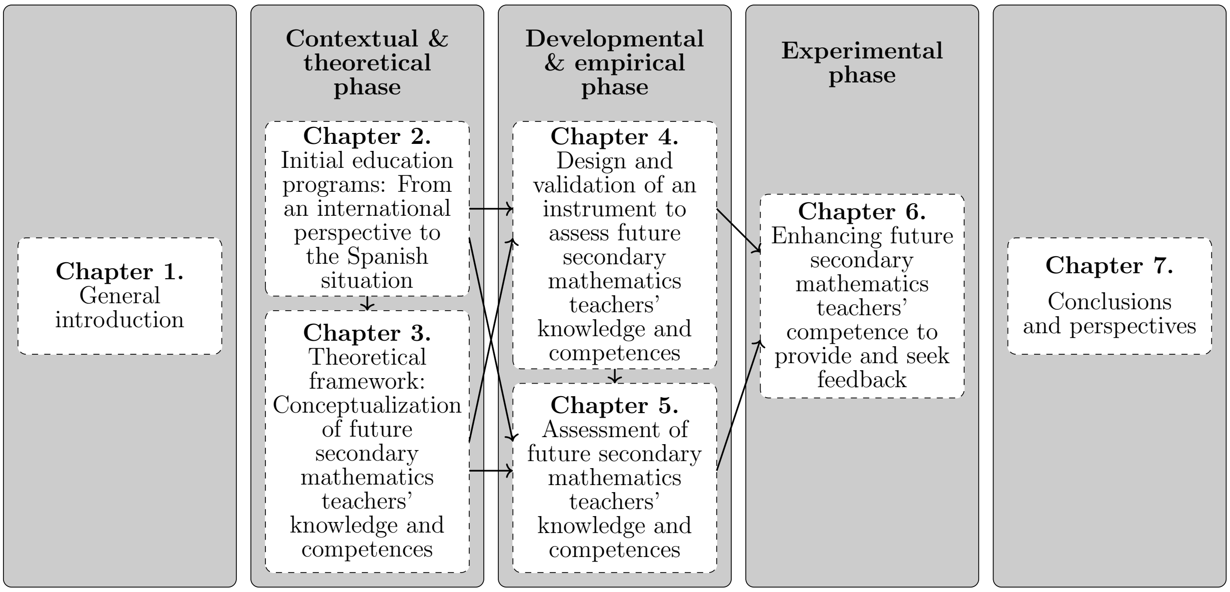

Figure 1.2. Overview of the dissertation.

This research went through three phases. The preliminary contextual and theoretical phase – Chapter 2 and Chapter 3 – focused on the current state of the art of the initial education of future secondary mathematics teachers in Spain and the development of the theoretical framework that guided the subsequent phases. In particular, Chapter 2 presents an international perspective on initial teacher education programs, followed by a description of the Spanish situation. This preliminary study helped identifying the similarities and differences in the organizational characteristics of initial teacher education programs between countries and, specially, the strengths and weaknesses of the Spanish system. The findings suggest to pay more attention to the academic profile of students who enroll in an initial education program for future secondary mathematics teachers, and the attainment of teaching competences. This problem is tackled in Chapter 3 where the subject-matter content knowledge and competences of future secondary mathematics teachers are conceptualized. In particular, this chapter presents the theoretical framework and the methodology followed in order to develop and validate a competence framework for secondary mathematics student teachers. This process resulted in a comprehensive list of thirty-three competences for secondary mathematics student teachers, classified into twelve clusters.

Next, the developmental and empirical phase – Chapter 4 and Chapter 5 – consisted of the design and validation of an instrument to empirically measure the subject-matter content knowledge and competences of secondary mathematics student teachers. Building on the validated framework, an instrument to assess future teachers' mathematical knowledge and competences was designed. The instrument was later validated by means of a pilot study conducted by recently graduate secondary mathematics teachers in Spain. The results support the reliability of the instrument in view of future research. This is described in Chapter 4. Chapter 5 describes a nationwide study set up to identify the perceptions of student teachers, teacher educators, mentors, and recently graduate teachers about the extent to which professional teaching competences are pursued and attained during initial teacher education programs in Spain. To this end, the aforementioned research instrument was employed. The results confirmed the hypothesis that initial education programs in Spain are moderately effective in view of preparing future secondary mathematics teachers for the profession, and point at critical competences hardly developed during initial teacher education.

Finally, the experimental phase – Chapter 6 – tested the impact of an intervention based on the use of video-vignettes to tackle the development of a key competence in secondary mathematics student teachers, namely *providing constructive, purposeful and timely feedback to students.* Chapter 6 presents the design, implementation, and evaluation of the intervention study. A pre-test/post-test design was set up, involving secondary mathematics student teachers from one Spanish university. The results reflect a clear and positive impact of video-vignettes on the development of teaching competences.

This dissertation concludes with a synthesis of the most relevant findings obtained in the preceding chapters, aligned with the research objectives – Chapter 7. These results provide input for an in-depth discussion of initial teacher education in Spain. The last chapter also describes the limitations of the different studies, together with the directions for future research and the implications for theory, practice, and policy.

CHAPTER 2

Initial education programs: From an international perspective to the Spanish situation

The first aim of this research was to identify the principal strengths and weaknesses of initial education programs for future secondary mathematics teachers in Spain. For that purpose, an international comparison was drawn. The starting point was a literature review of initial education programs for future secondary teachers in fifteen countries. This international perspective was next used to analyze the Spanish situation. This chapter starts with an overview of the international situation, focusing on organizational characteristics such as the structure, the duration, the admission requirements, the level of the degree awarded at the completion of the initial education program, and the existence of a competence framework. Then, the Spanish situation is described, starting with a brief historical review of the previous model, and continuing with a detailed description of the current approach, focusing on the mathematics specialty. The results show clear differences when comparing Spain with other countries, and indicate the need of introducing measures in order to overcome the current deficiencies of initial education programs for future secondary mathematics teachers in Spain.

This chapter is based on: Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2016). Is there a gap in initial secondary mathematics teacher education in Spain compared to other countries? *Revista de Educación, 372*, 111-140. doi: 10.4438/1988-592X-RE-2015-372-317

2.1 An international view of initial education programs for future secondary teachers

In many countries, in order to become a teacher, candidates are required to have successfully finalized an initial education program. However, the characteristics of such programs vary considerably across nations. This section presents a literature review about how countries around the world prepare student teachers to teach in secondary education. The analysis compares the situation in fifteen selected countries: Australia, Belgium, Chile, England (United Kingdom), Finland, France, Germany, Israel, Italy, Japan, Norway, Poland, Republic of Korea, Turkey, and United States. The author of this dissertation opted for these countries since they involve diverse and representative educational models in the international framework. Moreover, these fifteen countries belong to the Organization for Economic Co-operation and Development (OECD), which ensures the availability of and accessibility to comprehensive and reliable databases.

2.1.1 Structure of initial education programs

Initial education programs are typically organized according to two well-distinguished structures (Eurydice, 2012):

- **The concurrent model**, in which general and professional education occurs simultaneously in a single program.
- **The consecutive model**, in which students pursue their subject-matter studies first and after take a professional course in education, which provides them with the theoretical and practical competences needed to succeed as a teacher.

Some authors differentiate a third structure, named the mixed model, in which the concurrent and the consecutive model are offered simultaneously within the same country (Manso & Valle, 2013). This alternative is gaining more and more prominence at the international level.

These models present clear advantages and disadvantages (see Table 2.1). For instance, the concurrent model directly promotes teachers' professional identity because student teachers know that they are being trained to become a teacher right from the start of their studies (Bolívar, 2007; Esteve, 2006). This model also allows a more integrated learning as pedagogical and subject-matter content knowledge are pursued and attained at the same time (Musset, 2010). On the other hand, the consecutive model allows student teachers to gain a deeper subject-matter content knowledge in a specific discipline and provides more flexibility in entering the teaching profession (Musset, 2010). Alternatively, the mixed model attracts a higher number of teachers to the profession (Musset, 2010). This is of particular interest for countries affected by a shortage of teachers. Despite these dissimilarities, the literature concludes that there are no significant differences between the three models regarding the learning performance of student teachers (Valle & Manso, 2011). Actually, each model appeals to different types of potential teachers.

Table 2.1. Advantages and disadvantages of concurrent, consecutive and mixed programs.

Model	**Advantages**	**Disadvantages**
Concurrent	Strong professional identity Integrated learning	Restricted entry into other professions
Consecutive	Deep content knowledge Flexible entry into the teaching profession	Weak professional identity Weak pedagogical knowledge Fragmented learning
Mixed	Higher attraction for future teachers	More costly for the country Less effective

As shown in Table 2.2, the structure of initial education programs varies from country to country (OECD, 2014). In some cases, the pattern is different between lower- and upper-secondary education. For lower-secondary education, while in Belgium, Finland, Japan, Poland, and Turkey the concurrent model is predominant, in England (UK), France, Germany, and Italy initial education programs follow a consecutive model. At the same time, both concurrent and consecutive models coexist in some nations such as Australia, Chile, Israel, Norway, Republic of Korea, and United States. For upper-secondary education, the organization is alike in most countries, except for Belgium, Norway and Turkey. Nevertheless, in Germany initial education programs are differently organized among the different länder.

Table 2.2. Structure of initial education programs.

Structure	**Lower-secondary education**	**Upper-secondary education**
Concurrent	Belgium, Finland, Japan, Poland, Turkey	Finland, Japan, Poland
Consecutive	England (UK), France, Germany, Italy	England (UK), France, Germany, Italy, Norway
Mixed	Australia, Chile, Israel, Norway, Republic of Korea, United States	Australia, Belgium, Chile, Israel, Republic of Korea, Turkey, United States

Note: Data from OECD (2014).

2.1.2 Duration of initial education programs

The duration of initial education programs for future secondary teachers ranges from 3 years in Belgium (lower-secondary education) to between 6 and 6.5 years in Germany and Italy (OECD, 2014). In the remaining countries, initial education programs last between 4 (in Australia, England (UK), Israel, Japan, Republic of Korea, and United States) and 5 years (in Chile, France, Finland, Norway, Poland, and Turkey). The duration of the program is often determined by its structure. The concurrent model commonly lasts 3 or 4 years, whereas, in the consecutive model, the first phase (subject-matter education) typically lasts between 3 or 4 years, and the second phase (pedagogical education) 1 or 2 years. The length of initial teacher education programs in countries where the mixed model exists is determined according to the chosen structure. The duration of initial teacher education is of major concern to policymakers. Longer programs are ordinarily more expensive, but shorter programs may be less effective (Tatto et al., 2012).

Initial teacher education programs commonly involve a theoretical and a practical component. However, the required duration of the practical component varies significantly among the fifteen countries. For instance, in Israel, Japan, Republic of Korea, and Turkey the total duration is between 20 and 60 days, as opposed to 120 days in England (UK), and at least 282 days in Germany. In recent years, most countries have tended to longer periods of practice during initial education programs (Tatto et al., 2012).

2.1.3 Admission requirements

In the concurrent model, there is only one access phase to an initial teacher education program, whereas in the consecutive model, there are commonly two: a first one to undertake the subject-matter studies, and a second one to start the professional training. In the following, we refer to the second access phase when talking about consecutive programs.

In all selected countries, the minimum requirement to enter into an initial education program is an upper-secondary (concurrent model), university (consecutive model) or any equivalent diploma (OECD, 2014). Besides, some countries impose additional requirements. In such cases, candidates are selected based on their previous training grade point average, *numerus clausus* policies, a competitive examination, a personal interview, or a standardized test[1]. Table 2.3 provides detailed information about the additional admission requirements established in each country.

Table 2.3. Admission requirements to enter in an initial education program.

Criteria	**Country**
Grade point average from previous degree	Australia, England (UK), Finland, Israel, Norway, Republic of Korea, Turkey
Numerus clausus policies	England (UK), Finland, Germany, Israel, Japan, Norway, Republic of Korea, Turkey
Competitive examination	Finland, Israel, Republic of Korea, Turkey
Personal interview	Israel, Republic of Korea
Standardized test	Israel, Republic of Korea

Note: Data from OECD (2014).

[1] *Numerus clausus* refers to the limited number of student teachers positions for entry into initial teacher education. A competitive examination refers to an exam organized by local, regional or national authorities in order to select applicants with the best results for a limited and fixed number of places for the public education system. A standardized test refers to a test administered and scored in a consistent manner in order to check that applicants meet certain minimum requirements (OECD, 2014).

2.1.4 Level of the degree awarded

The level of the degree awarded at the completion of an initial education program also differs across countries, mainly depending on its length (OECD, 2014). In this way, master degree diplomas are obtained after at least five years of tertiary education (see Table 2.4).

Table 2.4. Level of the degree awarded at the completion of an initial education program.

Level of the degree awarded	**Country**
Bachelor	Australia, Belgium (lower-secondary education), Chile, Israel, Japan, Norway (lower-secondary education), Republic of Korea, Turkey, Unites States
Master	Belgium (upper-secondary education), England (UK), Finland, France, Germany, Italy, Norway (upper-secondary education), Poland

Note: Data from OECD (2014).

2.1.5 Existence of a competence framework

Among countries, there is a distinctive variety of approaches to specify the competences that student teachers are required to be able to demonstrate at the end of an initial education program. While some countries put forward very clear and detailed descriptions, in others very general guidelines are provided. Some examples are:

- detailed lists of specific competences linked to professional standards and benchmark levels are available in Australia (AAMT, 2006), England (UK) (GTCS, 2012), and United States (NCATE, 2008);
- specific standards to guide the assessment of newly trained teachers in line with the competences to be developed during the initial education program exist in Chile (Avalos, 2005) and Germany (Lohmar & Eckhardt, 2013);

- a framework of teaching competences exists and is waiting for approval in Turkey (Erebus International, 2008);
- teaching competences are mentioned in the national educational curricula of initial teacher education programs in Finland (European Commission, 2013), Poland (European Commission, 2013), and Republic of Korea (Erebus International, 2008).

In addition to the mentioned differences in the level of detail in which competences are described, countries also vary in the policy tools employed to establish teaching competences, or the aims and uses to which competences are put (European Commission, 2013). Nevertheless, there is a common belief that, worldwide, policymakers and educational leaders increasingly acknowledge the need to clearly define which knowledge, skills and attitudes student teachers are expected to achieve during their initial education.

2.2 Initial education of future secondary teachers in Spain

In Spain, initial education programs have undergone several changes during recent decades (see a review in Gutiérrez, 2011; Viñao, 2013). Taking advantage of the introduction of the Bologna reform, the former Certificate of Pedagogical Aptitude (CAP[2]) was replaced with the Master Degree in Teacher Training in Secondary Education (MDTTSE). The suppression of the CAP has been a substantial improvement, but the implementation of the MDTTSE has not been exempted from difficulties. Both programs are described below.

2.2.1 A brief historical remark: the CAP

Before 2009, initial education programs for future secondary teachers were based on a course to obtain the CAP. This certificate was regulated by the Ministry of Education and Science since 1971 (Ministerio de Educación y Ciencia, 1971). The program was structured in two stages. The first one was theoretical in nature and consisted in the study of the foundations and general principles of education necessary for teaching. The second one consisted in the exercise of the teaching profession during a practical period in a secondary

[2]Hereafter, the Spanish acronym is used because it is well-known within this national context.

education school. In theory, the length of this program was 300 hours, with an equal balance between theory and practice. In practice, the duration of the CAP was reduced in a number of universities, becoming in some cases 80 hours of theory versus 40 hours of practice (Font, 2013).

Due to the low participation and dissatisfaction of teacher educators, the unstructured and inefficient organization, the widespread increase of students, and the disappointment of student teachers, researchers criticized the fact that the CAP was not adequate to train future teachers (Font, 2013; García-Longoria & Blanco, 2005; Gutiérrez, 2011; Rico, 2004; Viñao, 2013). Thus, in 2010 the Spanish education system launched a new initial education program, the MDTTSE. Consequently, the CAP disappeared.

2.2.2 The MDTTSE

In the academic year 2009-2010 the MDTTSE was implemented. This certificate has been regulated by the Ministry of Education and Science since 2007 (Ministerio de Educación y Ciencia, 2007). In each university, the MDTTSE is usually coordinated by the Faculty of Teacher Training or Education.

The current initial education program is designed to train future secondary specialist teachers, qualified to teach one specific subject such as mathematics, physics and chemistry, biology and geology, language and literature, among other specialties. In this sense, the specialties of the MDTTSE correspond to the curricular domains of secondary education. This certificate is mandatory to apply for a teaching position in lower- and upper-secondary schools and vocational training centers; both in the public and in the private sector.

The MDTTSE is set up as a one year full-time program and comprises 60 ECTS (European Credit Transfer and Accumulation System) credits. It is structured – as stipulated in the ministerial order – into three modules, two theoretical and one practical, which cover at least 52 of all the 60 ECTS credits:

- **The generic module** (at least 12 ECTS credits) consists of topics considered relevant for all teachers, such as educational theory, general principles of instruction, classroom management, curriculum theory, and so on. It is divided into three areas: Personality development and learning, Educational contexts and processes, and Society, family and education.

- **The specific module** (at least 24 ECTS credits) covers content and pedagogical content knowledge. It is also divided into three areas: Additional specialty related training, Learning and teaching specialty related processes, and Research and teaching innovation.

- **The internship** (at least 16 ECTS credits) includes a school-based experience (practicum) and a master thesis. The practicum commonly consists of an observation period followed by an intervention. During the observation, student teachers spend a short span of time observing to professional teachers in their day-to-day teaching activities: planning, developing and organizing instruction, managing classrooms, assessing and mentoring, among other professional responsibilities. While during the intervention, they demonstrate their micro-level teaching skills.

Each university has the autonomy to distribute the remaining 8 ECTS credits among generic, specific or optional courses. Consequently, broad differences in the number of ECTS credits assigned to each module can be expected when comparing initial education programs from different universities. This point is explained in more detail in the next sections of this chapter.

The ministerial order that regulates initial education programs for future teachers in secondary education in Spain establishes the following admission requirements to enter into the MDTTSE (Ministerio de Educación y Ciencia, 2007):

- The accreditation of the mastery of the competences related to the specific specialty that the candidate desires to take, by means of the accomplishment of a specialty related test designed by each university. Candidates holding a direct admission bachelor degree, related to the chosen specialty, will be exempted from the test.

- The accreditation of the mastery of a foreign language equivalent to level B1 according to the Common European Framework of Reference for Languages. If candidates are not accredited at this level by means of an official certificate, they must pass a language test designed by each university.

According to the first condition, the admission requirements depend on the chosen specialty. For instance, in mathematics, applicants must either pass a mathematics test organized by each university, or hold a direct admission bachelor degree related to mathematics. However, each Spanish university has the autonomy to determine the direct admission bachelor degrees that allow candidates to enter into the MDTTSE in mathematics. This is a critical point of initial education programs in Spain and triggers a strong heterogeneity between national curricula. For instance, in order to enroll in the specialty of mathematics, some universities accept any bachelor degree as direct admission as long as candidates have attained a minimum of 30 to 120 ECTS credits in mathematics: algebra, calculus, geometry or statistics. In other universities, a bachelor degree in mathematics or statistics has priority over other degrees, such as engineering. Besides, in most universities, a direct admission bachelor degree prevails over the accomplishment of a specialty related test. This is thoroughly tackled in the next section of this chapter.

The curriculum of the MDTTSE is organized according to international trends, i.e., around professional competences (Ministerio de Educación y Ciencia, 2007). The eleven competences of the Spanish initial teacher education curriculum at secondary education level are presented in Table 2.5. Note that these competences are common to all specialties.

Table 2.5. Competences of the Spanish initial teacher education curriculum at secondary education level.

Competence No.	**Competence description**
Competence 1	Know the curricular contents related to the specialty, as well as the relevant teaching and learning processes.
Competence 2	Plan, develop, and assess the teaching and learning process, enhancing educational processes which facilitate the acquisition of the competences, taking into account the level and the background of students as well as their orientation, both individually and in collaboration with other teachers and professionals of the school.
Competence 3	Seek, retrieve, process, and communicate information (oral, printed, audiovisual, digital, or multimedia), transform it into knowledge, and apply it in the teaching and learning processes of their specialty.

Table 2.5: *Continued.*

Competence 4	Specify the curriculum to be implemented in the school, participating in the collaborative planning. Develop and implement teaching methodologies both in groups and individually, adapted to the diversity of the students.
Competence 5	Design and develop learning environments with special attention to equality, emotional education, values, equal rights, and opportunities between men and women, citizenship education, and respect for human rights that facilitates the life in society, decision-making, and the development of a sustainable future.
Competence 6	Acquire strategies to stimulate the effort of students and encourage their ability to learn both individually and in collaboration with others, and develop thinking and decision making skills which enhance personal autonomy, confidence and initiative.
Competence 7	Know the interaction and communication processes in the classroom, master necessary social skills to encourage learning and team working in the classroom, and deal with discipline disorders and conflict resolution.
Competence 8	Develop formal and informal activities fostering participation and culture within the school and its environment. Assume mentoring and guidance roles in a collaborative and coordinated way. Participate in the assessment, research, and innovation of the teaching and learning processes.
Competence 9	Know the current regulations and institutional organization of the education system and the quality improvement approaches applicable to schools.
Competence 10	Know and analyze the historical characteristics of the teaching profession, its current situation, perspectives and relation to different social realities.
Competence 11	Inform and advise families about the teaching and learning process, and personal, academic and professional guidance of their children.

Note: Data from Ministerio de Educación y Ciencia (2007).

The MDTTSE has some characteristics in common with the CAP. For instance, both programs follow a consecutive model and build on a theoretical, followed by a practical, stage. However, both are also dissimilar. For example, the government used to regulate all the guidelines of the CAP such as the admission requirements or the awarding and accreditation of the diploma. Conversely, the control and management of the MDTTSE has become the full responsibility of higher education institutions. Moreover, the practical component of the MDTTSE is close to 40%, while in the CAP was less than 10%.

In Spain, the recruitment of teachers at public secondary education is based on a competitive examination system. The MDTTSE is a compulsory requisite to be able to take the exam, no matter the specialty chosen. This fact has been constantly criticized. Besides, national researchers question why graduate teachers need to pass a competitive examination after having completed an initial teacher education program which has supposedly provided them the knowledge, skills and attitudes necessary to perform effectively as teachers (Esteve, 2006; Viñao, 2013). In the private sector, there is a greater leeway to hire teachers.

2.3 Methodology

As previously mentioned, the ministerial order that regulates initial education programs for future secondary mathematics teachers in Spain puts forward quite general guidelines. Consequently, universities are largely autonomous in detailing the different elements of the MDTTSE, such as the specialty offering, the structure, or the admission requirements (Eurydice, 2011; Valdés & Bolívar, 2014). Moreover, the minimum and maximum number of students admitted to each specialty is not stipulated by the ministerial order (Valdés & Bolívar, 2014). Each university decides how many candidates are accepted every year in each specialty. As a result, broad differences between universities can be expected. Thus, the next goal of this research was to analyze the diversity of the set of initial education programs in mathematics offered in Spain.

A comparative document analysis of national curricula and their underlying policy documents was chosen for the research design. This aimed at providing empirical evidence of the similarities and differences between initial education programs curricula in Spain. Document analysis is considered as an efficient and cost-effective method (Bowen, 2009). The documents were obtained from two different sources: universities websites and the

RUCT (Spanish acronym for Registro de Universidades, Centros y Títulos) designed by the Spanish Ministry of Education, Culture and Sport. In the next section, we present the educational offering of initial education programs in Spain, which constitutes the research sample of this first study.

2.4 Results

This section presents the results of the comparative analysis regarding the educational offering, the structure, and the admission requirements of the MDTTSE in mathematics between universities.

2.4.1 Educational offering

The MDTTSE is currently offered by 68 universities out of the 84 currently accredited in the Spanish university system (Ministerio de Educación, Cultura y Deporte, 2016). Only 55 of them, 37 public and 18 private, provide mathematics as a specialty. Some universities offer the specialty of mathematics together with technology and computing. In addition, the MDTTSE in mathematics is set up as an inter-university program in seven universities. Thus, the number of initial education programs for future secondary mathematics teachers is down to 50, 32 in public universities and 18 in private. This educational offering might change from one academic year to another, mainly because some universities require a minimum number of enrolled students to offer the program. In 12 universities, it is also possible for student teachers to follow the MDTTSE through a distance program. This acts as an incentive to attract more candidates into teaching.

At this early stage of the research, the research team in charge of the study struggled to estimate the population size of secondary mathematics student teachers in Spain, in order to design the upcoming studies and decide on a sampling technique. However, the attempt fell through. After repetitive queries to universities, societies, and organizations, such as the Royal Spanish Mathematical Society or the Conference of Deans and Directors of Mathematics, it has been impossible to specify the size and distribution of this population group. In many universities, the information systems do not store this kind of data, much less segregated by specialties. Besides, the data of the Spanish university system – released every year by the Ministry of Education, Culture and Sport (Ministerio de Educación, Cultura y Deporte, 2016) – are rather generic, no distinction is made between universities. By the end of the consultation process, 26 universities had provided information about the number of student teachers entering into the MDTTSE in mathematics, resulting in about 544 student teachers enrolled in the academic year 2011-2012, 599 in 2012-2013, and 781 in 2013-2014. From the data, it was possible to notice a substantial difference in the number of admitted student teachers by public universities in comparison with the private ones. For instance, every academic year, around 15 student teachers are allowed to access to the MDTTSE in mathematics in the public universities of Alcalá or Cádiz, whereas around 200 are admitted in the International University of La Rioja (private). Smaller numbers of student teachers ensures a better theoretical and practical training. The aforementioned difficulties to contact and locate secondary mathematics student teachers were also found by the TEDS-M research team in 2008. This is the reason why the Spanish participation in the study was limited to future teachers in primary education (Tatto et al., 2012).

2.4.2 Structure of the MDTTSE in mathematics

In order to reflect structural dissimilarities between initial education programs for future secondary mathematics teachers, the distribution of ECTS credits in each module is represented in a multiple box plot (see Figure 2.1).

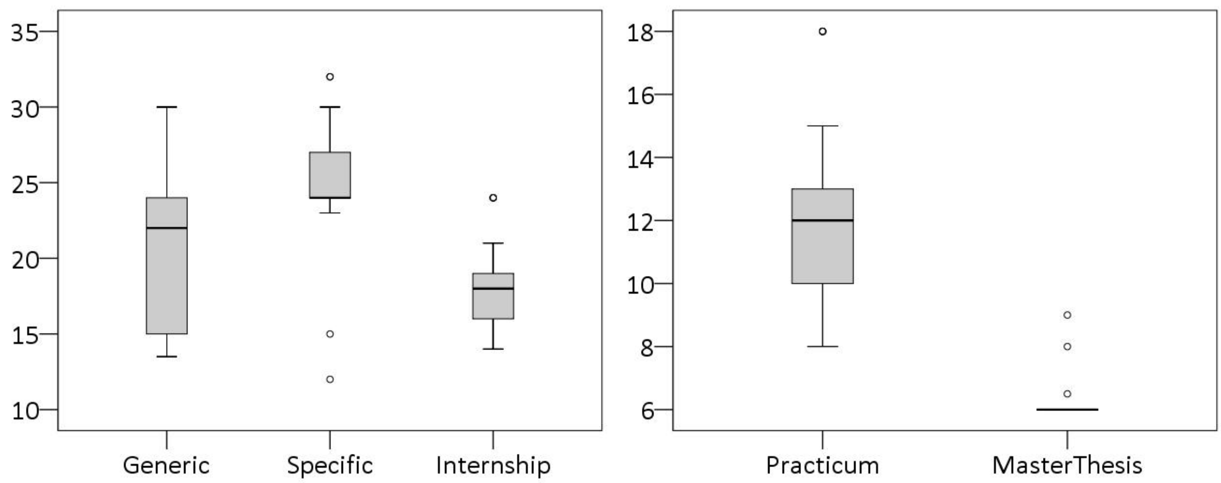

Figure 2.1. Distribution of ECTS credits in each module in the MDTTSE in mathematics.

Figure 2.1 clearly reflects an unequal distribution of ECTS credits between initial teacher education programs in mathematics and questions the extent to which all these programs can be aligned in terms of the competences being pursued and attained.

In the generic and the specific modules, the values of minimum, maximum and outliers point out a high degree of dispersion in the data. This means that there are broad differences regarding the distribution of generic and specific contents among the set of initial education programs. At the same time, the median values indicate an asymmetric distribution.

In the internship module, despite having a smaller spread, the variance between programs is also evident. According to the second box plot, this variance is clearly explained by an unequal duration of the school-based experience. With a minimum of 8 ECTS credits and a maximum of 18 ECTS credits, a wide disparity is observed between programs. On the other hand, in around 94% of initial education programs in mathematics, the master thesis requires 6 ECTS credits.

2.4.3 Admission requirements of the MDTTSE in mathematics

To develop a more comprehensive picture about the disparities regarding admission requirements, data about the direct admission bachelor degrees established by each university to enroll in the MDTTSE in mathematics was gathered. In this case, 39 initial education programs in mathematics – 29 offered in public universities and 10 in private – were taken into account. The remaining 11 were excluded due to the lack of available information. Considering their heterogeneity, the direct admission bachelor degrees were classified according to 10 fields of knowledge (see Table 2.6) as defined in the International Standard Classification of Education – Fields of Education and Training (ISCED-F) 2013 (UNESCO, 2014).

Figure 2.2 represents, for each field of knowledge, the number of initial education programs for future secondary mathematics teachers that accepts at least one direct admission bachelor degree to enroll in the specialty of mathematics.

As expected, in all universities candidates holding a bachelor degree in the field of mathematics and statistics (F) can enroll directly in the MDTTSE in mathematics. Note that a degree in statistics also includes contents in algebra, calculus and geometry.

Table 2.6. Classification of fields of knowledge.

Field code	Broad field	Detailed field
A	Education	Teacher training, education science
B	Humanities and arts	Audio-visual techniques and media production, design, music, religion, history, philosophy, language, literature
C	Social sciences, business, and law	Economics, political sciences, psychology, sociology, journalism, library, marketing, administration, law
D	Life sciences	Biology, biochemistry
E	Physical sciences	Physics, astronomy, chemistry, geology
F	Mathematics and statistics	Mathematics, statistics
G	Computing	Computer sciences, data processing, networks, operating systems, software development, system design
H	Engineering, manufacturing, and construction	Chemical engineering, electricity, electronics, mechanics, food processing, materials, mining and extraction, architecture, building and civil engineering
I	Agriculture	Agriculture, livestock, forestry, fishery, veterinary
J	Health and welfare	Dental, medicine, nursing, therapy, pharmacy, social care, social work

Note: Data from UNESCO (2014).

The same situation is found in the fields of physical sciences (E) and engineering, manufacturing and construction (H). Almost all universities (97.5% and 92.5%, respectively) consider a bachelor degree in any of these fields as direct admission. However, not all the engineering degrees reflect the same mathematical content. This will be clearly explained during the discussion.

Universities vary largely to the extent they accept other bachelor degrees. About 50% consider computing degrees (G) as an alternative pathway, and nearly 38% believe the

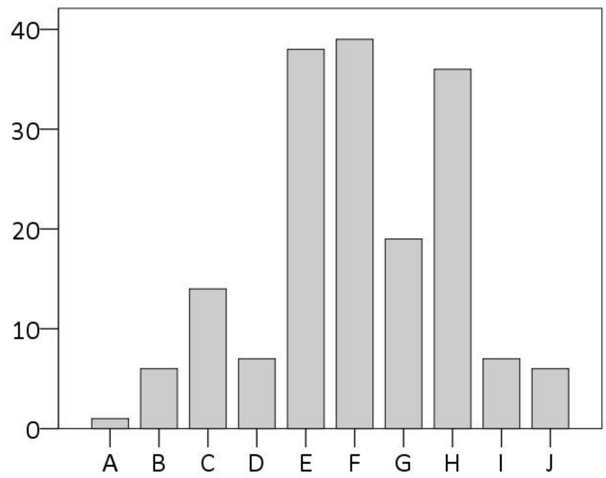

Figure 2.2. Overview of the direct admission bachelor degrees for the specialty of mathematics.

same about social sciences, business, and law (C) degrees. Within the latter field, some bachelor degrees are based on economics, finance, business administration, and accounting, which are closely related to mathematical knowledge, as opposed to other degrees such as law, sociology, or geography.

Around 15% of the universities still consider that a bachelor degree in humanities and arts (B), life sciences (D), agriculture (I), or health and welfare (J) contains a sufficient mathematical load to become a mathematics teacher in secondary education. This can be questioned. For instance, in most life sciences and health and welfare bachelor degrees the only mathematical knowledge being taught is limited to statistics. Algebra, calculus or geometry are not studied. This critical situation results from an unfavorable circumstance in the 80's and first 90's. Due to the lack of graduates in mathematics, it became widely accepted that graduates in biology or chemistry, without a high-level mathematical knowledge, were employed as mathematics teachers in secondary education. Some other degrees in these fields of knowledge completely lack mathematical content, such as occupational therapy or agricultural and food industry.

Only in one university, a bachelor degree in education (A) is admitted. In this case, students have to attend complementary courses related with infinitesimal calculus, matrix and vector calculus, and statistical knowledge.

One may wonder if there is any difference between public and private universities when it comes to determining the direct admission bachelor degrees for the specialty of mathematics. Table 2.7 shows significant differences between the public and private sector in a couple of fields of knowledge and a weighted balance in the others.

Table 2.7. Differences between public (29) and private (10) universities regarding the direct admission bachelor degrees for the specialty of mathematics.

Field	**Public**	**Private**	**Chi-square**
Education	3.4%	0.0%	0.354
Humanities and arts	17.2%	10.0%	0.300
Social sciences, business and law	37.9%	30.0%	0.203
Life sciences	6.9%	50.0%	9.381*
Physical sciences	96.6%	100.0%	0.354
Mathematics and statistics	100.0%	100.0%	.[a]
Computing	55.2%	30.0%	1.886
Engineering manufacturing and construction	89.7%	100.0%	1.121
Agriculture	17.2%	20.0%	0.038
Health and welfare	6.9%	40.0%	6.260*

Note: [a] No statistics are computed because F is a constant. *p < .05

Only in life sciences (D) and in health and welfare (J) differences between the public and the private sector are significant. In both fields, there is a major predominance of private universities. As we have pointed out before, the bachelor degrees related with these fields of knowledge have a substantial amount of statistical contents, not covering other mathematical branches such as algebra, calculus or geometry. In the other fields of knowledge, there are barely any differences between public and private universities.

2.5 Discussion

Spanish initial teacher education programs reflect organizational similarities and differences with respect to those in other countries. These differences lie in the structure, the duration, the admission requirements, the level of the degree awarded at the completion of the program, and the existence of a competence framework. These characteristics are of importance because they can influence the extent to which initial education programs prepare student teachers for their future role (OECD, 2014).

In Spain, initial education programs for future teachers in secondary education have been historically structured according to the consecutive model, as in some other European countries such as England (UK), France, Germany, or Italy. However, the suitability of one model or another has not been exempt from debate at the national level (Barberá, 2010; Rico, 2004; Santos & Lorenzo, 2015). In this sense, Rico (2004) suggests that initial teacher education as an undergraduate program may be an attractive and convenient alternative for those who undoubtedly wish to start a teaching career (see also Campillo, 2004).

As a consequence of the sequential structure, the overall length of training of future secondary mathematics teachers in Spain is 5 years, since the access to an initial education program (1 year) is conditioned on graduation from a bachelor degree (4 years). Other countries with the same distribution are Chile, France, or Turkey. The duration of the MDTTSE has also been in the spotlight. Some authors consider that the balance between the subject-matter training (4 years) and the pedagogical training (1 year) is inappropriate (Santos & Lorenzo, 2015; Valdés & Bolívar, 2014). As a result, student teachers acquire insufficient pedagogical training in a hasty way. During the shaping of the MDTTSE, it was expected an overall length of 2 years: the first one for the theoretical component and the second one for the practical (Viñao, 2013). But since the implementation of the current initial teacher education program in the academic year 2009-2010, this question remains in the air. In this regard, the implementation of what is called *MIR educativo* has been subject of debate during the last years. This idea comes from the medical education field where those who aim at obtaining a position as a doctor in the public sector have to pass an examination process as an intern resident doctor. Such process consists of an access exam followed by a training period. The intention is to adopt this approach to the teacher education field (see Comisión de Educación y Deporte, 2017).

In most countries, the minimum requirement to access into an initial education program is an upper-secondary (concurrent model) or a university (consecutive model) diploma, often in combination with *numerus clausus* policies, and/or further requirements such as a competitive examination, a standardized test, or a personal interview. In Spain, the admission requirements seem to be relatively flexible. Moreover, the recruitment system of the MDTTSE is decentralized. This means that the selection process is full responsibility of universities. As a result, the admission requirements differ between programs. According to the OECD (2014) the nature of the admission requirements determines whether or not the teaching profession is open to attracting qualified candidates from diverse backgrounds.

In the specialty of mathematics, the problem comes up when the mathematical content of some direct admission bachelor degrees is not enough to teach mathematics in secondary education. In very few cases, extra mathematical courses are required. On the one hand, a degree in physical sciences, engineering, or even computing almost always include, at least, algebra, calculus and statistics, even in some cases discrete mathematics. This is why they are strongly promoted in both public and private institutions as an entry requirement. But even in these fields, the mathematical knowledge of students can vary significantly from one engineering degree to another, and among universities. For example, while in the University of Oviedo or in the University of Zaragoza engineering students have at least 24 ECTS credits (up to 33 ECTS credits in some cases) assigned to specific mathematical knowledge, at the University of Santiago de Compostela the range is situated from 18 ECTS credits in forestry or civil engineering, up to 30 ECTS credits in computer engineering. A bigger gap appears if we consider that some years ago an industrial engineer could even have more than 50 ECTS credits of mathematical load. On the other hand, a degree in business administration and management is commonly accepted. However, previous research demonstrates the inadequacy of this degree since it is not aligned with the teaching competences necessary for the profession (Díaz & Marbán, 2016). A similar situation occurs with a degree in life sciences and health or health and welfare. Thus, the admission requirements policy is a major weakness in the Spanish initial teacher education system. This finding confirms the results of previous studies pointing at the narrow mathematical knowledge of the student teachers who enter into the MDTTSE in mathematics (Font, 2013; López et al., 2013).

The level of the degree awarded at the completion of an initial education program in Spain is a master degree, comparable to the approach adopted in most European countries (such as England (UK), Finland, France, Germany, Italy, Norway, or Poland), and in contrast to other countries where the qualification is merely a bachelor degree.

Initial teacher education programs should be organized towards a well-defined framework of competences (Darling-Hammond, 2006). However, this is not a common feature at the international level. In Spain, the ministerial order that regulates the MDTTSE puts forward rather general competences required for the accreditation of initial education programs (Ministerio de Educación y Ciencia, 2007). Besides, how competences for secondary mathematics student teachers are defined can be questioned. Some competences are completely redundant and clearly overlap between each other. In this sense, the author of this dissertation agrees with previous research that there is potential ambiguity in how these competences should be understand (Escudero, 2009). Besides, important gaps can be identified. For instance, none of the competences refers to the knowledge of students' social and cultural contexts, beliefs and motivations towards the subject-matter, or cognitive and emotional development. Some competences are superficially mentioned. For example, the subject-matter content knowledge is described in minor detail. In relation to the teaching and learning processes, competences do not allude to the importance of understanding the impact of the adopted strategies and techniques on student achievement. At the same time, the technological knowledge required seems to be pretty scarce. Beyond knowing and using information and communication technology systems, future teachers should design and develop learning experiences and assessment methods using digital tools. At the same time, previous studies point at the doubtful relevance of personal commitment in the Spanish competence framework, in particular when it comes to personal attributes (López-Goñi & Goñi, 2012). On the other hand, the competences established by the ministerial order are common, at the national level, to all specialties, i.e., the competences for mathematics student teachers are exactly the same as the competences for biologist student teachers. Each university is responsible for developing a specific competence framework for each specialty following their own criteria (Echeita & Pérez, 2010). Taking into account that competence frameworks are widely employed for developing the curriculum of initial teacher education programs (Erebus International, 2008; Morris et al., 2009), one may expect broad differences at the national level in future teachers' training.

Another problem in Spain is the lack of benchmark levels which specify to what extent these competences should be attained. The experience of other nations like Scotland (Quality Assurance Agency for Higher Education, 2000) shows that the availability of benchmark information ensures the quality of initial teacher education programs.

The previous national and international comparative analysis brings out the principal strengths and weaknesses of initial education programs for future secondary mathematics teachers in Spain. Among the positive aspects, the professionalizing nature of the MDTTSE and the increase of the practical component in comparison with previous models stand out. Still, two major problems have been identified. On the one hand, the mathematical knowledge of secondary mathematics student teachers is of a heterogeneous nature and, in some cases, insufficient. The cause of this problem lies on the autonomy of universities to establish their own admission requirements to enter into an initial education program (Eurydice, 2011). On the other hand, the MDTTSE lacks a specific and comprehensive framework of competences for future secondary mathematics teachers at the national level.

Appropriate measures should be introduced in order to overcome the current deficiencies of initial teacher education in Spain. First, the differences in admission requirements between universities should be minimized through the definition and implementation of a common framework of direct admission bachelor degrees at the national level. In this way, the quality of initial teacher education would be improved (Esteve, 2006). Responsibility for the latter is placed in the hands of policymakers and educational leaders. Second, building on the examples available at the international level and their relevance for the Spanish situation, a framework of specific and measurable competences for secondary mathematics student teachers should be designed.

This preliminary study provided avenues for consequent research objectives that have been tackled in the upcoming chapters of this dissertation. Chapter 3 presents the development and validation of a competence framework for secondary mathematics student teachers. Next, based on such framework, Chapter 5 presents the extent to which teaching competences are pursued and attained during the MDTTSE in mathematics according to the perception of student teachers, teacher educators, mentors, and graduate teachers. Further, this dissertation aims at carefully analyzing the academic background of future secondary mathematics teachers, beyond the admission requirements established by the different Spanish universities. This problem is also tackled in Chapter 5.

CHAPTER 3

Theoretical framework: Conceptualization of future secondary mathematics teachers' knowledge and competences

Initial education programs are expected to provide student teachers with the necessary competences to develop themselves as teachers. Although a generic framework of teaching competences covering all specialties is available in Spain, the curriculum of initial education programs does not specify which competences secondary mathematics student teachers should acquire during their initial education. This explains why this study aimed at developing and validating a competence framework for secondary mathematics student teachers in Spain. Building on existing theoretical models and international frameworks, a preliminary list of competences was first drawn up. The subsequent validation process was based on a Delphi method. To this end, experts were invited to express their opinions about the formulation of the chosen competences. A comprehensive framework of thirty-three competences for secondary mathematics student teachers was then validated.

This chapter is based on: Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2017). Developing and validating a competence framework for secondary mathematics student teachers through a Delphi method. *Journal of Education for Teaching, 43*(4), 383-399. doi: 10.1080/02607476.2017.1296539

3.1 Introduction

Worldwide, initial teacher education institutions struggle to define core teaching competences in view of the accreditation of initial teacher education programs and resulting diplomas. However, there is hardly any international consensus about which competences student teachers should master after completing their initial education. It is, however, an important question to be addressed, taking into account the influence of teachers' competences on student achievement (European Commission, 2013; Rivkin, Hanushek, & Kain, 2005).

In Spain, the ministerial order that regulates the MDTTSE puts forward rather general competences required for the accreditation of initial education programs (Ministerio de Educación y Ciencia, 2007). Specific competences fitting the specifics of specialist fields, such as mathematics, are lacking (Muñiz-Rodríguez et al., 2016a). This explains why national scientific societies keep stressing the need for the development, application, and assessment of a framework of specific competences for secondary mathematics student teachers at the national level (Comisión de Educación del CEMat, 2011; Font, 2013). Notwithstanding, Spain is not an exception. According to the OECD (2005), in countries where the teaching profession follows a career-based system and teachers are generally expected to stay in the public sector employment throughout their working life, entry criteria do hardly emphasize student teachers' competences.

In recent years, research about the competences deemed essential for future teachers has increased at the different educational levels (Alake-Tuenter, Biemans, Tobi, & Mulder, 2013; Malm, 2009; Mohamed et al., 2016; Tang, Cheng, & Wong, 2016). In the international mathematics related field, significant input is also available at the secondary education level (AAMT, 2006; NCTM, 2012). However, up to now, no operational proposals are available in the Spanish context. The present research addressed this specific call for the development and validation of a competence framework for secondary mathematics student teachers in Spain. Thus, this study is considered pioneering at the national level.

The purpose of this study was twofold. On the one hand, it aimed at developing a comprehensive framework of professional competences for secondary mathematics student teachers in Spain. On the other hand, it attempted to validate this framework through an expert panel consultation method. This method aimed at reaching, as far as possible, a consensus about the core competences to be acquired by secondary mathematics student teachers during an initial teacher education program.

3.2 Theoretical framework

The adoption of competence-based systems in initial teacher education has increased all over the world. As defined earlier in this dissertation, the concept of competence in teaching refers to the combination of knowledge, skills, and attitudes that enables teachers to develop effective teaching practice at multiple levels: the individual teacher, the school environment, the educational system, the educational authorities, and beyond. A set of competences leads to the compilation of a competence framework.

In the literature, it is possible to observe a conceptual confusion between competences and standards (Reynolds, 1999). Standards build on a comprehensive competence framework by also providing benchmark information on effective practice. In some countries, initial teacher education institutions have already moved forward to the development of national standards for the accreditation of teachers, but other countries, as Spain, are still at the ground level, i.e., defining a competence framework. Standards are more oriented to the quality assessment of teaching and learning (Quality Assurance Agency for Higher Education, 2000).

As stated earlier, the existence of comprehensive and structured frameworks of professional teaching competences has important practical implications. A competence framework defines which proficiency levels student teachers should achieve and strengthen during their educational process. They can therefore be employed as reference points for developing initial teacher education programs and guiding curriculum development (Erebus International, 2008; Morris et al., 2009). Besides, they provide clear, long-term goals for teachers' learning and professional growth (Kleinhenz & Ingvarson, 2007), and, together with benchmark levels, serve as measures to assess the quality of teaching (European Commission, 2013).

Kleinhenz and Ingvarson (2007) established three essential steps in developing teaching competences and professional standards:

1. to define what is to be measured (i.e., the competences).

2. to decide how it should be measured (i.e., the instruments).
3. to identify what counts as meeting the standards (i.e., the benchmark information).

So, a first step in our research led to determine what professional competences should secondary mathematics student teachers develop during initial teacher education. Therefore, this study started from an in-depth literature review about the most predominant models describing the knowledge and competences of mathematics teachers.

3.2.1 The TPACK and the subsequent models about mathematics teachers' knowledge and competences

Research on the knowledge and competences of mathematics teachers has gradually increased in the last years. In the literature, it is possible to find different theoretical models aiming at identifying and conceptualizing the mathematical knowledge, pedagogical skills, and personal and professional attitudes that mathematics teachers should have for an effective teaching. In this section, the most well-known models within the educational research community are introduced to the reader.

Shulman is recognized as one of the pioneering researchers in conducting studies in relation to the conceptualization of teachers' knowledge. Initially, he distinguished among two knowledge domains in teaching:

- The *content knowledge* (CK), which refers to "the amount and organization of knowledge per se in the mind of the teacher" (Shulman, 1986, p. 9).
- The *pedagogical knowledge* (PK), which relates to "the knowledge of generic principles of classroom organization and management" (Shulman, 1986, p. 14).

In 1986, Shulman introduced the notion of *pedagogical content knowledge* (PCK), which addresses the preceding dichotomy between content (C) and pedagogy (P) of teaching. According to Shulman (1986, p. 9) this category includes "the ways of representing and formulating the subject-matter that make it comprehensible to others", and "an understanding of what makes the learning of specific topics easy or difficult".

Along his research career, Shulman (1987) introduced four additional equally important categories of teachers' knowledge, named *curricular knowledge*, *knowledge of learners and their characteristics*, *knowledge of educational contexts*, and *knowledge of educational ends, purposes and values and their philosophical and historical grounds.*

Beyond these domains of knowledge, Shulman (1987) linked to his theory a set of processes that teachers are supposed to adopt in view of effective teaching. This cycle, named *model of pedagogical reasoning and action*, builds upon five core activities:

- **Comprehension:** understanding of the educational purposes, the subject-matter, and the relation of a given idea to other ideas within and outside the discipline.
- **Transformation:** preparation and critical interpretation of the text materials, representation of the ideas in different forms (analogies, metaphors, examples, demonstrations, explanations, and so forth), selection of appropriate teaching strategies and processes, and adaptation and tailoring of these representations to the general and specific characteristics of the students.
- **Instruction:** organization and management of the classroom, presentation of clear explanations and vivid descriptions, assignation and checking of work, and interaction with students in an effective way.
- **Evaluation:** checking of students' understanding and misunderstanding during and at the end of the lessons or units, and assessment and adjustment of one's own teaching.
- **Reflection:** revision, reconstruction, critical analysis and, as consequence, improvement of one's own teaching and students' performance.

Further on in time, Mishra and Koehler (2006) developed Shulman's initial theory by adding one more knowledge domain: technology (T) (see also Koehler & Mishra, 2009). This led to the definition of the *technological pedagogical content knowledge* (TPACK). Thus, this widespread model builds on the intersection of the three sources of knowledge: content (C), pedagogy (P), and technology (T). In doing so, seven domains of knowledge emerge (see Figure 3.1). This outcome grounds how teaching is to be understood, how teachers are to be trained, and how teaching competences may be organized. Notwithstanding, some authors remain reluctant to the TPACK model, identifying signs of weakness (Dalziel & Dobozy, 2016; Kimmons, 2015).

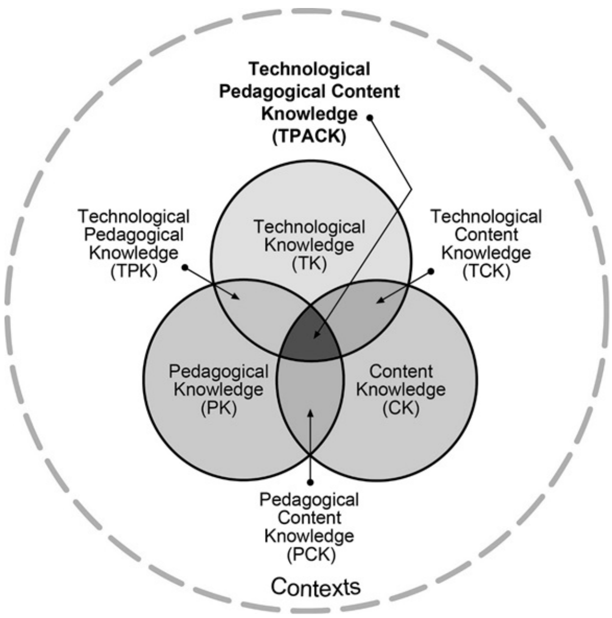

Figure 3.1. The TPACK model (reproduced with permission of the publisher, © 2012 by `tpack.org`).

According to Koehler and Mishra (2009), the three main components of teachers' knowledge and the interactions between and among these bodies of knowledge are described as follows:

- The *content knowledge* (CK) refers to "the knowledge about the subject-matter to be learned or taught" (Koehler & Mishra, 2009, p. 63). This domain includes "the knowledge of concepts, theories, ideas, organizational frameworks, evidence and proof, as well as the practices and approaches necessary to develop such knowledge" (Koehler & Mishra, 2009, p. 63).
- The *pedagogical knowledge* (PK) applies to "the knowledge about the processes and practices or methods of teaching and learning", "the understanding about how students learn, general classroom management skills, lesson planning, and student assessment" (Koehler & Mishra, 2009, p. 64). As such, this domain requires "an understanding of cognitive, social, and developmental theories of learning and how they apply to students in the classroom " (Koehler & Mishra, 2009, p. 64).
- The *technological knowledge* (TK) goes beyond the knowledge about standard and digital technologies and the skills required to operate with them (Mishra &

Koehler, 2006); it also requires "to recognize when information technology can assist or impede the achievement of a goal, and to continually adapt to changes in information technology" (Koehler & Mishra, 2009, p. 64).

- The *pedagogical content knowledge* (PCK) alludes, coinciding with Shulman (1986), to the transformation of the subject-matter for teaching. This transformation takes place "as the teacher interprets the subject-matter, finds multiple ways to represent it, and adapts and tailors the instructional materials to alternative conceptions and students' prior knowledge" (Koehler & Mishra, 2009, p. 64).

- The *technological pedagogical knowledge* (TPK) regards to understand how teaching and learning are influenced by the use of particular technologies (Koehler & Mishra, 2009). This means knowing the pedagogical opportunities and limitations of a range of technological tools and the disciplinary contexts within which they operate (Koehler & Mishra, 2009).

- The *technological content knowledge* (TCK) is "an understanding of the manner in which technology and content influence and constrain one another" (Koehler & Mishra, 2009, p. 65). This means to understand which specific technologies are more suitable for addressing specific subject-matter learning, and vice versa.

- The *technological pedagogical content knowledge* (TPCK) is "the basis of effective teaching with technology" (Koehler & Mishra, 2009, p. 66). This domain requires: an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies to constructively teach content; knowledge of what makes specific concepts difficult or easy to learn and how technologies can help addressing these problems; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies build on existing knowledge to develop new learning or strengthen old one (Koehler & Mishra, 2009).

In the mathematics field, and parallel to the development of the TPACK model, another group of researchers built on Shulman's theory in an attempt to characterize the specific knowledge of mathematics teachers. Thus, Ball et al. (Ball, Lubienski, & Mewborn, 2001; Ball et al., 2008; Hill, Ball, & Schilling, 2008; Hill, Schilling, & Ball, 2004) introduced the notion of *mathematical knowledge for teaching* (MKT), which refers to "the mathematical knowledge that teachers use in classrooms to produce instruction and student growth" (Hill et al., 2008, p. 374). In this way, these authors developed an alternative model for the conceptualization of the necessary knowledge for teaching mathematics (see Figure 3.2). Further, they proved how teachers' mathematical knowledge for teaching contributes to students' mathematics achievement (Hill et al., 2005).

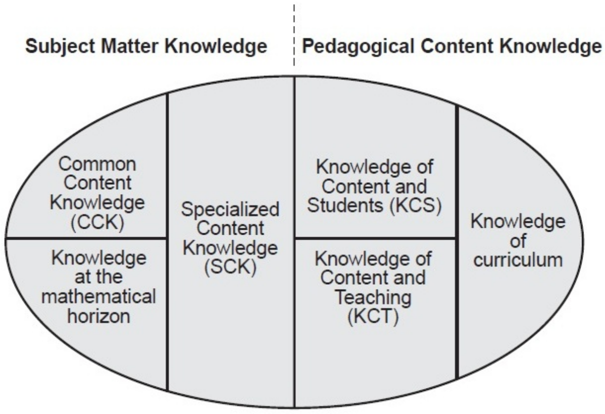

Figure 3.2. The MKT model (Hill et al., 2008, p. 377).

This model introduces some refinements to Shulman's categories of teacher knowledge. Figure 3.2 illustrates the relation between the MKT and two of the domains proposed by Shulman (1986): the *subject-matter knowledge* and the *pedagogical content knowledge*. The left side of the oval proposes three subdomains within the *subject-matter knowledge* domain, namely:

- The *common content knowledge* (CCK), described as "knowledge that is used in the work of teaching in ways in common with how it is used in many other professions or occupations that also use mathematics" (Hill et al., 2008, p. 377). Ball et al. (2008) explain that this knowledge is not exclusive to teaching, rather it is relevant in a wide variety of settings and professions.
- The *knowledge at the mathematical horizon*, defined as "an awareness of how mathematical topics are related over the span of mathematics included in the curriculum" (Ball et al., 2008, p. 403).
- The *specialized content knowledge* (SCK), i.e., "the mathematical knowledge and skill unique to teaching" (Ball et al., 2008, p. 400). Hill et al. (2008, p. 377) describe this subdomain as "the mathematical knowledge that allows teachers to engage in particular teaching tasks, including how to accurately represent mathematical ideas,

provide mathematical explanations for common rules and procedures, and examine and understand unusual solution methods to problems".

On the other hand, the right side of the oval distinguishes between three subdomains within the *pedagogical content knowledge* domain, labeled:

- The *knowledge of content and students* (KCS), bounded as "content knowledge intertwined with knowledge of how students think about, know, or learn this particular content" (Hill et al., 2008, p. 375).
- The *knowledge of content and teaching* (KCT), which results from the "interaction between specific mathematical understanding and an understanding of pedagogical issues that affect student learning" (Ball et al., 2008, p. 401). This domain includes mathematical knowledge needed for the design and sequencing of content for instruction, the selection of the examples used to introduce and delve into the content, and the assessment of the representations and different methods and procedures used to teach (Ball et al., 2008).
- The *knowledge of curriculum*, which, following Shulman (1986), represents the range of programs and instructional materials designed for teaching mathematics as well as the set of characteristics that serve as indications and contraindications of their use in particular circumstances.

Many practical implications of the previous conceptualizations of teacher knowledge are discussed in the literature in relation to: initial teacher education curriculum development (Papanikolaou, Gouli, & Makri, 2014), learning environment design (Doering, Veletsianos, Scharber, & Miller, 2009), pre-service and in-service teachers' pedagogical content knowledge measurement and assessment (Prescott, Bausch, & Bruder, 2013; Rowan, Schilling, Ball, & Miller, 2001), or teachers' professional development (Hansen, Mavrikis, & Geraniou, 2016).

From a theoretical point of view, the aforementioned models have led to new insights about teachers' knowledge and competences. For instance, Godino (2009) built on the MKT to suggest a new approach that includes more detailed categories of analysis for mathematics teachers' knowledge: the *didactic-mathematical knowledge* (DMK). This new categorization is based on the onto-semiotic approach to mathematical knowledge and instruction (Godino, Batanero, & Font, 2007). This model was later used in numerous research studies that sought to characterize the didactic-mathematical knowledge of teachers in specific areas of mathematics (see Gómez-Torres, Contreras, & Batanero, 2015; Pino-Fan, Godino, & Font; 2014) or assess initial teacher education both at primary and secondary education level (see Gonzato, Godino, Contreras, & Fernández, 2013; Vásquez & Alsina, 2015).

Similarly, another group of researchers proposed a reformulation of the MKT. Instead of talking about *specialized content knowledge*, Carrillo et al. (2013) support the notion of *mathematics teachers' specialized knowledge* (MTSK). The MTSK differentiates between the general pedagogical knowledge, the specialized knowledge of teachers of other disciplines, and the specialized knowledge of other mathematics professionals. With regard to the MKT model, these authors suggest to eliminate the CCK category, and rename and reinterpret the KCS, the KCT and the *knowledge of curriculum*. This results in six new knowledge domains: the *Knowledge of Topics* (KoT), the *Knowledge of the Structure of Mathematics* (KSM), the *Knowledge of the Practice of Mathematics* (KPM), the *Knowledge of Features of Learning Mathematics* (KFLM), the *Knowledge of Mathematics Teaching* (KMT), and the *Knowledge of Mathematics Learning Standards* (KMLS) (see Figure 3.3). This model has been used as a potential tool for analyzing the knowledge of mathematics teachers both at primary and secondary education level (see for instance Aguilar, 2016; Montes & Carrillo, 2015).

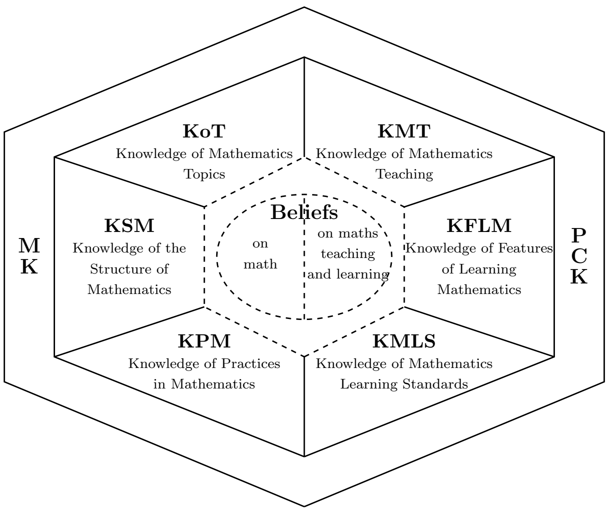

Figure 3.3. The MTSK model (Carrillo et al., 2013).

Nevertheless, there is still no international consensus on what is the most appropriate theoretical model to describe the knowledge and competences of a mathematics teacher. The previous literature review helped to build the first layer of the competence framework object of this study. Next, a document analysis of available competence frameworks for secondary mathematics student teachers at the international level was conducted. In this sense, only examples consistent with the previous theoretical base were considered. This method prevents adopting an additive approach when it comes to determining teaching competences.

3.2.2 An international overview of teaching competences and professional standards

A search of the academic literature including teacher education organizations in a set of countries – the United States, Australia, the United Kingdom (UK), Germany, and the Asia-Pacific region – was carried out in order to develop a second layer of our competence framework. Different approaches have been developed in many countries around the world that could serve as models for the design of a framework within the Spanish context, where at this moment no common ground exists at the competence level. Because some national initial teacher education institutions have already moved forward from teaching competences to professional standards, this literature review sometimes refers to national standard frameworks. In such cases, the analysis was carried out only at the competence level. Although our attention focused on competences for the teaching of mathematics, also generic core competences for student teachers were considered. This is because specialist teachers must be qualified not only to teach one particular discipline, but also in relation to general core competences.

The National Council for the Accreditation of Teacher Education (NCATE) is a coalition of organizations of teachers, teacher educators, professional content specialists, and policymakers, committed to quality teaching within the United States. The main goal of the NCATE is to assure that graduates of accredited institutions acquire the knowledge, skills, and dispositions necessary for effective teaching. The NCATE developed a framework of competences, put forward as standards and reviewed every seven years, which describes the specialized content knowledge that teacher candidates should master (NCATE, 2008). Each competence is associated with a rubric describing different performance levels. Nowadays, nearly all the United States have adopted the NCATE's professional standards for the accreditation of teacher education programs.

The NCATE deals with a variety of disciplines, including mathematics. Through the Council of the Accreditation of Educator Preparation (CAEP), the National Council of Teachers of Mathematics (NCTM) was one of the first subject-matter organizations responsible for setting teaching competences and professional standards in the mathematics field in the United States context. The NCTM CAEP Standards provide a guide to institutions to design initial education programs for prospective mathematics teachers at elementary, middle-grade and secondary education level (NCTM, 2012). The NCTM CAEP Standards largely fits the TPACK model in the field of mathematics teacher education. However, the technology dimension is not sufficiently represented.

Still under the NCATE's umbrella, the International Society for Technology in Education (ISTE) established a framework of competences and performance indicators for teachers of the digital age in the United States (ISTE, 2008). According to these competences, at the completion of an initial education program student teachers must (a) use technology to facilitate and inspire students' learning and creativity, (b) design and develop digital age learning experiences and assessments, (c) model digital age work and learning, (d) promote and model digital citizenship and responsibility, and (e) engage in professional growth and leadership. These technological competences were taken into account in our study.

Parallel to the NCATE's program but in another geographic area, the Australian Association of Mathematics Teachers (AAMT) is a federation of associations of mathematics teachers from all Australian states aiming at supporting the teaching profession and promoting mathematics learning. The AAMT has developed a range of competences which reflects a national consensus about the knowledge, skills and attributes required for teaching mathematics (AAMT, 2006). Taken as a whole, these competences provide a framework for teachers' initial education and professional growth.

In the UK, four national agencies are responsible for the education and development of teachers and the improvement of teaching quality: the Teaching Agency (TA) in England – formerly the General Teaching Council for England (GTCE) –, the General Teaching Council for Scotland (GTCS) in Scotland, the General Teaching Council for Wales (GTCW) in Wales – renamed as the Education Workforce Council (EWC) –, and the General Teaching Council for Northern Ireland (GTCNI) in Northern Ireland. All of them set out competences defining what a trainee teacher must know, understand and be able to do to be accredited for the teaching profession (Department for Education, 2011; GTCNI, 2011; GTCS, 2012; Welsh Government, 2011).

In Germany, the “Standards für die Lehrerbildung: Bildungswissenschaften” for teacher education, adopted in 2004, define the requirements to be met by teachers (Lohmar & Eckhardt, 2013). These requirements are generated by the competences aimed for. In terms of mathematics teacher education, the German COACTIV (Professional Competence of Teachers, Cognitively Activating Instruction, and Development of Students' Mathematical Literacy) project, was set up to investigate teacher competences as a key determinant of instructional quality in mathematics. Combining findings from various research perspectives, the COACTIV team proposed a theoretical model of teachers' professional competences and applied it to mathematics teachers (Baumert & Kunter, 2006).

In the broader Asia-Pacific region, the findings of a scoping study show that most countries in this region have developed or are developing teaching competences as a tool for guiding teacher education and teaching practice (Erebus International, 2008). For instance, the Ministry of Education of the People's Republic of China published in 2012 the National Professional Standards for K-12 Teachers (Wu, 2014). This document represents the first national set of competences for teachers in China and serves as a common framework of basic requirements for initial teacher education graduates in elementary and secondary education. On the other hand, the development of distinctive competences for mathematics is a recurrent issue in Sri Lanka and Korea.

3.3 Methodology

The aforementioned theoretical approaches together with the international perspective served as a proxy for the development of the competence framework (see Table 3.1).

Table 3.1. Relationship between the theoretical/literature input and the preliminary framework.

Cluster	NCATE	NCTM CAEP	AAMT	United Kingdom	Germany	Asia-Pacific Region	NPST
Mathematical content knowledge	Have in-depth knowledge of the content to be taught	Demonstrate knowledge of mathematics concepts	Have coherent knowledge of mathematics	Have a secure knowledge, understanding of the subject	Know the content to be taught	Know the mathematics content to be taught	Acquire specific-subject knowledge
	Use current research to inform practice	Incorporate research-based mathematical experiences	Understand theories relevant to math learning	Apply relevant findings from research	Know relevant educational theories	Know mathematics education theory	Know main theories of the subject-matter
Mathematical pedagogical knowledge	Address students' preconceptions; build on prior knowledge	Identify and address students' misconceptions	Know students math development and how they learn	Build on prior knowledge to enable students apply new learning	Know students ways of learning	-	Know students cognitive characteristics to learn
	Present the content in challenging and clear ways	Represent and communicate mathematical ideas	Understand how math is represented & communicated	Explain new concepts clearly and in a stimulating way	Communicate content in different ways	-	-
	Engage mathematical connections	Recognize math connections across domains	Understand connections within/ outside math	-	-	Relate subject content to real life	Know how the subject is related with other subjects

Table 3.1: *Continued.*

Teaching and learning processes	Select and develop instructional strategies	Include multiple instructional strategies	Know effective techniques for teaching and learning math	Know diverse teaching and learning strategies	Know different teaching methods	Use a range of teaching approaches	Know teaching methods for the subject
	Be able to explain the choices made in the practice	Recognize when teaching and learning is enhanced	Reflect on practice and learn from experiences	Evaluate teaching and modify planning	Check the quality of own teaching	Reflect on teaching in view of improvement	Improve teaching based on evaluation
	Use school resources that support learning	Use instructional tools	Enhance teaching using different resources	Select and use a wide variety of resources	-	Use appropriate resources for teaching	Make good use of teaching resources
Classroom management	Establish classroom climate that values diversity	Establish an environment that maximizes learning	Establish a clear framework for classroom discipline	Know methods of constructive conflict management	Create an environment of respect	Manage student behavior	Establish a harmonious environment
	Use learning outcomes to motivate students	Engage students in mathematical activities	Motivate enthusiasm for / interest in math	Use stimulating materials for teaching	Motivate students	Engage students in learning	Stimulate curiosity; foster learning interests
	-	Know class organizational models to work in groups	Encourage cooperation and collaboration in the class	Make use of space to accommodate group/individual work	Know methods of promoting cooperative learning	-	Conduct group activities regularly

Table 3.1: *Continued.*

Lesson planning	Plan instruction from learning goals	Plan lessons incorporating a variety of strategies	Plan coherent learning experiences	Design effective learning sequences	Plan lessons professionally and properly	Plan lessons using diverse teaching activities	Plan instruction appropriate for students
	-	Apply knowledge of curriculum standards	Understand mathematics curriculum	Understand statutory curricula and frameworks	Plan curriculum	Know the current curricula	Design teaching objectives and programs
	-	-	Involve students in math activities beyond class	Plan homework and activities to consolidate learning	-	Participate in appropriate extra-curricular activities	-
Assessment and mentoring	Asses and analyze student learning	Select and use formative and summative assessment	Use a range of assessment strategies	Know a range of approaches for assessment	Know procedures for teaching assessment	Know and use a variety of assessment methods	Use multiple evaluation methods
	Monitor students' progress from assessment results	Monitor students' progress using assessment	Report outcomes; map progress; plan future experiences	Use evaluation to monitor progress	Make the teaching/learning process based on knowledge acquisition	-	-
	Interact with students' families to support learning	Inform instruction by reflecting on math essential proficiency	Inform families about students learning progress	Provide timely, accurate and constructive feedback	Know approaches to advise students and parents	Provide feedback to students; communicate with families	Use assessment to give students appropriate guide

Table 3.1: *Continued.*

	Know students' context	Know individual cultural and language diversity	Know students' cultural and math background	Understand that cultural context influences progress	Know the social and cultural contexts of students	Know students' characteristics	Understand students' cultural characteristics
Developmental psychology	Know the ways children and adolescents develop	Know adolescent learning development	Be aware of psychological and emotional students' needs	Understand how children and young people develop	Know psychological theories of development	-	Understand students' mental/ psychological development
	Develop learning based on students' developmental levels	Plan developmentally appropriate learning opportunities	Address students' psychological needs	Adapt teaching to students' characteristics	Assist students based on individual development	-	Know strategies to promote psychological development
Inclusion and diversity	Understand diversity of student population	Incorporate knowledge of individual differences	Be aware of students' individual needs and talents	Identify special educational needs or disabilities	Know possible educational needs faced by students	Recognize diversity among groups and individuals	Understand students' special needs
	Develop lessons for students with different learning styles	Plan learning building from students skills	Respond to students' individual needs	Adapt teaching to students with special educational needs/disabilities	Implement educational assistance based on students' needs	Support diversity among groups and individuals	Acquire strategies of promoting students with educational needs

Table 3.1: *Continued.*

Inclusion and diversity	-	-	Use inclusive, appropriate assessment strategies	Assess the learning needs of students	-	-	-
Technology knowledge	Use range of technologies that promote learning	Include math-technological tools in their teaching	Be aware of the use of ICT in math	Pass the professional skills tests in ICT	Integrate ICT didactically	Know appropriate technology for teaching	Adapt subject-content to ICT methods
	Integrate technology in instruction	Plan lessons incorporating technology	Enhance teaching strategies by technology	Know how to use ICT to support teaching	Know the use of ICT in teaching	-	Apply educational technology into teaching
Communication skills	Communicate effectively with students, families and colleagues	-	Foster communication skills; ensure interaction	Communicate effectively with students, families and colleagues	Have knowledge of communication and interaction	Communicate clearly and accurately	Communicate effectively with students, parents, colleagues
Contribution to school organization	-	-	-	Be aware of the statutory framework	Know the structure and history of the education system	-	Know state education policies
	Be involved in a variety of school-based activities	-	Attend curriculum changes; contribute to school	Share responsibility for policies and practices implementation	Participate in the planning, implementation of school projects	Contribute to the life of the learning center	Design teaching programs

Table 3.1: *Continued.*

Contribution to school organization	Share expertise through leadership and mentoring	-	Participate actively in school decision making	-	Participate in school decision making	Display leadership	-
Personal commitment	Develop and model professional dispositions	Demonstrate equitable treatment	Reflect a range of personal attributes to engage students	Demonstrate the values, attitudes, behavior expected from students	Reflect personal values	Maintain confidentiality, trust and respect	Have professional morals; serve as role models; respect
	Collaborate with colleagues to support learning	Engage in collaborative learning	Contribute to improvement of math teaching collaborating	Be committed with collaborative, cooperative working	Contribute cooperatively to school/learning development	Cooperate with colleagues	Reflect and improve education and teaching
	Engage in professional development	Take an active role in professional growth	Be committed to the continual improvement of teaching	Improve practice through professional development	View the profession as a permanent learning task	Develop professionally	Be committed to improving practice by professional development

Document analysis resulted in a comprehensive list of competences. These competences were compared looking for commonalities and differences and classified by related domains through a content analysis technique. This helped to filter isolated or less relevant ideas. Overlapping competences were removed. Next, competences referring to similar concepts, skills, attitudes or values were combined. The overall process resulted in a preliminary list of thirty-two competences (see Table 3.2), categorized into twelve clusters: Mathematical content knowledge (MCK), Mathematical pedagogical knowledge (MPK), Teaching and learning processes (TLP), Classroom management (CM), Lesson planning (LP), Assessment and mentoring (AM), Developmental psychology (DP), Inclusion and diversity (ID), Technology knowledge (TK), Communication skills (CS), Contribution to school organization (CSO), and Personal commitment (PC). This preliminary framework was the basis to tackle the validation process through an expert panel consultation study, using the Delphi method.

Table 3.2. Preliminary competence framework for initial teacher education programs in mathematics.

Mathematical content knowledge (MCK)
MCK1. Know and understand mathematical concepts, ideas, theories and procedures according to different mathematical branches such as calculus, algebra, geometry, discrete mathematics, statistics and probability, and measurement. MCK2. Know the history and recent findings of mathematics to convey a dynamic mathematical perspective.
Mathematical pedagogical knowledge (MPK)
MPK1. Identify students' beliefs and attitudes about mathematics, and comprehend how students learn mathematics. MPK2. Communicate and represent mathematical thinking coherently and clearly both orally and in writing. MPK3. Make connections between mathematical concepts and other subject areas and real life problems.
Teaching and leaning processes (TLP)
TLP1. Select creative and innovative strategies for teaching and learning mathematics appropriate to students' needs. TLP2. Evaluate and justify the approaches chosen in view of learning and teaching mathematics in view of their impact on students.

Table 3.2: *Continued.*

TLP3. Use a wide variety of materials and resources, including technology and the outdoor environment, for teaching and learning mathematics.
Classroom management (CM)
CM1. Establish rules and routines for behavior in classroom in accordance with the school behavior policy. CM2. Use a variety of techniques to motivate students to develop enthusiasm for and interest in mathematics. CM3. Make efficient use of classroom space to accommodate different learning techniques both collaboratively and individually.
Lesson planning (LP)
LP1. Plan well-structured lessons that address appropriate learning goals, considering national mathematics curricula standards. LP2. Contribute to the design of an engaging and spiral curricula that focus on students' needs and prior knowledge. LP3. Set homework and plan other out-of-class activities to consolidate and extend the knowledge and understanding students have acquired.
Assessment and mentoring (AM)
AM1. Employ adequate strategies to assess student learning outcomes with respect to skills, mathematical knowledge, and attitudes that are appropriate to the student in accordance with statutory requirements. AM2. Use the information obtained from assessment to map students' progress and to plan appropriate future learning experiences. AM3. Provide constructive, purposeful and timely feedback to students, their families, and school authorities.
Developmental psychology (DP)
DP1. Know student characteristics (e.g., motivation, attitudes,...) and their social context. DP2. Understand the stages of student personality development and its possible impact on students learning. DP3. Adapt the teaching process to support students' learning at different stages of development using adequate strategies and methods.
Inclusion and diversity (ID)
ID1. Identify different student needs, including those with special educational needs, high ability, and/or disabilities.

Table 3.2: *Continued.*

ID2. Adapt teaching to respond to the strengths and needs of all students, designing differentiated instruction that addresses student diversity and encouraging an inclusive education. ID3. Assess learning outcomes of students with diverse abilities.
Technology knowledge (TK)
TK1. Exhibit knowledge and skills about information and communication technology systems as an effective tool for teaching and learning mathematics. TK2. Design, develop and assess learning experiences using digital tools.
Communication skills (CS)
CS1. Use effective verbal and nonverbal communication techniques to foster and support interaction in the classroom and in the school community.
Contribution to school organization (CSO)
CSO1. Know the historical evolution of the Spanish education system. CSO2. Contribute in the design of the comprehensive education plan and common school activities with special attention to teaching quality improvement. CSO3. Participate actively in school decision-making.
Personal commitment (PC)
PC1. Exhibit personal values – such as enthusiasm for mathematics and its learning, care and respect for the students, autonomy, self-esteem – that assist to engage students in their learning and maximize their achievement. PC2. Contribute to the improvement of mathematics teaching by actively engaging students and collaborating with colleagues in mathematical activities both inside and outside the classroom. PC3. Be committed to the continual improvement of teaching practice participating in programs for personal professional development.

3.3.1 The Delphi method

The Delphi method consists of an iterative process during which a group of experts expresses their opinion on a particular subject to reach a consensus (Hsu & Sandford, 2007; Linstone & Turoff, 1975). The Delphi method is a broadly used and accepted tool with a diverse range of applications in a wide variety of areas (Hsu & Sandford, 2007; Linstone & Turoff, 1975), including education (Green, 2014). In particular, the Delphi method has recently been adopted in the context of teacher education as a valuable tool to develop teaching competences for primary education teachers (Alake-Tuenter et al., 2013), to define quality indicators for teacher educators (Koster et al., 2005), or to integrate technology into teacher education (Volman, 2005).

The Delphi method – when focusing on the design of a competence framework – can be summarized as follows (Linstone & Turoff, 1975): a research group designs a preliminary competence framework which is sent to a respondent group; after the framework has been reviewed by participants, the research group analyzes the data and, based on the results, develops a new version to be submitted to – the same or a different – respondent group; the latter gets the opportunity to re-evaluate the original answers and modify their opinions according to the collective view of the group. The process is finished when consensus criteria are met.

Through a Delphi method, participants have the opportunity to reassess their initial judgment. As a result, original statements are changed or modified during consecutive rounds until convergence of opinions is achieved. Feedback is probably the most important element in a Delphi method and it is the driver of consensus development (Hsu & Sandford, 2007). Anonymity among participants is to be used to reinforce the self-concept of experts (Linstone & Turoff, 1975).

Several reasons justify the use of a Delphi method in this study. This research topic requires the dynamic of a consultation process, so that the final outcome is viewed as a reflection of agreement on the opinions of experts. In this sense, the Delphi method is considered an effective and reliable tool (Linstone & Turoff, 1975; Smith & Simpson, 1995). In this study, an online Delphi approach was adopted, in which communication with experts and questionnaire design, delivery and administration was accomplished through the Internet. The use of an online procedure provides additional benefits. For instance, it does not require the physical presence of participants, which is time-consuming and cost-ineffective, affecting the feasibility of the study. Through the online approach, participants chose in a flexible way the time and place to take part in the survey.

3.3.2 Sample

The Delphi method involved two groups: a monitor team and an expert panel. The monitor team consisted of the research group in charge of this study. They were responsible for the design, development and management of the Delphi method, i.e., selection of and communication with the expert panel, preparation of the materials, data collection, data analysis, and presentation of the results.

The expert panel involved two subgroups: A (n_A=21) and B (n_B=10). In the first round, only experts from panel A participated. In the subsequent rounds, both panels were involved. The incorporation of new members in the expert panel during subsequent rounds increases and ensures validity and reliability of the results until a consensus is achieved (Linstone & Turoff, 1975). Of the 31 experts, 13 were female and 18 were male. Experts were sought to represent different and relevant backgrounds and fields. Thus, 7 secondary mathematics teachers, 21 university professors – 6 in mathematics, 3 in psychology and/or education, and 12 in mathematics education –, and 3 mathematics teaching technical advisers working in the Spanish Ministry of Education, Culture and Sport participated in this study. These professors, teachers and practitioners with long and valuable experience (mean=35.7 years) were selected on the basis of literature search and monitor team's networks. A non-probability sampling technique was used. The criteria for selection the sample were based on professional profile, experience and expertise in the field of mathematics teacher education, and/or scientific publications. According to Fricker (2008), responses from convenience samples are trustworthy for collecting sorts of non-inferential data. All experts were familiar with teacher education and teaching competences from both a theoretical and a practical perspective. Some of them had participated in curriculum design at the request of the Spanish Ministry of Education, Culture and Sport.

3.3.3 Procedure for the data collection and analysis

According to Linstone and Turoff (1975), setting up three rounds is usually enough for a Delphi method approach. Additional rounds hardly tend to result in further significant changes. In this study, the data analysis showed how ratings hardly changed during the third round, suggesting that a consensus was attained. In every round, an online questionnaire – both in English and in Spanish – was sent to the expert panel, and it took about fifteen minutes to complete. The instrument was modified for each subsequent round according to the results of the previous one. Instruments were designed and managed through the software LimeSurvey®. Appendix A shows the items of the Delphi questionnaire in the first round (the layout was similar in the following rounds).

In the first-round instrument, participants were asked to rate the extent to which each competence was adequately defined in view of teaching mathematics at secondary education level. A five-point Likert scale – from (1) *Not adequate* to (5) *Extremely adequate* – was used. Experts were invited to justify their low ratings by proposing modifications in the wording of a competence definition. This helped to minimize redundancy and ambiguity in the formulation of competences and limit the number of rounds required to reach consensus. Experts were invited to add new teaching competences if deemed necessary. The results from round one were next scrutinized by the monitor team and presented to the expert panel in round two.

The second round of the Delphi method started with an adaptation of the initial competence framework based on the results from round one. Participants were asked to rate the adequacy of modified competences that did not reflect a consensus after the first round. In addition, experts were asked to indicate whether they agreed or disagreed with the addition of three new competences resulting from the former round. In view of this, an alternative five-point Likert scale was used. The results from round two were used to design the third-round instrument.

In the third and last round, the focus was again on competences not reflecting any consensus thus far. This helped drawing up the final version of the competence framework. Consistent with the literature (Hsu & Sandford, 2007), a consensus was stated to be achieved when at least 80% of the experts agreed about the formulation of a competence. After each round, the competences were classified into three groups according to this consensus criteria:

- **Validated,** if at least 80% of the experts' ratings were at level 4 or higher. In this case, the competence remained unchanged.
- **Minor revision,** if between 70% and 80% of the experts' ratings were at level 4 or higher.
- **Major revision,** in any other case.

Data collection took place from April to July 2015. Data analysis was performed using SPSS ® (version 24) for quantitative analysis. Answers to open questions were qualitatively analyzed through Weft QDA ⓒⓒ and classified into relevant categories for later examination.

3.4 Results

From the literature review and the document analysis, a preliminary version of the competence framework consisting of thirty-two teaching competences, classified into twelve domains, was outlined (see Table 3.2). In each round of the Delphi method, competences not meeting the consensus criteria were modified, taking into account the suggestions from the experts. Table 3.3 provides an example of the evolution of a specific competence (MPK1) during the consultation process. This competence was validated in the third round.

Table 3.3. Example of the evolution of a competence (MPK1) during the Delphi method.

Round	**Competence description**	**Experts' suggestions**
1	Identify students' beliefs and attitudes about mathematics, and comprehend how students learn mathematics	- Replace *beliefs and attitudes* with *background and prior mathematical knowledge* (n=2) - It is necessary to add *difficulties and mistakes* (n=2) - The second part is not clear (n=2)
2	Know students' background and prior mathematical knowledge, as well as difficulties and mistakes, and the variety of approaches than can help to face and solve them	- Replace *know* with *identify* (n=2) - Should be *apply* different approaches, not only *know* them (n=2)
3	Identify students' background and prior mathematical knowledge, as well as difficulties and mistakes, and apply those processes that can help students to face and solve them	

Following the three rounds, the preliminary version of the competence framework was refined and consolidated according to the experts' opinions (see Table 3.4).

Table 3.4. Results from the validation process.

Competence	**Round 1**	**Round 2**	**Round 3**
MCK1	81.0% - Validated		
MCK2	81.0% - Validated		
MPK1	66.7% - Major	73.1% - Minor	78.3% - Minor
MPK2	90.5% - Validated		
MPK3	90.5% - Validated		
MPK4	New	92.3% - Validated	
TLP1	81.0% - Validated		
TLP2	66.7% - Major	65.4% - Major	56.5% - Major
TLP3	76.2% - Minor	88.5% - Validated	
TLP4	New	88.5% - Validated	
CM1	76.2% - Minor	61.5% - Major	56.5% - Major
CM2	81.0% - Validated		
CM3	90.5% - Validated		
CM4	New	84.6% - Validated	
LP1	81.0% - Validated		
LP2	66.7% - Major	69.2% - Major	60.9% - Major
LP3	76.2% - Minor	73.1% - Minor	91.3% - Validated
AM1	71.4% - Minor	80.8% - Validated	
AM2	71.4% - Minor	88.5% - Validated	
AM3	81.0% - Validated		
DP1	81.0% - Validated		
DP2	71.4% - Minor	76.9% - Minor	78.3% - Minor
DP3	90.5% - Validated		
ID1	85.7% - Validated		
ID2	85.7% - Validated		
ID3	66.7% - Major	65.4% - Major	69.6% - Major
TK1	66.7% - Major	76.9% - Minor	91.3% - Validated
TK2	61.9% - Major	Merged	
CS1	81.0% - Validated		
CSO1	52.4% - Minor	Deleted	

Table 3.4: *Continued.*

CSO2	81.0% - Validated	
CSO3	71.4% - Minor	88.5% - Validated
PC1	66.7% - Major	80.8% - Validated
PC2	85.7% - Validated	
PC3	76.2% - Minor	84.6% - Validated

Note: The percentage represents the proportion of ratings at level 4 or higher.

Based on the consensus criteria mentioned above, during the first round 16 of the 32 initial competences were validated, 9 competences needed minor revision and 7 competences needed major revision. As a consequence of the revision process, 14 competences were reformulated, 2 competences (TK1 and TK2) were merged, and 1 competence (CSO1) was removed. Three new competences were added to the list in order to check their adequacy during round two.

In the second round, 6 additional competences were validated and 8 competences remained under revision. Experts were almost unanimous in their opinion to incorporate the three new competences suggested during the first round. During the third and last round, 2 extra competences were validated; 6 remained under revision: 2 minor and 4 major.

The monitor team considered competences MPK1 and DP2 as validated with 78.3% of the consensus. As competences TLP2, CM1, LP2 and ID3 did not reach a consensus, they were labeled as *debatable competences*. They will be thoroughly commented later in the discussion section.

The resulting validated framework consists of thirty-three competences, organized into twelve different clusters (see Table 3.5). As such, it represents a consensual view of the knowledge, skills, and attitudes that secondary mathematics student teachers should acquire along an initial teacher education program for effective teaching in mathematics. These competences mirror targets to which all secondary mathematics student teachers should aspire and work towards in their initial education. Each competence is shaped by and inter-related to the others. It should be borne in mind that TK1 and TK2 were merged and renamed as TK1; CSO1 was removed.

Table 3.5. Validated competence framework for initial teacher education programs in mathematics.

Mathematical content knowledge (MCK)
MCK1. Know and understand mathematical concepts, ideas, theories and procedures according to different mathematical branches such as calculus, algebra, geometry, discrete mathematics, statistics and probability, and measurement. MCK2. Know the history and recent findings of mathematics to convey a dynamic mathematical perspective.
Mathematical pedagogical knowledge (MPK)
MPK1. Identify students' background and prior mathematical knowledge, as well as difficulties and mistakes, and apply those processes that can help students to face and solve them. MPK2. Communicate and represent mathematical thinking coherently and clearly both orally and in writing. MPK3. Make connections between mathematical concepts and other subject areas and real life problems. MPK4. Know relevant findings from teaching mathematics research as guidance for professional practice in the classroom.
Teaching and leaning processes (TLP)
TLP1. Select creative and innovative strategies for teaching and learning mathematics appropriate to students' needs. *TLP2. Be able to explain the impact on students of the strategies adopted for mathematical learning.* TLP3. Use a wide variety of materials and resources, such as games, puzzles, riddles, and technological devices, for teaching and learning mathematics. TLP4. Know resources for mathematics teachers, such as mathematical research journals, professional mathematics organizations web sites, among others.
Classroom management (CM)
CM1. Enforce rules and routines of behavior in classroom practice during mathematics lessons, in accordance with the school behavior policy. CM2. Use a variety of techniques to motivate students to develop enthusiasm for and interest in mathematics. CM3. Make efficient use of classroom space to accommodate different learning techniques both collaboratively and individually.

Table 3.5: *Continued.*

CM4. Promote mathematical learning situations that allow students to ask questions themselves, investigate, and seek answers.
Lesson planning (LP)
LP1. Plan well-structured lessons that address appropriate learning goals, considering national mathematics curricula standards.
LP2. Know the curriculum framework in force in Spain, identify its different elements and its application in the area of mathematics in secondary education.
LP3. Set homework and plan other out-of-class activities to reinforce the mathematical knowledge that students have previously acquired.
Assessment and mentoring (AM)
AM1. Employ different methods and techniques to assess students mathematical learning that are rigorous, objective and fair.
AM2. Use the results obtained from the assessment to diagnose difficulties, set goals and plan future learning experiences within the area of mathematics.
AM3. Provide constructive, purposeful and timely feedback to students, their families, and school authorities.
Developmental psychology (DP)
DP1. Know student characteristics (e.g., motivation, attitudes,...) and their social context.
DP2. Know the stages of student cognitive development and its influence on mathematics learning.
DP3. Adapt the teaching process to support students' learning at different stages of development using adequate strategies and methods.
Inclusion and diversity (ID)
ID1. Identify different student needs, including those with special educational needs, high ability, and/or disabilities.
ID2. Adapt teaching to respond to the strengths and needs of all students, designing differentiated instruction that addresses student diversity and encouraging an inclusive education.
ID3. Know when and about which aspects to seek support and to cooperate with specialized supporting staff for students with specific educational needs.
Technology knowledge (TK)
TK1. Apply information and communication technologies within educational settings and mathematics teaching, analyzing its impact on mathematics learning.

Table 3.5: *Continued.*

Communication skills (CS)
CS1. Use effective verbal and nonverbal communication techniques to foster and support interaction in the classroom and in the school community.
Contribution to school organization (CSO)
CSO2. Contribute in the design of the comprehensive education plan and common school activities with special attention to teaching quality improvement. CSO3. Participate actively in school decision making, especially in those that apply to the mathematics department.
Personal commitment (PC)
PC1. Exhibit personal attributes – such as enthusiasm for mathematics and its learning, care and respect for the students, autonomy, self-esteem – that assist to engage students in their learning and maximize their achievement. PC2. Contribute to the improvement of mathematics teaching by actively engaging students and collaborating with colleagues in mathematical activities both inside and outside the classroom. PC3. Commit to teaching professional development, participating in training programs for mathematics teachers.

Note: The four debatable competences are printed in italics.

3.5 Discussion

In Spain, a common nationwide framework of competences guiding the curriculum of initial education programs for future secondary mathematics teachers is currently lacking. Available frameworks are narrowly defined or had not been validated thus far. This research has therefore contributed to the identification of the knowledge, skills, and attitudes that secondary mathematics student teachers should acquire during the MDTTSE, in order to become effective mathematics teachers. A key outcome of this study has been the development and validation of a consensual framework of professional competences for secondary mathematics student teachers. This framework can be used as a starting point for initial teacher education assessment and curriculum development.

Although changes in wording throughout the validation process were necessary, the preliminary version of the competence framework could already be considered a rational approximation of the final result. All competences and clusters seem to be in accordance with the aforementioned theoretical models about teachers' knowledge, i.e., Shulman's theory (1986, 1987), the TPACK model (Koehler & Mishra, 2009), the MKT model (Ball et al., 2008), the DMK model (Godino, 2009), and the MTSK model (Carrillo et al., 2013). Besides, they are largely in line with available frameworks at the international level (see AAMT, 2006; Department for Education, 2011; Erebus International, 2008; GTCNI, 2011; GTCS, 2012; Lohmar & Eckhardt, 2013; NCATE, 2008; NCTM; 2012; Welsh Government, 2011; Wu, 2014). Additionally, during the consultation process, most experts highlighted the quality of the competence framework as well as its significance to initial teacher education and teaching practice. Experts described the framework as interesting, comprehensive, clear, coherent, and consistent. Only two participants indicated it was excessively long and pointed out the fact that some competences could distract teachers from their core activities.

Modifications in competences were consistently evaluated and approved of by the monitor team based on their professional judgment. Only 4 competences of the 32 initially proposed, did not reach consensus (see Table 3.4). Although these competences received lower ratings during the validation process, the monitor team did not find a logical explanation for their exclusion. Below, the reasons to keep each of them are explained.

The first debatable competence refers to teachers' ability to explain the impact on students of the strategies adopted for learning mathematics (TLP2). Analysis of teaching practice allows teachers to identify areas in which their instruction is (or not) successful and, consequently, improve their practice. However, it seems experts participating in the study considered this competence of lesser importance (only 66.7%, 65.4%, and 56.5% of ratings at level 4 or higher in the respective rounds). This is strange given the strong rationale from the academic literature. To begin with, this competence is directly related to the *reflection* process of Shulman's (1987) *model of pedagogical reasoning and action* and to the *knowledge of content and teaching* (KCT) subdomain within the MKT model (Ball et al., 2008). Regarding the international overview, this competence appears in all analyzed frameworks (see Table 3.1). At the same time, a growing body of research studies has also stressed this competence as all-important for effective teaching (see Morris et al., 2009; Yeh & Santagata, 2015). In particular, in mathematics education, the extent to which mathematics teachers recognize, deal with, and engage in teaching reflection has been referred to as *teaching noticing* (Jacobs, Lamb, & Phillip, 2010).

According to these authors, teachers' ability to analyze and learn from their own practice provides benefits for both students and teachers, linked to rich instructional environments, gains in students' achievement, or advantages in teachers' professional development. Notwithstanding, the result obtained during the validation process in relation to this competence is consistent with previous studies. Also Black (2015) observed that mathematics teachers encounter more difficulties in this domain by stating that they see fewer alternative or creative solutions to tackle learning and teaching strategies in their classes. One possible explanation to this observation is that experts consider this competence is to be developed during continuous professional development, instead of during initial teacher education. Even supposing that it is unrealistic to expect student teachers to act as expert teachers by the end of their initial education, they should acquire, during their initial education, the knowledge, skills, and attitudes that would enable them to reflect on their own practice (Hiebert, Morris, Berk, & Jansen, 2007).

The second not completely validated competence is related to classroom management. More specifically, it says: enforce rules and routines of behavior in classroom practice during mathematics lessons, in accordance with the school behavior policy (CM1). Experts justified their low ratings (76.2%, 61.5%, and 56.5% of ratings at level 4 or higher in the respective rounds) by stressing this competence does not align with the job of mathematics teachers. However, in the opinion of the research team, this is a wrong interpretation. Classroom management competences are applicable to teachers at all subject-matter areas and grade levels (Brophy, 2006). Indeed, mathematics student teachers usually find classroom behavior management challenging at the beginning of their teaching practice (see Goh & Matthews, 2011; Nkhata, Chituta, Banda, Choobe, & Jumbe, 2016). Within the Spanish context, García-Longoria and Blanco (2005) conducted a study to determine the major difficulties that novice teachers encounter when entering the teaching profession. Around 35% of the participants – including mathematics novice teachers – reported fearing disciplinary problems in classroom. These authors explain initial teacher education programs are largely responsible for this problem. Regarding this competence, it is also possible that the experts involved in the Delphi method adopted a too narrow and dated conception of classroom management by stressing discipline, rules, and authority. Emmer and Stough (2001) clearly state classroom management goes beyond this dimension and comprises all strategies and approaches fostering a conducive learning environment to attain the learning objectives.

The third debatable competence – know the curriculum framework in force in Spain, identify its different elements and its application in the area of mathematics in secondary education (LP2) – belongs to the lesson planning cluster. This competence is linked to Shulman's (1986) notion of *curricular knowledge*, later on adopted by the MKT model (Ball et al., 2008). However, after the overall consultation process, experts did not reach consensus on the definition of this competence (66.7%, 69.2%, and 60.9% of ratings at level 4 or higher in the respective rounds). Previous research agreed a focus on curriculum knowledge is often weaker in the mathematics domain, where content knowledge dominates teaching approaches (Speer, King, & Howell, 2015). One reasonable explanation behind this finding lies in the regional nature of the competitive examination system that regulates secondary mathematics teachers recruitment. In this sense, experts may think that the curricular elements vary across autonomous communities and, therefore, this competence is not full responsibility of initial teacher education programs. The graduate teacher should know the curriculum in force in the autonomous community where (s)he aims at being recruited. Notwithstanding, curricular knowledge contributes to instructional quality (Hill & Charalambous, 2012). So this competence is still of importance at the initial teacher education level.

Lastly, there is a lack of consensus (66.7%, 65.4%, and 69.6% of ratings at level 4 or higher in the respective round) in relation to the competence about inclusive education: know when and about which aspects to seek support and to cooperate with specialized supporting staff for students with specific educational needs (ID3). Previous findings also point out that middle- and high-school mathematics teachers and pre-service teachers have limited understanding of students' educational needs in an inclusive setting, and that initial education programs hardly help them meeting this competence (Echeita & Pérez, 2010; Van Reusen, Shoho, & Barker, 2000). However, this raises concerns. Absence of sustained experiences during initial teacher education may weaken student teachers' attitudes towards inclusion and diversity (Sosu, Mtika, & Colucci-Gray, 2010). On the other hand, inclusion and coping with diversity build on competences that belong to an interrelated cyclic process: identifying students with specific educational needs (ID1), cooperating with specialized supporting staff to seek advice about students with specific educational needs (ID3), and adapting teaching in view of students' needs (ID2). It is expected from teachers to seek the support of specialized supporting staff, in order to adequately assist students with special educational needs. Especially because of its key position in the cyclic process, the monitor team still considers this competence as relevant to be included in the final version of the competence framework.

At this point, some limitations have to be discussed. The validated competence framework does not include benchmark information specifying mastery levels in regard of pre- or in-service teachers' assessment. As mentioned before, such lack is a common international feature. Only few countries have already moved forward to the definition of benchmark levels determining the extent to which teaching competences should be mastered (Erebus International, 2008; Quality Assurance Agency for Higher Education, 2000). In this sense, this study was limited to undertake the first essential step in developing teaching competences and professional standards (as established by Kleinhenz & Ingvarson, 2007). The previous framework should now be used as a starting point for determining how competences should be measured and the extent to which they should be achieved (i.e., benchmark levels).

A second limitation builds on the fact that teaching practice depends on particular educational contexts. In this sense, the validated competence framework reflects priorities outlined for secondary mathematics student teachers in Spain. Nevertheless, it may serve as a foundation for the international research community, in view of developing teaching competence frameworks at other specific disciplines, educational levels, and/or national or regional contexts.

Some implications and directions for future research were linked to the results of this study. Building on the previous framework, a nationwide study was set up to analyze the extent to which these competences are actually pursued and attained in initial education programs for future secondary mathematics teachers in Spain (see Chapter 5). A multi-actor perspective was adopted, involving student teachers, teacher educators, mentors, and recently graduate teachers in mathematics at secondary education level. Special attention was paid to the four debatable competences. To this end, a research instrument to assess teaching competences was first designed and validated (see Chapter 4). The findings of the competence assessment study helped identifying critical competences mastered below a predefined level. This outcome provided avenues to the development of support trajectories in view of the improvement of such competences. This problem is tackled in Chapter 6.

CHAPTER 4

Design and validation of an instrument to assess future secondary mathematics teachers' knowledge and competences

Up to here, this dissertation aimed at conceptualizing future secondary mathematics teachers' knowledge and competences. This is significant taking into account the relevance of both factors on student achievement and their relation with initial teacher education programs. This chapter presents the results of a pilot study which purpose was to design and validate an instrument to assess future secondary mathematics teachers' subject-matter knowledge and competences. To this end, an online survey was conducted by 51 recently graduate mathematics teachers in the MDTTSE. The results support the validity of the instrument in view of future research. Further, the statistical analysis provides a preceding evaluation of initial education programs for future secondary mathematics teachers in Spain. These findings allowed to identify deficiencies in certain areas of future teachers' mathematical knowledge and critical competences weakly pursued and attained during initial teacher education. Implications and directions for future research are discussed.

This chapter is based on: Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2016). Are future mathematics teachers ready for the profession? A pilot study in the Spanish framework. *Procedia – Social and Behavioral Sciences, 16*, 735-745. doi: 10.15405/epsbs.2016.11.76

4.1 Introduction

Ensuring competent teachers are recruited for the teaching profession is a primary goal for policymakers and educational leaders. Today's society does not only require teachers to demonstrate specific subject-matter content knowledge, but also to know and understand the factors influencing the learning process; to develop and implement learning environments in the classroom, by making use of information and communication technologies; to be aware of students' background, prior knowledge, educational needs, and social or cultural contexts; to engage and motivate students; to ensure a favorable classroom environment; to assess learning and report students' progress, by building reliable relationships with students, parents, and colleagues; to be a team player in the school context, an innovator, a researcher, a lifelong learner. This is also the kind of teacher that initial teacher education programs strive for. As previously stated, this combination of knowledge, skills, and values is usually defined as teaching competences (European Commission, 2013). Although a large group of researchers have proved how teaching competences contribute to students' achievement (Hill et al., 2005), other research findings highlight that student teachers' practices are furthermore significantly influenced by other factors, such as their beliefs, environment, or identity (Korthagen, 2004). In this sense, initial teacher education programs are expected to qualify student teachers to perform effectively as teachers. In order to evaluate whether programs accomplish its goal, a valid assessment instrument to measure future teachers' knowledge and competences is deemed necessary.

In Spain, previous research relative to the assessment of the teaching competences supposed to be achieved during the MDTTSE can be divided between non-subject-matter and subject-matter studies. Non-subject-matter studies measure the extent to which core competences are developed regardless of the specialty, whereas subject-matter studies measure the level of development of specific competences focusing on a particular specialty, for instance, mathematics. Research instruments relative to non-subject-matter studies commonly build on the general competences established by the ministerial order that regulates the MDTTSE (see Buendía et al., 2011; García et al., 2011; Serrano & Pontes, 2015; Zagalaz et al., 2015). These studies are based on self-reported measures, i.e., data originate from student teachers' perception about the extent to which each competence is pursued and/or attained in the MDTTSE, building on a Likert scale. In few cases, teacher educators participate also in the study (see

Zagalaz et al., 2015). This approach easily permits the collection and analysis of data from big samples, despite validity problems of self-reported data. On the other hand, subject-matter studies measuring secondary mathematics student teachers' competences put forward a richer variety of research instruments. For instance, Font, Breda, and Sala (2015) designed a formative cycle for the evaluation of the competence in didactic analysis in mathematical instruction processes. This cycle consists of the analysis of written- and video-cases according to certain *suitability criteria* (Font & Godino, 2011). Similarly, Seckel and Font (2016) assessed student teachers' competence in teaching reflection through the analysis of a portfolio assignment and follow-up interviews. These studies involved rather small samples of student teachers performing actions while being observed and evaluated by one or two teacher educators. Measures based on observation and performance-based tasks are considered more valuable because they guarantee direct appraisals of complex competences (Messick, 1994). However, they are also time consuming, costly, and difficult to conduct by large and representative samples.

In particular, secondary mathematics student teachers' subject-matter knowledge has been scarcely researched within the Spanish context. This is due to the consecutive nature of initial teacher education, in which case the subject-matter knowledge has been pursued before entering the MDTTSE. However, assuming that student teachers enter initial education with sound mathematical knowledge is probably one of the major problems in our research context (Font, 2013). In the academic year 2011-2012, i.e., three years after the implementation of the MDTTSE, López et al. (2013) measured the mathematical knowledge of 33 secondary mathematics student teachers at the beginning of the MDTTSE. To that end, these authors designed a test consisting of 25 questions about mathematical contents relative to lower- and upper-secondary education level. The results show a lack of subject-matter content knowledge. But specially more worrying is that a large proportion of questions were not answered. Graduates are commonly reluctant to be evaluated because they fear revealing deficiencies in their mathematical content knowledge. Other available studies are more oriented to the assessment of mathematical pedagogical knowledge. For instance, Fernández et al. (2015) measured the competence of 25 secondary mathematics student teachers in understanding the process of learning mathematics. To that end, these authors designed a task in which participants had to anticipate students' responses that reflect different levels of conceptual understanding of the limit of a function. The findings of this study reveal two different ways of understanding of the limit concept, which has implications on the characteristics of the problems proposed to support students' learning. Besides, these authors highlight the challenge faced by teacher educators who have to design learning environments in the MDTTSE that enable student teachers to overcome certain conceptions about learning. Note that the sample size of both studies was relatively small.

Previous research has also investigated other factors influencing student teachers' initial education as they perform the MDTTSE, such as their beliefs and attitudes towards mathematics, their emotions, or their motivation for teaching. For instance, Costillo et al. (2013) compared student teachers' emotions in the different science subjects of secondary education with regard to their emotions as secondary education students. Overall, participants showed positive emotions in the subjects related to their specialty and negative in the rest. With regard to the assessment of student teachers' beliefs towards mathematics, a number of studies explain how previous experiences and education significantly influence student teachers' beliefs on problem solving (Giné & Deulofeu, 2014), inquiry-based learning (Abril, Ariza, Quesada, & García, 2014), or assessment (Pontes, Poyato, & Oliva, 2016). In the motivation related context, literature is scarce at the national level.

The general purpose of this dissertation is to evaluate whether the MDTTSE provides secondary mathematics student teachers with the necessary competences to perform effectively as teachers. To this end, this study aimed at designing and validating an instrument to measure, on the one hand, the mathematical knowledge of those who enter into an initial teacher education program in Spain and, on the other hand, the extent to which teaching competences are pursued and attained in the MDTTSE, focusing on the mathematics specialty. Attention was also paid to future teachers' motivation for teaching mathematics. The instrument was designed building on available reliable measures, and subsequently validated by means of a pilot study. The findings of this study made a significant contribution to this dissertation in view of subsequent studies. Moreover, this study tried to tackle the scarcity of nationwide subject-matter research relative to the assessment of the knowledge and teaching competences of future secondary mathematics teachers.

4.2 Theoretical framework

According to Kleinhenz and Ingvarson (2007), a second step in developing teaching competences and professional standards lies in deciding how competences should be measured. Such measures are important because they can provide information about levels of pursuance and achievement of teaching competences in initial teacher education programs, they can raise student teachers' awareness of the need to improve specific competences, they support the development of timely interventions to improve teaching, and they play a leading role in the assessment and quality assurance of initial teacher education programs (Darling-Hammond, Newton, & Wei, 2010; European Commission, 2013). However, up to now, no conventional measurement system has been internationally adopted.

In the academic literature, there is a rich variety of techniques and tools currently employed in measuring future teachers' knowledge and competences. In general, two types of approaches can be distinguished: direct measurement methods (such as classroom observations, video analysis, or written-portfolios) and indirect measurement methods, which typically rely on the perception of student or graduate teachers or teacher educators about the knowledge or competences of those who complete an initial teacher education program. Both approaches conform and differ in several aspects. Regardless of the method used, the measurement of teachers' knowledge and competences is based upon a competence framework – established by the national educational curricula of initial teacher education programs or by the researchers themselves – which reflects a common understanding about what is being measured (European Commission, 2013). Such framework is broken down into several indicators so that they shape a research instrument to measure future teachers' knowledge and competences. These instruments can be later used by means of a survey (e.g., when measurement is based on self-assessment), a rubric (e.g., when using written-portfolios), or an action framework (e.g., when analyzing classroom observations).

At the same time, methodological differences exist between direct and indirect measurement methods. The characteristics of the context and the purpose(s) of the research study largely determine which measurement system is more appropriate (Darling-Hammond & Snyder, 2000). When choosing a measurement system, some key issues ought to be taken into account:

- **Validity.** Direct methods are considered more valuable because knowledge and competence measurement is based on the analysis of directly performed actions or reflections (Darling-Hammond & Snyder, 2000). In this sense, many authors remain reluctant to indirect measurement methods due to their inherent validity problems.

Perceptions tend to under- or over-estimate knowledge and competences and respond to socially desirable answers (Zlatkin-Troitschanskaia et al., 2015). Notwithstanding, previous research has found significant correlations between future teachers' perceptions and their sense of self-efficacy, which is itself correlated with students' achievement (Darling-Hammond et al., 2010). Direct measurement methods can also encounter validity problems. Darling-Hammond and Snyder (2010, p. 528) explain that "two people looking at the same evidence base might draw entirely different conclusions about its meaning if they have different levels or kinds of expertise or if they are applying different expectations for what constitutes a good or competent performance" (see also Goe & Croft, 2009; Kersting, 2008). In this sense, performance measurement is only reliable when it has been assessed by individuals with relevant expertise.

- **Generic versus specific knowledge and competences.** Direct methods are generally used to measure a limited number of specific knowledge domains or competences and, commonly, under determined circumstances. Because student teachers' performance may vary across teaching situations, results based on direct measures cannot be used to draw generalizations (Darling-Hammond & Snyder, 2000). In this sense, indirect methods allow to measure a larger number of knowledge or competence indicators, regardless of specific settings.

- **Sample size.** One major weakness of studies using direct measurement methods is the small number of participants involved, which prompts questions about the representativeness of the sample (see Dotger et al., 2016 when exploring iconic interpretation through clinical simulations). Indirect measurement methods, usually employed in survey studies, have the ability to reach larger number of participants (Blanton, Sindelar, & Correa, 2006; Darling-Hammond, Eiler, & Marcus, 2002).

- **Resources and time consumption.** The multiplicity and amount of data gathered through some direct measurement methods, such as written-portfolios, can be both potential and critical (Darling-Hammond & Snyder, 2000). For instance, using a classroom observation measure for evaluation is rather costly in terms of personnel (Goe & Croft, 2009). Besides, qualitative data usually require long periods of time for the analysis. Studies using indirect measurement methods allow to collect and analyze data in an efficient and cost-effective way (Blanton et al., 2006). This is of special importance in view of longitudinal studies which aim at detecting trends in future teachers' subject-matter knowledge and competences over time (Darling-Hammond et al., 2002).

International assessment studies also provide potential instruments for subsequent research. In the context of initial teacher education, the TEDS-M measured the mathematical content knowledge, the mathematical pedagogical content knowledge, and the beliefs about mathematics teaching and learning of future primary and lower-secondary mathematics teachers (Tatto et al., 2012). This survey study was driven by the International Association for the Evaluation of Educational Achievement (IEA) and conducted in 2008 in a set of 17 countries, including Spain. The TEDS-M research team designed a reliable instrument that can be adapted and improved for use on subsequent teacher education studies. Such instrument was elaborated to gather information about multiple aspects related to initial teacher education programs through the perceptions of student teachers and teacher educators (i.e., indirect measures). However, the Spanish participation in the TEDS-M was limited to primary education because of special difficulties anticipated in collecting data from dispersed and difficult-to-reach future teachers in secondary education (Tatto et al., 2012).

As mentioned in the introduction, this research aimed at assessing the subject-matter knowledge and competences of future secondary mathematics teachers in Spain. To that end, the first step was to design and validate a measurement instrument. This study intended to scope a wide range of mathematical knowledge domains and teaching competences, using a national, representative sample, in a cost-efficient way. This explains why an indirect measurement system was chosen. Thus, the research instrument was elaborated in view of a subsequent survey study that analyzed the perception of student teachers, teacher educators, mentors, and recently graduate teachers about the extent to which professional teaching competences are pursued and attained during initial education programs. The use of a multi-actor perspective attempted to address the validity problems of self-reported data. Some items, already described and validated in the TEDS-M were taken into account (Brese & Tatto, 2012). Although previous research has mainly focused on future teachers' cognitive outcomes, i.e., subject-matter knowledge and competences, the measurement of future teachers' motivation for teaching is equally relevant and complex (Zlatkin-Troitschanskaia et al., 2015). Thus, in line with the TEDS-M, this dissertation aimed also at exploring future teachers' motivation for teaching mathematics. This research can be therefore understood as an extension of the TEDS-M within the Spanish context at the secondary education level.

4.3 Methodology

Building on the competence framework designed in an earlier stage of this research (see Chapter 3) and taking into account some of the TEDS-M items that measured future teachers' knowledge and motivation for teaching mathematics (see Brese & Tatto, 2012), a data collection instrument was first designed. Next, a pilot study was conducted in order to explore the validity of the instrument. In this section, information about the sample, the instrument, and the data collection and analysis procedure is presented.

4.3.1 Sample

All recently graduate secondary mathematics teachers in Spain (i.e., those who received a degree on completing the MDTTSE in mathematics since its implementation in the academic year 2009-2010) represented the target population of this pilot study. Taking into account the difficulty to access to a database of the population being studied (see page 31 of this dissertation), a non-probability sampling technique was used. The research team got first in contact with a number of teacher educators of the MDTTSE in different Spanish universities. Some of them agreed to send by email the invitation to participate in the pilot study to recently graduate secondary mathematics teachers from their universities. Due to the data protection law, the teacher educators could not provide the contact data of the graduate teachers to the research team. Of the 205 invitations that the research team was aware that were sent, 51 recently graduate secondary mathematics teachers from 8 public Spanish universities[1] participated in the pilot study. The response rate – around 24.9% – was coherent for an online survey (Comley, 2000). The average age of the graduate secondary mathematics teachers participating in the pilot study was 30.82 years old (SD=5.47), ranging from 23 to 48 years old. The majority of the participants, 72.5%, were women.

[1]The graduate secondary mathematics teachers who participated in the pilot study belonged to the following Spanish universities: University of Cantabria, University of Extremadura, Jaume I University, University of Oviedo, Public University of Navarre, University of Santiago de Compostela, University of Valladolid, and University of Zaragoza.

4.3.2 Instrument

The research instrument consisted of three sections of questions (see Appendix B). The first section focused on demographic variables (age and sex), academic background (bachelor degree, marks in university, and mathematical background), initial teacher education program characteristics (university, academic year, specialty, and access route), motivation for teaching mathematics (reasons for becoming a mathematics teacher and future teaching intention), and teaching experience.

Participants' mathematical background was measured using 19 items about mathematics topics representing four different domains: discrete structures and logic, geometry, continuity and functions, and probability and statistics. Because mathematical knowledge is supposed to be acquired before initial teacher education, respondents were asked to check a box indicating whether they had ever studied each topic prior to the MDTTSE. These items were taken from the TEDS-M instrument (Brese & Tatto, 2012).

Motivation for teaching mathematics was first explored through a list of 6 reasons people might have for becoming a mathematics teacher. These reasons can be classified in two groups: internal or vocational reasons (such as talent for teaching, working with young people, or teaching as a challenging job), and external or professional reasons (such as teacher salaries or long-term job security). Each reason was considered as an independent variable. Participants' were asked to identify those that had been a significant or major reason for them, using a seven-point Likert scale from (1) *An extremely minor reason* to (7) *An extremely major reason*. Participants' perception about their future in the teaching profession was used as an alternative measure of their motivation. An analogous seven-point Likert scale – from (1) *I will probably not seek employment as a teacher* to (7) *I expect it to be my lifetime career* – was used. These items were adapted from the TEDS-M instrument (Brese & Tatto, 2012).

The second section of the instrument aimed at measuring participants' perceptions about the competences for teaching mathematics in secondary education. Items were based on the framework of thirty-three competences designed and validated in an earlier stage of this research (Muñiz-Rodríguez, Alonso, Rodríguez-Muñiz, & Valcke, 2015b; Muñiz-Rodríguez, Alonso, Rodríguez-Muñiz, & Valcke, 2017). Each competence was presented as a statement and participants were invited to indicate:

- the importance of each competence for the teaching profession as a secondary mathematics teacher;
- the extent to which each competence is pursued/covered during the MDTTSE; and
- the extent to which each competence is attained/mastered by the time student teachers graduate.

The scale relative to the importance of each competence was employed as a complementary measure to explore the adequacy of the designed and validated framework from an alternative point of view (the one of graduate teachers). Special attention was paid to the four *debatable competences* (see Chapter 3). Once again, a seven-point Likert scale – from (1) *To an extremely small extent* to (7) *To an extremely large extent* – was employed.

The third and last section of the instrument included one open-question concerning the opinion of participants about the survey, this is: adequacy of the questions, wording mistakes that disrupt comprehension, response time, among other difficulties that might have arisen during the survey. Answers to these questions provided valuable feedback in view of the validation and improvement of the instrument.

4.3.3 Procedure for the data collection and analysis

Data collection took place from October to December 2015. An online survey was designed, administered, and conducted via LimeSurvey®. The link to participate was individually sent via email. Respondents were requested to indicate their informed consent when submitting their replies. The questionnaire took about fifteen minutes to fill out. A reminder was sent two weeks after the initial email.

Data analysis was performed using SPSS® (version 24). The psychometric properties of the instrument were screened by calculating Cronbach's alpha values. Statistical analysis was also performed in order to make a preceding evaluation of the MDTTSE in the mathematics specialty. Answers to the last question were managed using Weft QDA©. Items were modified according to the results of the data analysis.

4.4 Results

This section is structured by looking first at the results of the psychometric analysis. Next, the descriptive statistics for the different variables are presented.

4.4.1 Quality of the research instrument

The questions of the first section were mainly derived from the TEDS-M survey (Brese & Tatto, 2012), reflecting good validity and reliability. The items relative to the competence assessment built on the competence framework validated by experts in a previous phase (see Chapter 3). On the base of the pilot study, the results of the psychometric analysis indicated high reliability of the three perception scales: importance (Cronbach's $\alpha = .955$), level of pursuance (Cronbach's $\alpha = .973$), and level of attainment (Cronbach's $\alpha = .977$). Responses to the last survey question showed all items to be clear, consistent with the MDTTSE curriculum, and fit to be answered. Notwithstanding, some indications for improvement were also suggested. For instance, participants recommended to include a more detailed description of the indicators used to measure the mathematical background.

4.4.2 Graduate secondary mathematics teachers' academic background

In total, 98% of the participants entered into the MDTTSE holding a direct admission bachelor degree. However, data reflected a rather heterogeneous academic background: mathematics (n_1=22), a wide range of engineering degrees (n_2=21), business administration and management (n_3=3), chemistry (n_4=3), architecture (n_5=1), and statistics (n_6=1).

The majority of participants indicated their average marks in university were either *pass* or *remarkable* (56.9% and 37.2%, respectively). Only two participants ranked their academic achievement in university as *outstanding*.

Table 4.1 shows the percentage of graduate teachers who had studied each mathematics topic before entering into the MDTTSE in mathematics. Around half of the topics were studied by more than 80% of the participants before entering the MDTTSE, but the percentage of respondents who acknowledged having studied the other half of the topics ranged between 60.8% and 76.5%.

Table 4.1. Graduate secondary mathematics teachers' mathematical background.

Domain	Mathematics topic	Percentage
Discrete structures and logic	Numbers and operations	96.1%
	Lineal algebra	98.0%
	Set theory	74.5%
	Abstract algebra	60.8%
	Discrete or applied mathematics	76.5%
	Mathematical logic	68.6%
Geometry	Foundations of geometry or axiomatic geometry	72.5%
	Analytic or coordinate geometry	98.0%
	Non-euclidean geometry	72.5%
	Differential geometry	74.5%
	Topology	70.6%
Continuity and functions	Introduction to calculus	100.0%
	Calculus	100.0%
	Multivariate calculus	98.0%
	Advanced calculus, real analysis, measure theory	66.7%
	Differential equations	94.1%
	Complex functions or functional analysis	80.4%
Probability and statistics	Probability	94.1%
	Theoretical or applied statistics	96.1%

The next step was to analyze whether participants' bachelor degree was associated with the mathematics topics they studied before entering into the MDTTSE in mathematics. To this end, the bachelor degrees were classified into three groups: mathematics, engineering, and other. Similarly, mathematics topics were aggregated for each knowledge domain: discrete structures and logic, geometry, continuity and functions, and probability and statistics. Next, a new categorical variable was computed indicating the adequacy of the number of studied topics in each knowledge domain. Mastery learning research was taken into account (Zimmerman & Dibenedetto, 2008). Thereby, the mathematical background in each domain was considered as inadequate if less than 80% of the topics were studied, adequate if 80% of the topics were studied, and optimal if 100% of the topics were studied (always considering rounded quantities). The clustered bar charts suggest that there is a strong association between the bachelor degree and the mathematics studied by graduate secondary mathematics teachers before entering into the MDTTSE (see Figure 4.1), except for the probability and statistics domain (this difference is discussed in the next section).

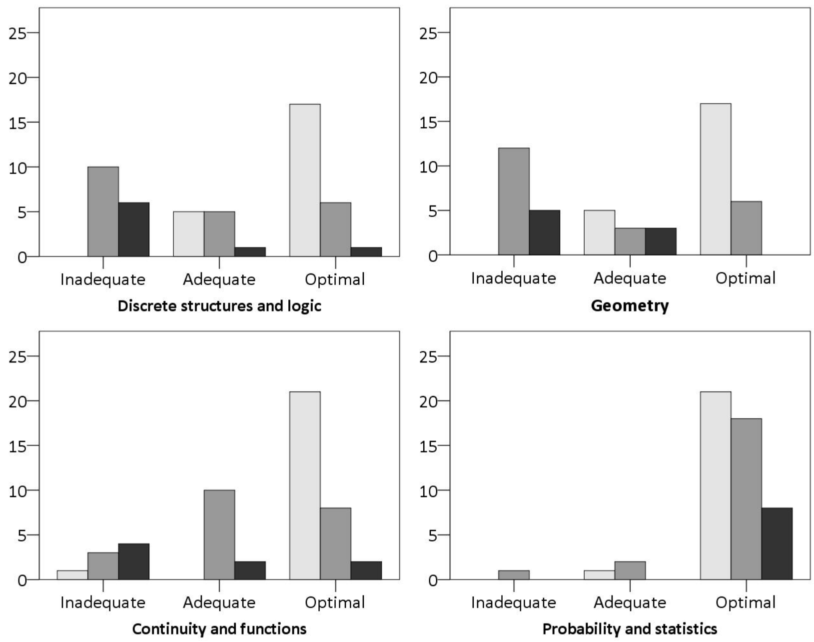

Figure 4.1. Adequacy of the number of studied mathematics topics according to the bachelor degree: mathematics (light gray), engineering (dark grey), or other (black).

4.4.3 Graduate secondary mathematics teachers' motivation for teaching mathematics

With regard to graduate teachers' motivation for teaching mathematics, *I love mathematics* was the most important reason for becoming a secondary mathematics teacher. On average, internal or vocational reasons, such as having a talent for teaching or working with young people, were selected most by the participants, rather than external or professional reasons, such as being attracted by teacher salaries or seeking the long-term security associated with the teaching profession. Seeing teaching as a challenging job was mainly selected as a moderate reason by a major proportion of the graduate secondary mathematics teachers participating in the pilot study (see Figure 4.2).

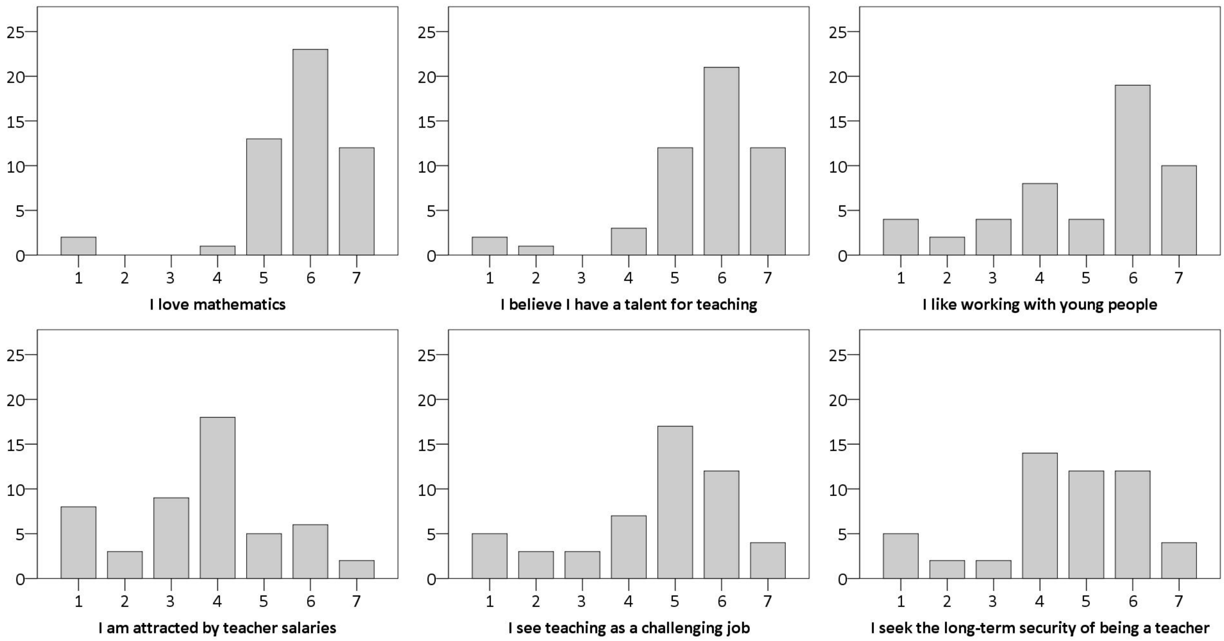

Figure 4.2. Graduate teachers' reasons for becoming a secondary mathematics teacher.

Regarding participants' perception about their future in the mathematics teaching profession, nearly 14% of the responses were lower than or equal to 3, and around 25.5% answered either 4 or 5. On the other hand, about 60.5% expected being in the teaching profession for a long time with ratings between 6 and 7. The majority of participants, 78.4%, were not working or had never worked as a secondary mathematics teacher after finishing the MDTTSE.

4.4.4 Graduate secondary mathematics teachers' perception about the competences for teaching mathematics in secondary education

Mean values from participants' perception about the importance of the set of teaching competences ranged from 5.02 to 6.33 on the seven-point Likert scale (see Table 4.2). The most important domain according to the graduate secondary mathematics teachers was *mathematical pedagogical knowledge* as opposed to *contribution to school organization* with the lowest mean value.

With a minimum of 3.31 and a maximum of 5.14, participants reported most competences were not intensively pursued during the MDTTSE (see Table 4.2). The competence domains *contribution to school organization* or *assessment and mentoring* seemed to be mostly overlooked, as opposed to *lesson planning* reported as the competence domain pursued to the largest extent.

Similar results were obtained regarding the attainment level of each competence, with mean values ranging from 3.55 to 5.04 (see Table 4.2). The three least attained competence domains were *contribution to school organization*, *assessment and mentoring* and *mathematical content knowledge*, whereas *lesson planning* seemed to be attained to the highest extent.

Table 4.2. Graduate teachers' perceptions about competences' importance, pursuance and attainment level.

	Importance	**Pursuance**	**Attainment**
Competence	M (SD)	M (SD)	M (SD)
MCK1	6.00 (1.08)	3.96 (1.44)	4.02 (1.52)
MCK2	5.24 (1.27)	3.75 (1.41)	3.76 (1.49)
MPK1	6.22 (1.08)	4.16 (1.54)	4.12 (1.40)
MPK2	6.33 (0.89)	4.20 (1.54)	4.47 (1.64)
MPK3	6.20 (0.96)	4.29 (1.59)	4.47 (1.52)
MPK4	5.45 (1.24)	3.90 (1.63)	3.96 (1.54)
TLP1	5.92 (1.16)	4.39 (1.55)	4.41 (1.46)
TLP2	5.24 (1.18)	3.63 (1.40)	3.63 (1.36)
TLP3	5.73 (1.23)	4.43 (1.70)	4.45 (1.54)
TLP4	5.27 (1.06)	4.10 (1.30)	4.20 (1.27)
CM1	5.47 (1.16)	3.73 (1.60)	4.04 (1.57)
CM2	6.24 (1.14)	4.12 (1.72)	4.33 (1.72)
CM3	5.29 (1.36)	3.78 (1.58)	3.94 (1.69)
CM4	5.84 (1.07)	3.94 (1.50)	4.02 (1.44)
LP1	5.82 (1.09)	4.67 (1.58)	4.67 (1.51)
LP2	5.49 (1.21)	5.14 (1.40)	5.04 (1.39)
LP3	5.45 (1.22)	3.76 (1.54)	4.10 (1.69)
AM1	5.69 (1.27)	4.06 (1.54)	4.08 (1.50)
AM2	5.76 (1.21)	3.75 (1.50)	3.86 (1.43)

Table 4.2 *Continued.*

AM3	5.67 (1.09)	3.57 (1.58)	3.73 (1.48)
DP1	5.96 (1.04)	4.31 (1.44)	4.47 (1.43)
DP2	5.78 (1.08)	4.65 (1.31)	4.51 (1.43)
DP3	5.75 (1.00)	4.22 (1.42)	4.14 (1.47)
ID1	6.20 (0.75)	4.12 (1.61)	3.92 (1.50)
ID2	5.84 (1.03)	4.00 (1.70)	4.02 (1.59)
ID3	5.80 (0.85)	3.94 (1.79)	3.88 (1.75)
TK1	5.63 (1.06)	4.51 (1.55)	4.57 (1.40)
CS1	5.57 (1.04)	3.96 (1.66)	4.04 (1.54)
CSO2	5.02 (1.21)	3.65 (1.59)	3.88 (1.52)
CSO3	5.25 (1.21)	3.31 (1.58)	3.55 (1.53)
PC1	6.16 (1.12)	4.10 (1.51)	4.45 (1.63)
PC2	5.92 (0.98)	4.00 (1.55)	4.35 (1.61)
PC3	5.71 (0.94)	3.53 (1.52)	4.04 (1.79)

Note: M = Mean. SD = Standard Deviation.

4.5 Discussion

Within the Spanish context, previous research on the assessment of future secondary mathematics teachers' subject-matter knowledge and competences was mostly conducted regardless of the specialty or considering very specific knowledge domains or competences. This study aimed at designing and validating an instrument to measure, on the one hand, the mathematical background of those who enter into an initial teacher education program in Spain, and, on the other hand, the extent to which teaching competences are pursued and attained during the MDTTSE, focusing on the mathematics specialty.

The results of this pilot study support the validity and reliability of the designed instrument, which can be used in future research to evaluate whether the MDTTSE provides secondary mathematics student teachers with the necessary competences to perform effectively as teachers. In particular, this instrument helps to identify deficiencies in certain areas of future teachers' mathematical knowledge and critical competences weakly pursued and attained during initial teacher education. Next to a focus on cognitive outcomes, future teachers' motivation for teaching mathematics in secondary education can be also examined by means of this research instrument.

Most of the recently graduate secondary mathematics teachers participating in the pilot study were women. This was also observed in the TEDS-M where most future teachers in primary and secondary education were females, both in Spain and in many other participant countries (Tatto et al., 2012). Dispersion in recently graduate teachers' age is explained by the set of different cohorts involved in the study.

Although a large proportion of participants hold a bachelor degree in mathematics or engineering, the academic background of future secondary mathematics teachers seems very heterogeneous. This can be critical since mathematical training varies largely between bachelor degrees and universities (see page 36 of this dissertation). A concrete example can be found in the study of Díaz and Marbán (2016) who discussed the mathematical competence in the business administration and law degree.

Previous studies in the context of the MDTTSE in mathematics proved that there is no cause-effect relationship between the bachelor degree of future secondary mathematics teachers and their mathematical content knowledge (López et al., 2013). This dissertation intends to explore the mathematical background of the student teachers enrolled in the MDTTSE in mathematics, going beyond the name of their bachelor degree. The results of this pilot study question to what extent students entering into the MDTTSE in mathematics have a solid subject-matter knowledge. As shown in Table 4.1, around 40% of participants had never studied some mathematics topics, such as abstract algebra, advanced calculus, real analysis, or measure theory. In this sense, the nature and depth of mathematical knowledge that graduate secondary mathematics teachers need to demonstrate remains open to question. Notwithstanding, the general consensus of opinion is that the level of mathematical knowledge of a teacher must go beyond the content that (s)he teaches (Ernerst, 1989; Sultan & Artzt, 2011). Besides, the statistical analysis suggests that the nature of the bachelor degree influences the mathematical training received by those who enter into the MDTTSE in mathematics, except for the probability and statistics domain (see Figure 4.1). Analogous findings were obtained in the TEDS-M, where results also varied significantly depending on the admission policies from the programs concerned (Tatto et al., 2012). Due to limited mathematical content, some direct admission bachelor degrees appear not to be suitable to enter into the MDTTSE in mathematics.

As explained above, the results were less clear in the probability and statistics domain. The underlying cause of that difference lies in the generic nature of these topics. It is quite feasible all bachelor degrees – even those in the social sciences branch – cover in a rather broad sense content related to probability and theoretical or applied statistics. The way items are described hides possible differences between bachelor degrees curricula. This fact was also indicated by participants, who recommended to include a more detailed description of the indicators used to measure the mathematical background. Though these items were in line with the TEDS-M survey, these categories should be more specifically defined in view of future research (see Appendix D).

The results about graduate secondary mathematics teachers' motivation for teaching are also in line with the TEDS-M's findings (Tatto et al., 2012). Internal or vocational reasons overruled external reasons. This was also observed in previous research studies, revealing that graduates' teaching commitment is strongly related to their entrance in the teaching profession (Caires & Almeida, 2005; Rots, Aelterman, Vlerick, & Vermeulen, 2007). But, despite their motivation, respondents experienced difficulties to find a position as a secondary mathematics teacher after finishing the MDTTSE. This can be due to high unemployment rates during the last years in Spain.

The items of the instrument relative to the assessment of competences for teaching mathematics at secondary education level were based on the framework of thirty-three competences designed and validated in an earlier stage of the research carried out in the context of this dissertation (Muñiz-Rodríguez et al., 2015b; Muñiz-Rodríguez et al., 2017). All teaching competences were considered of importance by graduate secondary mathematics teachers. Also García et al. (2011) found that student teachers in the MDTTSE have a positive perception about the teaching competences established in the ministerial order that regulates initial teacher education programs in Spain (Ministerio de Educación y Ciencia, 2007). During the analysis, special attention was paid to the four *debatable competences* detected during the validation process of the competence framework (see Chapter 3), namely *be able to explain the impact on students of the strategies adopted for mathematical learning* (TLP2); *enforce rules and routines of behavior in classroom practice during mathematics lessons, in accordance with the school behavior policy* (CM1); *know the curriculum framework in force in Spain, identify its different elements and its application in the area of mathematics in secondary education* (LP2); and *know when and about which aspects to seek support and cooperate with specialized staff for students with specific educational needs* (ID3). Participants ratings for the four debatable competences support their relevance to be included in the competence framework (mean values on the seven-point Likert scale: 5.24, 5.47, 5.49, and 5.80, respectively).

The most critical finding of this pilot study was that, according to the perception of the participants, the teaching competences are weakly pursued and attained during the MDTTSE in mathematics. In particular, competences in the *mathematical content knowledge* cluster seem to be overlooked, next to those related to *contribution to school organization* and *assessment and mentoring*. These findings confirm those of previous non-subject matter studies indicating that student teachers consider teaching competences are not sufficiently pursued and attained during the MDTTSE (Buendía et al., 2011; García et al., 2011; Serrano & Pontes, 2015; Zagalaz et al., 2015).

A limitation of this study is the use of an indirect measurement system to explore subject-matter knowledge and teaching competences. It is difficult to say whether the former conclusions guarantee realistic appraisals. Notwithstanding, recently graduate secondary mathematics teachers' perceptions allowed us to gain insight into the MDTTSE in the mathematics specialty. In this sense, the study was not limited to graduate teachers from one specific initial teacher education program. Participants represented different Spanish universities. In the literature, a significant amount of valid studies have been conducted using this methodology approach (Alkharusi et al., 2011; Mohamed et al., 2016; Nkhata et al., 2016). In view of this dissertation, one major strength of the instrument is the possibility to analyze a significant number of teaching competences.

Some implications and directions for future research were linked to the conclusions of this pilot study. The validated instrument was next used in a nationwide survey study that analyzed whether the MDTTSE provides future teachers with the necessary competences to perform effectively as teachers (see Chapter 5). In order to reduce the bias from self-reported data, a multi-actor perspective was adopted. Thereby, the perceptions of student teachers, teacher educators, mentors, and recently graduate teachers about the extent to which professional teaching competences are pursued and attained during the MDTTSE in the mathematics specialty were analyzed. Attention was also paid to student and graduate teachers' subject-matter knowledge and motivation for teaching mathematics. The findings of this study helped identifying critical competences mastered below a desired level. This evoked the design, implementation, and evaluation of a competence development intervention, as explained in Chapter 6.

CHAPTER 5

Assessment of future secondary mathematics teachers' knowledge and competences

In Spain, the implementation of a new master diploma in secondary teacher education in 2009-2010 aimed at improving the quality of initial teacher education. The goal of the study described in this chapter was to assess whether the current initial teacher education program (i.e., the MDTTSE) achieved this purpose, focusing on mathematics education. In view of this, a nationwide study was set up. A multi-actor perspective was adopted to identify the perceptions of student teachers, teacher educators, mentors, and recently graduate teachers about the extent to which professional teaching competences are pursued and attained during initial teacher education programs in mathematics in Spain. Data were gathered through an online survey administered to 315 participants. The results reflect modest pursuance and attainment levels. Significant differences appear between groups. Stakeholders qualified the current initial teacher education program as moderately effective in view of preparing future secondary mathematics teachers. Implications and directions for future research are discussed.

This chapter is based on: Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2017). *Are initial teacher education programmes effective? A multi-actor perspective on mathematics student teachers' content knowledge and mastery of teaching competences.* Manuscript submitted for publication.

5.1 Introduction

During the last decades, changes in society have pushed an increasing number of reforms in mathematics teacher education, especially challenging teachers' knowledge and competences (Buchberger et al., 2000; Darling-Hammond, 2006; European Commission, 2013; Tatto et al., 2012). Previous research highlights that the quality of teachers is among the most powerful influences in learning (Hattie 2009; Rowan et al., 2002). International research about the quality of education has consequently turned to studying teacher education as an imperative factor (Darling-Hammond, 2000; Rice 2003). Critical performance indicators very often invoked a feedback loop starting up reforms about the nature and quality of teacher education (Erl, 2006; Kleickmann et al., 2013).

In Spain, initial teacher education has been a point of national concern as reflected in the series of reforms implemented during the last decades. Nine years ago, a new ministerial order introduced a major change in initial secondary teacher education in Spain (Ministerio de Educación y Ciencia, 2007). The former CAP was replaced by a one-year professional master program: the MDTTSE. Thereby, from the academic year 2009-2010 onward, the MDTTSE became a prerequisite for those seeking to enter the teaching profession. The main goal for its implementation was to improve teacher education quality, reducing the theory-practice gap, and strengthening the professional position of beginning teachers and their readiness to teach. The latter is doubtlessly the most significant characteristic of the current program (Santos & Lorenzo, 2015; Valdés & Bolívar, 2014).

Even so, available research shows how the reforms have not fully achieved their purpose (Santos & Lorenzo, 2015). A number of national studies have shown concern about the narrow subject-matter knowledge of student teachers (López et al., 2013; Muñiz-Rodríguez, Alonso, Fernández-Blanco, Rodríguez-Muñiz, & Valcke, 2015a), the management of the program (Manso & Martín, 2014; Valdés & Bolívar, 2014), the balance between the theoretical and the practical component (Manso & Martín, 2014), or the role of the practicum and the master thesis (García et al., 2011; Valle & Manso, 2011; Vilches & Gil-Pérez, 2010). However, little attention has been paid to the mastery of teaching competences resulting from the reformed initial teacher education program within the mathematics specialty.

Therefore, the main aim of this study was to examine the extent to which professional teaching competences are actually pursued and attained via the MDTTSE, focusing on the mathematics specialty. To this end, the perceptions of four groups of stakeholders – mathematics student teachers enrolled in the MDTTSE, mathematics teacher educators teaching in the MDTTSE, mentors supporting field experiences in secondary education schools, and recently graduate mathematics teachers in the MDTTSE – were analyzed. This multi-actor point of view provided a rich quality perspective. For this purpose, the research team built on a validated competence framework listing the professional teaching competences expected to be achieved by the time student teachers graduate (Muñiz-Rodríguez et al., 2015b; Muñiz-Rodríguez et al., 2017). This framework describes in a large way the kind of secondary mathematics teacher that initial education programs strive for. Thereby, this study contributed to an evaluation of the quality of initial teacher education in Spain. In addition, the profile of the four population groups was analyzed in order to have a grasp of initial teacher education reality in Spain. The development of the conceptual framework and research method was grounded in the Context Input Process Output (CIPO) model of Scheerens (1990, 2015). The methodology was based on an online quantitative survey, presenting three versions of a questionnaire, one for student and graduate teachers (see Appendix D), one for teacher educators (see Appendix E), and one for mentors (see Appendix F). The following research questions guided this study:

(RQ1) What is the profile of student teachers and recently graduate teachers enrolled in the MDTTSE in mathematics?

(RQ2) What level and depth of mathematics knowledge did student and recently graduate teachers attain before starting the MDTTSE in mathematics?

(RQ3) What is the profile of teacher educators teaching in the MDTTSE in mathematics?

(RQ4) What is the profile of mentors supporting field experiences in secondary education schools?

(RQ5) To what extent are teaching competences integrated into the curricula of the MDTTSE in mathematics?

(RQ6) To what extent does the MDTTSE train future secondary mathematics teachers towards the mastery of teaching competences?

(RQ7) How effective is the MDTTSE to prepare future secondary mathematics teachers for the teaching profession?

This study is, as far as the author of this dissertation knows, the first major exploratory nationwide study about secondary mathematics initial teacher education in Spain. The only available study in this domain – the TEDS-M – focused on future primary mathematics teachers, and was part of an international study (Tatto et al., 2012).

5.2 Theoretical framework

The main purpose of initial teacher education programs is the development of teaching competences, reflected in changes in student teachers' knowledge, skills, and attitudes (Buchberger et al., 2000; Darling-Hammond, 2006; Darling-Hammond et al., 2005). The extent to which initial teacher education programs accomplish their purpose is in turn influenced by a number of factors (Rico et al., 2003). Initial teacher education programs can easily be described in terms of the CIPO model (Scheerens, 1990, 2015). The CIPO model distinguishes four components that define education as a production system in which *inputs* are transferred into *outcomes* through a *process* influenced by a *context*. This model serves as an analytic framework to identify educational quality indicators (Cuyvers, 2002). Likewise, the quality of initial teacher education programs can be measured in terms of context-, input-, process-, and output-indicators. Recent research added a fifth element to meet the specific demands of teacher education – *succession* (S) – focusing on the importance of continuing professional development in teachers' career (Gheyssens, Struyven, Valcke, & Rots, 2014). Given the focus on the efficacy of initial teacher education, the current study did not consider this S-component. Below, the rationale behind the selection of each indicator is explained.

The *context* component concerns the policy, technological, demographic, or economic developments that influence education. In the context of this dissertation, the *context* was set by the ministerial order that regulates initial teacher education programs in Spain since the academic year 2009-2010 (Ministerio de Educación y Ciencia, 2007). Context-indicators originate from the elements established by this policy document, such as the structure or the admission requirements (see Chapter 2 for a detailed description).

The *input* component refers to the profile and knowledge characteristics of the individuals. In the context of this dissertation, the target population encompassed four stakeholder groups: mathematics student teachers enrolled in the MDTTSE, mathematics teacher educators teaching in the MDTTSE, mentors supporting field experiences in secondary education schools, and recently graduate mathematics teachers. Besides demographic characteristics, the literature stresses student and graduate teachers' academic background, as well as teacher educators and mentors' experience and expertise, as quality input-indicators of initial teacher education programs. Previous research explains how teachers' mathematical knowledge significantly influences their students' mathematical achievement (Campbell et al., 2014; Hill et al., 2005). This reinforces the emphasis on student and graduate teachers' subject-matter knowledge as a main factor. Besides, Montalvo and Gorgels (2013) found that student and graduate teachers' motivation for teaching mathematics has a significant influence on their mathematical knowledge. On the other hand, research points at experience and expertise as key factors in teacher educators and mentors' professionalization (Dengerink, Lunenberg, & Kools, 2015; Murray & Male, 2005).

The *process* component concerns the didactic and pedagogical activities, procedures or techniques that determine the transition of *inputs* into *outputs*. In the context of this dissertation, the *process* examined the opportunities student and recently graduate teachers have during the MDTTSE to develop professional teaching competences. Previous studies relied on the perceptions of student teachers and teacher educators about the level of development of professional teaching competences during initial teacher education programs as quality process-indicators (Bhargava & Pathy, 2011; Cubukcu, 2010; Gheyssens et al., 2014). In particular, Darling-Hammond et al. (2010) found significant correlations between future teachers' perceptions and their sense of self-efficacy, which is itself correlated with students' achievement. Process-indicators measuring teaching competences should be based upon a framework which reflects a common understanding about the competences student teachers should master after completing their initial education (European Commission, 2013). Despite a long history of research, international consensus has yet not been achieved (see Chapter 3 for a review). In view of this study, a competence framework was designed and validated in an earlier stage (Muñiz-Rodríguez et al., 2015b; Muñiz-Rodríguez et al., 2017).

Although the structure of initial teacher education programs might vary among countries and universities, they commonly incorporate a theoretical and a practical component. In this sense, the development of professional teaching competences is influenced by both the theoretical courses and the field experiences. Darling-Hammond et al. (2005) emphasize that the stronger the linkage between the later components, the greater the impact of initial teacher education programs. Numerous studies stress how especially the practical experiences significantly influence future teachers' beliefs and personal mission (Caires, Almeida, & Vieira, 2012; Linden, Bakx, Ros, Beijaard, & Bergh, 2015; Rots, Kelchtermans, & Aelterman, 2012). Research focusing on the efficacy of initial teacher education therefore highlights this theory-practice connection and balance (Allen & Wright, 2013; Korthagen & Kessels, 1999; Goodnough, Falkenberg, & MacDonald, 2016). In an attempt to explore the theory-practice connection within the MDTTSE, some stakeholders explicitly reported the extent to which teaching competences are pursued, from the theoretical and the practical perspective.

The *output* component alludes the learning achievement in terms of acquired knowledge and competences. In the context of this dissertation, the *output* applied to the extent initial teacher education programs accomplish their purpose, i.e., the actual acquisition of the teaching competences (Buchberger et al., 2000; Darling-Hammond, 2006; Darling-Hammond et al., 2005). Thereby, a first output-indicator was the perception of student and graduate teachers about the level of attainment of the competences established in the framework. Very few research studies are available putting forward clear benchmarks in relation to the pursuance and attainment of competences (Valcke, Rots, Verbeke, & Van Braak, 2007). In this sense, teacher education is not different from many other competence domains, as described by Norris (1991, p. 331): "The trouble with competence". Building on mastery learning research, 80% was put forward to analyze whether perceived levels were in line with this benchmark (Zimmerman & Dibenedetto, 2008). Stakeholders' perception about the effectiveness of the MDTTSE to prepare future secondary mathematics teachers for the profession was used as an additional output-indicator.

The CIPO model set the stage for the empirical research about the quality of initial teacher education programs in Spain, with a particular focus on the assessment of future secondary mathematics teachers' subject-matter knowledge and teaching competences. The research design of this study was grounded on the aforementioned model and indicators, as explained in the following section.

5.3 Methodology

This section includes information about the sample, the instrument and the procedure for the data collection and analysis.

5.3.1 Sample

The sample consisted of four stakeholder groups: mathematics student teachers enrolled in the MDTTSE (n_1=95), mathematics teacher educators teaching in the MDTTSE (n_2=95), mentors supporting field experiences in secondary education schools (n_3=96), and recently graduate mathematics teachers in the MDTTSE (n_4=29). In total, 315 individuals participated voluntarily in the study. Due to difficulties in reaching stakeholders, a non-probability sampling technique was adopted in order to achieve a pre-set sample size (n=90). A comprehensive list of mathematics teacher educators teaching in the MDTTSE and secondary education schools involved in the practical component of the MDTTSE was obtained from universities websites. All of them were contacted by email to participate in the study. Besides, some of them agreed to send the invitation to secondary mathematics student teachers and recently graduate secondary mathematics teachers from their universities. It is to be stressed that little population information is available about the different stakeholders. The number of students enrolled in the MDTTSE in some universities is unknown or difficult to estimate (see page 31 of this dissertation). The reader notices recently graduate teachers in the MDTTSE represented the smallest subsample. Due to the data protection law, no direct contact information of these individuals could be obtained. Besides, not all universities gather this information about their students. This study intended to scope a nationwide representative sample. Student teachers, teacher educators, and recently graduate teachers participating in the study represent 47 of the 56 Spanish universities offering the mathematics specialty in the MDTTSE – 36 public and 11 private. In the case of mentors, participants represent a total of 86 secondary education schools in Spain – 79 public and 7 private. Appendix C provides a list of participant universities and secondary education schools.

5.3.2 Instrument

Data were gathered through an online survey presenting an adapted version of a questionnaire to each stakeholder group (see Appendix D, Appendix E, and Appendix F). Items were previously developed and validated in a pilot study conducted for the purpose of this research (see Chapter 4). As explained before, some items were adapted from the TEDS-M survey (Brese & Tatto, 2012). The CIPO model guided the structure and content of the questionnaires. Table 5.1 gives more details about the position of specific items in the online questionnaire.

Table 5.1. Input, process and output focus in the research instrument.

Component	**Research question**	**Questionnaire item(s)**
Input	RQ1	Age, gender, reason to become a teacher, future in the teaching profession, teaching experience
	RQ2	Bachelor degree, marks in university (i.e., average grade obtained in the bachelor degree), mathematical background
	RQ3 & RQ4	Gender, academic rank, years of experience, years of experience as teacher educator/mentor, specific training to be a teacher educator/mentor
Process	RQ5	To what extent are the teaching competences pursued – according to student and recently graduate teachers –, integrated – according to teacher educators –, or developed – according to mentors – in the MDTTSE?
Output	RQ6	To what extent – according to student teachers and recently graduate teachers – are the teaching competences attained during the MDTTSE?
	RQ7	To what extent – according to student teachers, teacher educators, mentors, and recently graduate teachers – is the MDTTSE effective?

In order to have a grasp of initial teacher education reality in Spain, the demographic characteristics (age and gender) of the four population groups were first analyzed.

Student and graduate teachers' mathematical background was measured using 22 items about mathematics topics representing four different domains: discrete structures and logic, geometry, continuity and functions, and probability and statistics. Because mathematical knowledge is supposed to be acquired before initial teacher education, respondents were asked to check a box indicating whether they had ever studied each topic prior to the MDTTSE. Motivation for teaching mathematics was first explored through a list of 6 reasons people might have for becoming a mathematics teacher. These reasons can be classified in two groups: internal or vocational reasons (such as talent for teaching, working with young people, or teaching as a challenging job), and external or professional reasons (such as teacher salaries or long-term job security). Participants were asked to identify those that had been a significant or major reason for them, using a seven-point Likert scale from (1) *An extremely minor reason* to (7) *An extremely major reason*. Participants' perception about their future in the teaching profession was used as an alternative measure of their motivation. An analogous seven-point Likert scale – from (1) *I will probably not seek employment as a teacher* to (7) *I expect it to be my lifetime career* – was used.

Teacher educators and mentors' experience and expertise were explored through three items were participants had to indicate the years of experience in the profession, the years of experience as a teacher educator or mentor, and whether they had ever received special preparation for training student teachers.

To assess the level of pursuance and the level of attainment of professional teaching competences, the questionnaire built on a framework of thirty-three competences (see Table 3.5). Respondents indicated – depending on their stakeholder perspective – the extent to which each competence was pursued (student and recently graduate teachers), actively integrated into the curriculum (teacher educators), or developed (mentors) during the MDTTSE. A seven-point Likert scale – from (1) *To an extremely small extent* to (7) *To an extremely large extent* – was employed.

Finally, a seven-point Likert scale – from (1) *Very ineffective* to (7) *Very effective* – was used to analyze the effectiveness of the MDTTSE to prepare future secondary mathematics teachers for the teaching profession from the point of view of the four stakeholder groups.

5.3.3 Procedure for the data collection and analysis

Data collection took place from February to May 2016. The online survey was designed, administered, and conducted via LimeSurvey®. Each questionnaire took about fifteen minutes to fill out. Respondents were requested to indicate their informed consent when submitting their replies. Anonymity and confidentiality among participants were also respected.

Data analysis was performed using SPSS® (version 24). Seven-point Likert scales were consistently used throughout the questionnaire (i.e., reason to become a teacher, future in the teaching profession, competence assessment, initial teacher education program effectiveness) helping to establish larger reliability and validity. Bachelor degrees were classified into three groups: mathematics, engineering, and other. Responses related to mathematics topics were aggregated for each knowledge domain: discrete structures and logic, geometry, continuity and functions, and probability and statistics. Questions about the thirty-three teaching competences were analyzed from the four different stakeholder perspectives. Based on the Likert scores, an average index was calculated for each cluster.

All responses were first examined through descriptive statistical analysis. Since not all assumptions as to normality of the data were met, non-parametric tests were used to determine if there were statistically significant differences between the stakeholder groups. A Mann-Whitney test helped comparing two independent samples. In the case more than two independent groups were compared, a Kruskal-Wallis test was used. A Wilcoxon signed-rank test was employed to compare two sets of scores from the same participants. A Chi-square test for independence was performed to discover whether there was a relationship between categorical variables. A significance level of $p < .05$ was used to interpret statistical analysis results. Building on mastery learning research, 80% was put forward to analyze whether perceived attainment levels were in line with this benchmark (Zimmerman & Dibenedetto, 2008).

5.4 Results

This section presents the results of the nationwide survey regarding the four stakeholder groups.

5.4.1 The profile of mathematics student and graduate teachers in the MDTTSE

The student teachers participating in the study were on average 29.35 years old (SD=7.33), and the recently graduate teachers were 31.28 years old (SD=8.38). Around 59% of the student teachers and 62% of the recently graduate teachers were female.

Table 5.2 summarizes student and recently graduate teachers' reasons to become a mathematics teacher. Overall, internal or vocational reasons prevailed over external or professional reasons. No statistically significant differences between groups were found.

Table 5.2. Student and recently graduated teachers' reasons to become a mathematics teacher.

Reason	**Student teachers M (SD)**	**Graduate teachers M (SD)**	**U**
I love mathematics	5.77 (1.11)	5.79 (1.24)	1341.5
I believe I have talent for teaching	5.68 (1.37)	5.86 (1.06)	1335.5
I like working with young people	5.43 (1.40)	5.52 (1.41)	1322.0
I am attracted by teacher salaries	3.98 (1.47)	3.72 (1.81)	1228.8
I see teaching as a challenging job	4.83 (1.65)	4.86 (1.81)	1345.0
I seek the long-term security associated with being a teacher	4.86 (1.62)	4.21 (2.01)	1144.0

Note: M = Mean. SD = Standard deviation. U = Statistic Mann-Whitney test.

Around 72% of both the student and the recently graduate teachers expected being a secondary mathematics teacher for a long time (score > 6). Around 24% of the participants reported a score between 4 and 5, and 4% of the responses were lower than or equal to 3 (see Figure 5.1). No statistically significant differences were found between both sample groups (U=1254.5, p=.438).

Until the moment of the survey, 92.6% of the student teachers and 55.2% of the graduate teachers had never worked as a secondary mathematics teacher. Of the 37.9% of

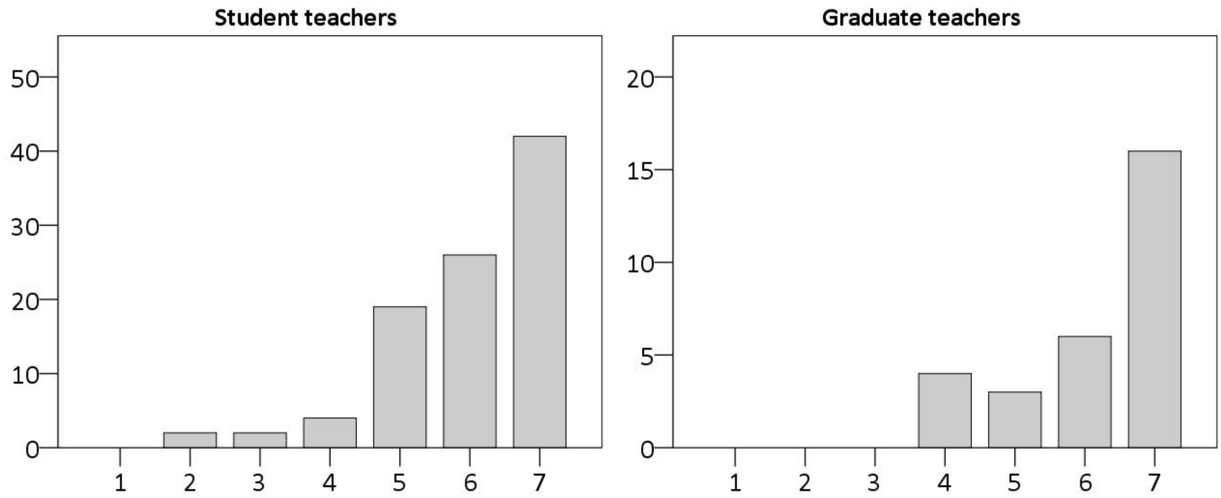

Figure 5.1. Student and graduate teachers' perception about their future in the teaching profession.

the graduates who got a position as secondary mathematics teacher after finishing their MDTTSE, 34.5% were working at the time of the survey and 3.4% were not.

5.4.2 The mathematical knowledge of mathematics student and graduate teachers in the MDTTSE

Most student and recently graduate teachers held a direct admission bachelor degree to enter into the MDTTSE (95.8% and 100%, respectively). Only 4.2% of the student teachers had to attend complementary mathematics courses. Although mathematics and statistics degrees were predominant, (53.7% and 62.1%, respectively), a variety of engineering degrees (such as agricultural, civil, forestry, industrial, mechanic, or telecommunications) played also a leading role (29.5% and 20.7%, respectively). Other degrees such as architecture, economy, physics, or chemistry were also present.

Most respondents reported their average marks in university were either *pass* (56.8% and 55.2%, respectively) or *remarkable* (37.9% and 41.4%, respectively). Low proportions of student and recently graduate teachers categorized their marks as *outstanding* (5.3% and 3.4%, respectively).

Regarding participants' mathematical background, all mathematics topics were studied only by at least 60% of the respondents (see Table 5.3). No statistically significant differences between student and graduate teachers' responses were found – except for *descriptive statistics* (p=.049[1]). On the other hand, statistically significant differences were detected between student teachers' bachelor degree (mathematics versus non-mathematics) and the number of mathematics topics studied before entering into the MDTTSE in mathematics (see Table 5.4)[2].

5.4.3 The profile of mathematics teacher educators teaching in the MDTTSE

Data showed a slightly larger proportion of male teacher educators (60%). The largest proportion of teacher educators was tenured with a PhD (65.3%) at full professor or associate professor level. Other teacher educators were tenured as lecturer, or got nontenured jobs as assistant professor or teaching assistant.

Average teaching experience was 23.49 years (SD=10.50) and 7.29 years (SD=7.25) as a mathematics teacher educator. Around 71.6% of respondents had never received special preparation for training student teachers. Within those receiving training, 23.1% did before and 5.3% after becoming a teacher educator.

5.4.4 The profile of mentors supporting field experiences in secondary education schools

A gender-balanced distribution of female (51%) and male (49%) mentors was obtained. Most mentors were themselves mathematics teachers in secondary education.

Average experience as a mathematics teacher was 22.67 years (SD=9.16) and 4.35 years (SD=5.61) as a mentor. A large proportion of mentors (85.4%) had never received special preparation for training student teachers. Of those with training, 11.5% received it before becoming a mentor and 3.1% afterwards.

[1]Fisher's Exact test

[2]This analysis was only performed at the student teachers level. The limited sample size of graduate teachers resulted in a high proportion of cells with expected count less than 5, in which case the Chi-square test is considered inappropriate.

Table 5.3. Student and recently graduate teachers' mathematical background.

Mathematics topic	**Student teachers**	**Graduate teachers**
Numbers and operations	98.9%	100.0%
Lineal algebra	100%	96.6%
Set theory	82.1%	79.3%
Abstract algebra	69.5%	79.3%
Applied or discrete mathematics	72.6%	86.2%
Mathematical logic	71.6%	82.8%
Foundations of / axiomatic geometry	75.8%	86.2%
Analytic or coordinate geometry	98.9%	100.0%
Non-euclidean geometry	76.8%	62.1%
Differential geometry	86.3%	82.8%
Topology	67.4%	65.5%
Introduction to calculus	100.0%	100.0%
Single variable calculus	100.0%	100.0%
Multivariate calculus	98.9%	96.6%
Advanced calculus, real analysis, measure	87.4%	86.2%
Differential equations	96.8%	89.7%
Complex functions, functional analysis	74.7%	65.5%
Introduction to probability	90.5%	96.6%
Stochastic processes	58.9%	65.5%
Descriptive statistics	88.4%	96.6%
Sequence of random variables	70.5%	89.7%
Inferential analysis	75.8%	89.7%

5.4.5 Teaching competences in the mathematics specialty of the MDTTSE

A multi-actor perspective was adopted in order to study the extent to which teaching competences are pursued and attained during the MDTTSE, focusing on the mathematics specialty. Table 5.5 summarizes the perceptions of each stakeholder group about the extent to which each competence cluster is integrated into the curricula of the MDTTSE in mathematics. For student and recently graduate teachers, a distinction is made between a theoretical and practical perspective as stressed in the theoretical framework section.

Table 5.4. Student teachers' mathematical background based on their bachelor degree.

Knowledge domain	**Chi-square**
Discrete and logic	49.116**
Geometry	41.359**
Continuity and functions	37.985**
Probability and statistics	46.102**

Note: *p < .05; ** p < .01

Table 5.5. Multi-actor perspective about the level of pursuance of teaching competences.

	Student teachers		**Teacher**		**Graduate teachers**	
	Theory	**Practice**	**educators**	**Mentors**	**Theory**	**Practice**
Cluster	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**
MCK	3.85 (1.69)	3.26 (1.60)	4.21 (1.59)	3.66 (1.46)	3.74 (1.70)	3.29 (1.68)
MPK	3.79 (1.53)	3.68 (1.61)	4.58 (1.27)	4.83 (1.20)	4.28 (1.73)	3.97 (1.74)
TLP	4.19 (1.48)	3.88 (1.64)	5.07 (1.25)	4.89 (1.25)	4.57 (1.63)	4.25 (1.80)
CM	3.61 (1.61)	3.50 (1.69)	4.73 (1.28)	5.13 (1.32)	4.53 (1.70)	4.02 (1.77)
LP	4.47 (1.49)	4.15 (1.64)	5.22 (1.18)	5.17 (1.25)	4.94 (1.58)	4.66 (1.79)
AM	3.62 (1.70)	3.29 (1.68)	4.50 (1.32)	4.75 (1.44)	4.47 (1.86)	4.33 (1.89)
DP	4.16 (1.70)	3.56 (1.77)	4.40 (1.49)	4.79 (1.40)	4.93 (1.66)	4.32 (1.88)
ID	3.98 (1.70)	3.34 (1.78)	4.31 (1.44)	4.71 (1.50)	4.76 (1.75)	3.95 (1.74)
TK	4.57 (1.62)	4.02 (1.98)	5.44 (1.46)	4.96 (1.38)	5.41 (1.72)	5.21 (1.93)
CS	3.67 (1.88)	3.47 (1.96)	4.57 (1.54)	4.92 (1.51)	4.69 (1.63)	4.45 (2.01)
CSO	3.23 (1.67)	2.79 (1.69)	3.83 (1.49)	3.87 (1.69)	4.00 (1.87)	3.67 (1.97)
PC	4.02 (1.75)	3.72 (1.92)	4.87 (1.52)	4.86 (1.44)	4.71 (1.81)	4.45 (2.02)

Note: M = Mean. SD = Standard deviation.

In general, participants perceived most competences were not intensively pursued during the MDTTSE. The results reflect statistically significant differences between stakeholders' perceptions in all competence clusters, except in the *mathematical content knowledge* domain (see Table 5.6). Overall, student and recently graduate teachers' responses were more negative than those of teacher educators and mentors.

Table 5.6. Differences between stakeholder groups per competence cluster.

Competence cluster	**Chi-square**
Mathematical Content Knowledge	5.902
Mathematical Pedagogical Knowledge	24.647**
Teaching and Learning Processes	19.706**
Classroom Management	44.613**
Lesson Planning	15.038**
Assessment and Mentoring	23.947**
Developmental Psychology	9.782*
Inclusion and Diversity	12.321**
Technology Knowledge	17.669**
Communication Skills	24.954**
Contribution to School Organization	10.840*
Personal Commitment	14.749**

Note: $^*p < .05$; $^{**}p < .01$

When focusing on the theory-practice gap, statistically significant differences were found in a number of clusters (see Table 5.7). Such differences diverged, in some clusters, between student and recently graduate teachers. Overall, student and recently graduate teachers perceived higher pursuance levels in theory than in practice.

Table 5.8 summarizes the perceptions of student and graduate teachers about the extent to which each competence cluster is attained during the MDTTSE in mathematics. Besides, for each competence cluster, we checked whether stakeholders' perceptions were significantly below or above the 80% benchmark. The results show statistically significant differences between the attainment level of competences and the 80% benchmark. The first was in all competences consistently lower than the latter.

5.4.6 The effectiveness of the MDTTSE

Participants were asked to rate the effectiveness of the MDTTSE to prepare future secondary mathematics teachers for the teaching profession. The average satisfaction was low from the four stakeholder perspectives: student teachers (mean=3.52, SD=1.46),

Table 5.7. Differences between theory and practice per competence cluster.

Competence cluster	Student teachers Z	Graduate teachers Z
Mathematical Content Knowledge	-5.113**	-2.174*
Mathematical Pedagogical Knowledge	-1.916	-1.991*
Teaching and Learning Processes	-3.323**	-2.263*
Classroom Management	-1.309	-2.405*
Lesson Planning	-3.447**	-2.213*
Assessment and Mentoring	-3.440**	-1.632
Developmental Psychology	-4.615**	-3.044**
Inclusion and Diversity	-5.107**	-3.104**
Technology Knowledge	-4.143**	-0.880
Communication Skills	-1.635	-1.143
Contribution to School Organization	-3.723**	-1.179
Personal Commitment	-2.663**	-1.006

Note: Z = Statistic Wilcoxon signed-ranks test. *p < .05; ** p < .01

teacher educators (mean=4.81, SD=1.40), mentors (mean=4.75, SD=1.27), and recently graduate teachers (mean=3.90, SD=1.59). Statistically significant differences were found between the four groups ($\chi^2(3)$=48.366, p=.000). In particular, student and recently graduate teachers' perceptions were less favorable than those of teacher educators and mentors.

5.5 Discussion

The following discussion is structured following the CIPO model and, therefore, the research questions (see Table 5.1).

The first research question concerns the profile of student teachers and recently graduate teachers. Regarding the age of student teachers enrolled in the MDTTSE in mathematics, the results show moderate variation. Candidates commonly start the MDTTSE right after graduation from a bachelor degree. That happens at the age of 23 or 24. However, the increase of the unemployment rate in Spain in the last eight years has resulted in

Table 5.8. Perceptions about the attainment level of competences and their position regarding the 80% benchmark.

	Student teachers		Graduate teachers	
Competence cluster	**M (SD)**	**Z**	**M (SD)**	**Z**
Mathematical Content Knowledge	3.46 (1.79)	-7.849**	3.53 (2.00)	-4.286**
Mathematical Pedagogical Knowledge	3.67 (1.59)	-8.096**	4.19 (1.81)	-3.984**
Teaching and Learning Processes	4.06 (1.59)	-7.792**	4.43 (1.68)	-3.835**
Classroom Management	3.62 (1.68)	-7.883**	4.09 (1.68)	-4.246**
Lesson Planning	4.29 (1.61)	-7.434**	4.64 (1.67)	-3.583**
Assessment and Mentoring	3.71 (1.81)	-7.713**	4.26 (1.85)	-3.886**
Developmental Psychology	3.96 (1.76)	-7.548**	4.56 (1.73)	-3.742**
Inclusion and Diversity	3.73 (1.73)	-7.787**	4.40 (1.71)	-4.006**
Technology Knowledge	4.31 (1.85)	-6.789**	5.07 (1.87)	-2.525*
Communication Skills	3.72 (1.87)	-7.490**	4.21 (1.80)	-3.874**
Contribution to School Organization	3.35 (1.72)	-8.008**	3.74 (1.69)	-4.389**
Personal Commitment	3.79 (1.76)	-7.735**	4.34 (1.95)	-3.701**

Note: M = Mean. SD = Standard deviation. Z = Statistic Wilcoxon signed-ranks test. *$p < .05$; ** $p < .01$

higher numbers trying to enter the teaching profession after long periods of unsuccessful employment search. Moreover, for several years, public examinations to get a position as a secondary mathematics teacher have not been convened. The dispersion in recently graduate teachers' age is explained by the different cohorts participating in the study.

The results indicate a balanced representation of male and female student teachers and recently graduate teachers. This seems to contradict previous studies in the European framework pointing at an over-representation of female future teachers both in primary and secondary education (Gheyssens et al., 2014; Tatto et al., 2012). However, the results of the present study might be related to the nature of mathematics. In this context, Mendick (2005, p. 235) links mathematics with beliefs such as "doing mathematics is doing masculinity". Research about this topic highlights the importance of gender-balance in the teacher profession taking into account its influence in role model behavior of students (Dee, 2007).

There is a strong motivation of student teachers and recently graduate teachers for the profession (see Table 5.2). Because teaching has been always a vocational profession (Bruinsma & Jansen, 2010), it is not surprising that internal factors such as having a talent for teaching, liking to work with young people, or seeing teaching as a challenging job are reflected in most participants' reasons to become a mathematics teacher. Bakker (2005) observed that motivated teachers put more dedication and enthusiasm in teaching, which consequently promotes student motivation and outcomes.

The second research question regards the level and depth of mathematical knowledge of secondary mathematics student and recently graduate teachers. There is a growing concern about the adequacy of certain bachelor degrees to enter into the MDTTSE and, therefore, to become a knowledgeable secondary mathematics teacher. When compared to mathematics, engineering and some other degrees appear insufficient, lacking sound mathematical content in their curricula. Due to the influence of teachers' mathematical knowledge on student mathematical achievement (Hill et al., 2005), this is a critical issue in initial teacher education in Spain. The current heterogeneity of direct admission bachelor degrees might be influencing students' learning achievement in a negative way. Moreover, student and recently graduate teachers reported a low or average mark in university. This suggests that Spanish universities do not always recruit outstanding aspirants. In order to meet the demand of teaching positions, universities select candidates with less remarkable academic achievement in mathematics.

Worldwide, the most common criteria to enter into initial teacher education are, in addition to diploma requirements, university grade-point average, personal interviews, prior teaching experience, and admission tests (OECD, 2014). Selecting student teachers with prior teaching experience assures vocational success and might avoid early dropout (Caspersen & Raaen, 2014; Stokking et al., 2003). Because students commonly reject admission tests, a better selection process might use a combination of criteria. In this regard, teacher education institutions should start a consultation process among the mathematical scientific community on minimum requirements for admission criteria in the MDTTSE in mathematics. The existing requirements and the increasing diversity of student teachers' profiles question the qualification of future secondary mathematics teachers.

As to the third and fourth research questions, teacher educators teaching in initial teacher education programs as well as mentors supporting field experiences in secondary education schools play an essential role in the preparation of future teachers (Even & Krainer, 2014; Murray & Male, 2005). In line with previous national research (see Santos & Lorenzo, 2015; Valdés & Bolívar, 2014), the most notable finding of the present study is the limited experience and expertise of both sample groups. It seems there are no specific requirements or professional trajectories to become teacher educator or mentor in the MDTTSE in mathematics in Spain. Some authors explain that the criteria for selecting teacher educators and mentors in Spain has been the availability of teaching credits, instead of their career profile (Gutiérrez, 2011; Vilches & Gil-Pérez, 2010). According to Even and Krainer (2014), Spain is not an exception. In most countries, teacher educators and mentors have little formal preparation for their work. So they learn through practice, with little institutional and professional support (Trent, 2013). Smith (2003) stresses that the profession of teacher educators and mentors is still the only profession in education where hardly formal training exists. Notwithstanding, a number of studies have already moved forward to the development of quality requirements for teacher educators and mentors (see Koster et al., 2005). In Spain, policymakers and educational leaders should address the urgent need to develop and establish a comprehensive framework which determines the requirements teacher educators and mentors have to fulfill and the competences they should master. Such requirements should strengthen both the experience and the expertise of these stakeholder groups.

Next research question concerns the extent to which teaching competences are integrated into the curricula of the MDTTSE in mathematics. Overall, participants' perceptions are quite negative (see Table 5.5). Building on student and recently graduate teachers' perceptions, all competences are insufficiently pursued both in theory and in practice. The failing or weak application of the learned competences during field experiences might explain the differences between the theoretical and the practical component. Previous research suggests that establishing stronger school-university partnerships helps to enhance the quality of initial teacher education (Korthagen & Kessels, 1999; Schleicher, 2012). Regarding the input of teacher educators and mentors, only a small number of exceptions are observed in specific competence clusters, such as *teaching and learning processes*, *classroom management*, *lesson planning*, and *technology knowledge*, where mean values are above 5, but not higher than 6. As a consequence of the low pursuance levels, student and recently graduate teachers perceive teaching competences are attained to a small or moderate extent (see Table 5.8). There is therefore little assurance that the MDTTSE train future secondary mathematics teachers towards the mastery of teaching competences and, consequently, towards the teaching career. The former suggests the need to implement new strategies which cover, in a comprehensive way, all the aforementioned competences during the MDTTSE in the mathematics specialty. Besides, the definition of a minimum benchmark for competence achievement is also imperative for the acquisition of a diploma in secondary mathematics initial teacher education in Spain.

As to the last research question, all participants indicated not being entirely satisfied with the MDTTSE in mathematics. This is understandable taking into account the shortcomings previously detected. Therefore, whether the MDTTSE has an added value for future secondary mathematics teachers is unclear.

This study contributed to the field of initial teacher education in several ways. The theoretical relevance is reflected in the development and disposal of validated instruments to assess initial teacher education programs (see Muñiz-Rodríguez, Alonso, Rodríguez-Muñiz, & Valcke, 2016b; Muñiz-Rodríguez, Alonso, Rodríguez-Muñiz, & Valcke, 2016c). Reliable measures were developed and implemented to assess the extent to which professional teaching competences are pursued and attained in initial teacher education programs in mathematics. To that end, they may serve as a starting point for the international educational research in view of analyzing the quality of initial teacher education programs within other specific national or regional contexts or specialties. From an empirical viewpoint, this study explained the nature and situation of initial teacher education in Spain. The results reveal a critical situation in view of future secondary mathematics teachers' subject-matter knowledge and mastery of teaching competences. Considering how initial education influences the nature of future teachers' teaching practices and professional development (Darling-Hammond et al., 2005), appropriate measures should be implemented. Finally, this study also contributed to educational practice and policy. These findings can be used to inform policymakers and educational leaders about specific elements (e.g., the admission requirements, the recruitment system of teacher educators and mentors, the collaboration between universities and secondary education schools, or the mastery of teaching competences) that need to be (re)addressed in the context of the MDTSSE.

At this position in the discussion, we have to mention some limitations of this study. The limited sample size and the use of a non-probability sampling technique may have caused a bias in the results. This suggests to start developing a public, centralized and comprehensive database of the profile of student teachers, recently graduate teachers, teacher educators, and mentors. National and international assessment studies show how the availability of systematic databases can help directing policy decisions, in particular when longitudinal data are accessible. Lacking these data makes it impossible to ground policies. But it also hinders the selection of candidates for the MDTTSE in mathematics and for the teaching profession.

CHAPTER 6

Enhancing future secondary mathematics teachers' competence to provide and seek feedback

Previous studies in the context of this dissertation point at critical competences, hardly developed during the MDTTSE in mathematics. Giving constructive, purposeful and timely feedback is one of such competences. This evoked the design, implementation, and evaluation of a competence development intervention involving secondary mathematics student teachers. The intervention built on videotaped clinical simulations. A pre-test/post-test design was used. Student teachers were invited to react to open-ended questions when watching the clinical simulations. Content analysis of student teachers' answers helped mapping changes in their feedback competence development. A scale was developed to capture their related feedback self-efficacy. The results reflect a clear positive impact of the intervention on the development of teaching competences. Implications and directions for future research are discussed.

6.1 Introduction

One critical aspect, exhaustively and consistently reported in the literature, about initial teacher education is the theory-practice gap (Allen & Wright, 2013; Korthagen & Kessels, 1999; Loughran, 2012). Although initial teacher education programs commonly comprise of a theoretical and a practical component, they do not necessarily complement each other in an efficient and effective way. Often, the development of teaching competences is left almost entirely to field experiences, the curriculum component less easily controlled or monitored (Jordan, Schwartz, & McGhie-Richmond, 2009). As a consequence, some teaching competences are scarcely pursued during initial teacher education programs and, therefore, weakly attained. Korthagen and Kessels (1999) criticized initial teacher education programs because of non-reality related training approaches, making teachers uneasy about their readiness for the profession (see also Loughran, 2002). Recent research underpins this critique (Gelfuso & Dennis, 2014; Goodnough et al., 2016; Hatch et al., 2016; Korthagen, 2017).

In Spain, the MDTTSE includes a field experience in a secondary education school, consisting of two phases: observation and intervention. During the observation, student teachers spend a short period of time observing professionals in their day-to-day teaching activities, while during the intervention student teachers demonstrate their micro-level teaching competences. Previous studies, set up in the Spanish context of initial teacher education, underlined that student teachers claim lacking sufficient practical preparation to deal with real-life classroom situations, for instance, when it comes to participating in school research and innovation, or informing and advising families (García et al., 2011; Zagalaz et al., 2015). In particular, a previous study carried out in the context of this dissertation pointed at the critical mastery level of a number of teaching competences (see Chapter 5). A key problem was identified in relation to *giving and seeking constructive, purposeful and timely feedback to/from students, their families, and colleagues* (AM3).

An alternative approach to develop teaching competences during initial education programs is based on clinical simulations. Simulation-based strategies aim at bridging the theory-practice gap, bringing real-life classroom situations without putting students, families, colleagues, or student teachers themselves at risk (Cioffi, 2001; Dotger, 2013). Simulation-based activities can be substantially different. Cioffi (2001) distinguishes between response-based simulations, in which the learner is a passive searcher who has no control over the data presented, versus process-based simulations, in which the learner is an active searcher who controls the information and its sequence over time. The core of the present study was to focus on the efficacy of videotaped clinical simulations as a type of response-based simulations. The latter represents an emerging tool in teacher education (Dotger et al., 2015; Hatch et al., 2016; Herbst, Aaron, & Chieu, 2013; Koc, Peker, & Osmanoglu, 2009). These video-vignettes – as they are labeled in the medical education literature – mirror realistic clinical cases and help to contextualize learning and assessment (Finch, 1987). Further, they are particularly interesting since they increase the fidelity and validity of the instructional approach and related assessment (Lievens & Sackett, 2006).

The previous explains the approach adopted in the present study: the design, implementation, and evaluation of a competence development intervention for secondary mathematics student teachers, based on video-vignettes. The following research question guided this study: to what extent are video-vignettes an effective tool to develop the competence: *giving and seeking constructive, purposeful and timely feedback to/from students, their families, and colleagues* during initial teacher education programs? To this end, a pre-test/post-test design was set up, involving secondary mathematics student teachers from one Spanish university.

6.2 Conceptual and theoretical framework

This study built on an integrated perspective towards teacher competences as developed by Blömeke, Gustafsson and Shavelson (2015). Based on their critical review of the literature, they consider competences along a continuum that evolves from cognitive and affective-motivational dispositions to observed behavior. Cognition, affect-motivation and behavior are connected through an analysis of situation specific demands. This requires three types of skills – Perception, Interpretation, and Decision (PID) – already introduced by Sherin and van Es (2002). Thereby, student teachers

1. have to be aware of what is important in a concrete situation (i.e., Perception),
2. have to be able to Interpret the situation drawing on their knowledge and experiences,
3. and have to take relevant Decisions.

Figure 6.1 gives a graphical representation of the theoretical framework for the present study. Because of the connectedness of all elements in the model, arrows making explicit the reciprocal connections were added. Also, the figure incorporates intervention design characteristics.

In view of the development of competences, this model has clear implications. Firstly, cognitions have to be developed by introducing specific knowledge and skills; in this case

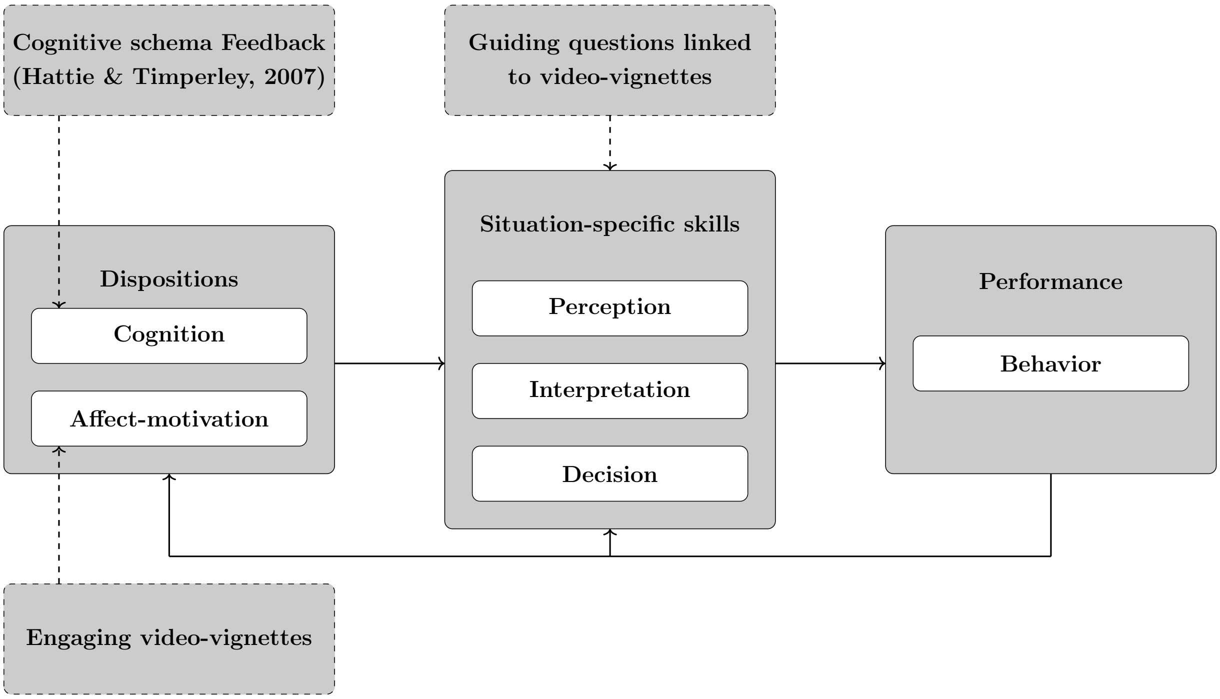

Figure 6.1. Integrated perspective on teacher competences and how they are influenced by the use of video-vignettes (based on Blömeke et al., 2015, p. 9).

related to giving feedback. From an information processing perspective, student teachers have to acquire what is called “scripts”. Geen and Donnerstein (1998, p. 80) state this as follows: “A script serves as a guide for behavior by laying out the sequence of events that one believes are likely to happen and the behaviors that one believes are possible or appropriate for a particular situation”. Scripts are cognitive schemas that have to be internalized (Duran & Kelly, 1985). In the present study, the feedback model of Hattie and Timperley (2007) was introduced as a cognitive schema to provide feedback (see below). In other words, an explicit instructional process to introduce a cognitive schema to develop this feedback behavior has been included.

The model of Blömeke et al. (2015) also implies that the affective-motivational dimension has to be fostered; this brings together affective, conative and motivational resources. The use of video-vignettes helps operationalizing this dimension. Video-vignettes present an authentic experiential setting that drives these resources. Several authors stress how instructional video-use boosts students’ motivation and engagement (see for instance Bryan & Recesso, 2006; Choi & Johnson, 2005; Tripp & Rich, 2012).

Next, the model indicates Perception, Interpretation and Decision making have to be boosted to invoke subsequent behavior. This PID-approach is central to many teacher education models that push reflection (Korthagen, 2004), pedagogical thoughts models (Shavelson & Stern, 1981), and studies involving novice and expert teachers. The latter shows that experts and novice teachers clearly differ in their PID-skills (Livingston & Borko, 1989; Sherin & van Es, 2002). In the intervention object of the present study, the video-vignettes continuously invite student teachers to react to the complex situations through open-ended questions. Video has proven to be effective to foster the much needed reflection cycle to learn from practice when real-life problems are encountered (Cherrington & Loveridge, 2014; Moon, 2013, Seidel, Blomberg, & Renkl, 2013). This reflection is difficult to invoke in traditional teacher education approaches (Zeichner & Liston, 2013). Video-vignettes are expected to invoke practice-related experiences that are sufficiently profound to invoke in-depth reflection (Bogo et al., 2013; Dieker, Rodríguez, Lignugaris, Hynes, & Hughes, 2014). In mathematics education, invoking reflection has been referred to as "noticing" (Jacobs et al., 2010).

In view of mapping this "noticing" or PID-activities of students, the literature presents a variety of approaches. Reflection is – according to many authors – a visible outcome (Hatton & Smith, 1995; Ward & McCotter, 2004). The latter authors present for instance a framework to analyze written student reflections. What we learn from these examples is that a specific rubric is being developed to screen student output. Since the present study focuses on a cognitive schema for giving feedback, this rubric will link this cognitive dimension to indicators that reflect levels in PID. In view of the latter, this intervention built on Bloom's revised taxonomy to distinguish between the remembering/perception and the understanding/interpretation level (Anderson & Krathwohl, 2001).

6.2.1 A model of feedback

Hattie and Timperley (2007) emphasize feedback is one of the most powerful instructional strategies influencing learning performance. Feedback is conceptualized as information provided by an agent (for instance, teacher, peer, book, parent, or one's own) about aspects of one's performance or understanding (Hattie & Timperley, 2007). Research shows some types of feedback are more powerful than others, such as providing cues or reinforcement to learners (Hattie, 2009; Hattie & Gan, 2011; Kluger & DeNisi, 1996). Also, the way feedback can be given differs: computer-generated feedback (Adesina, Stone, Batmaz, & Jones, 2014; Fyfe, 2016; van der Kleij, Feskens, & Eggen, 2015; Panaoura, 2012), formative versus standardized or interim assessment (Konstantopoulos, Li, Miller, & van der Ploeg, 2016; van den Berg, Harskamp, & Suhre, 2016), feedback on students' homework, workbooks or notebooks (Núñez et al., 2015), process-oriented versus social-comparative feedback (Rakoczy, Harks, Klieme, Blum, & Hochweber, 2013), individual versus collective feedback (Roschelle et al., 2010), or immediate versus summative feedback (Fyfe & Rittle-Johnson, 2016). To structure this variety, Hattie and Timperley (2007) proposed a model of feedback building on three perspectives:

- **Feed-up** – Where am I going? This stresses the learning goal related to the task or performance.
- **Feed-back** – How am I going? This gives information about – successful or unsuccessful – progress in view of the learning goal.
- **Feed-forward** – Where to go next? This provides information about greater possibilities for learning, such as enhanced challenges, more self-regulation, grater fluency and automaticity, more strategies and processes, or deeper understanding.

The same authors stress these questions can be answered at four levels:

- The **task level**: distinguishing correct from incorrect answers, acquiring more or different information, and building surface knowledge.
- The **process level**: information about the learning processes needed to understand or perform the task.
- The **self-regulation level**: focuses on the student's monitoring of his/her learning processes, implying autonomy, self-control, self-direction, and/or self-discipline.
- The **self-level**: invokes personal evaluations and affects about the students.

This feedback model has been used as an action framework (script) for teachers to work in real-life classroom situations when giving and seeking feedback to/from students.

These situations have been filmed to develop the video-vignettes for the current study. The model was also used as a framework for the content analysis of student teachers' responses to video-vignettes in order to map their competence development.

6.2.2 Mapping student teachers' competence development

A key outcome of initial teacher education programs is the development of teaching competences, reflected in changes in student teachers' knowledge, skills and attitudes. Recent research supports the idea of building on Bloom's taxonomy (Bloom, Krathwohl, & Masia, 1956) to map teacher education outcomes (Szabo & Schwartz, 2011). The revised version of the taxonomy distinguishes six behavioral mastery levels: remembering, understanding, applying, analyzing, evaluating, and creating (Anderson & Krathwohl, 2001). The present study focused on the two founding levels:

- **Remembering**, which means recognizing or recalling knowledge from memory to produce or retrieve definitions, facts, or lists, or to recite previously learned information. This level maps students' Perception skill.
- **Understanding**, which means constructing meaning from different types of functions be they written or graphic messages or activities like interpreting, exemplifying, classifying, summarizing, inferring, comparing, or explaining. This maps students' Interpretation skill.

The two Bloom's taxonomy levels helped developing questions invoking specific reflection skills (PID) in student teachers when watching the video-vignettes. Though also questions asked what they would "do" in the actual situation (Decision skill), answers to this question were still considered being at understanding level and not at the Decision level. Next, the two taxonomical levels were used as a framework for the subsequent content analysis of student teachers' reactions to the reflection questions to score their competence development.

6.2.3 Video-vignettes to develop the feedback competence

Researchers have been looking for new learning experiences to promote future teachers' readiness to teach. To this end, technology has become a useful proxy (Georgouli, Skalkidid, & Guerreiro, 2008; Szabo & Schwartz, 2011); in particular, the adoption of online environments. In this context, video-vignettes have become trendy for engaging students in real-life classroom contexts and problems (see Jeffries & Maeder, 2004). Video-vignettes represent a hypothetical scenario, to which individuals respond, exposing their perceptions, values and/or impressions. Also, they are considered an effective approach to assess future teachers' competences (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Koc et al., 2009; Santagata & Guarino, 2011).

Although watching a video-clip is different from engagement in a real-life context, the literature highlights benefits when using video in initial teacher education. Video-vignettes are valuable to address difficult-to-explore and sensitive topics (Jeffries & Maeder, 2004), they support the understanding of the complexity of teaching (Koc et al., 2009), they boost motivation (Herbst et al., 2013), and they help connecting theory and practice (Hatch et al., 2016). Video-vignettes can be re-watched and are therefore a better base to reflect from multiple perspectives (Seidel et al., 2013). They allow collaboration between student teachers and between them and teacher educators (Hess, 2004; Sherin, 2004). At the same time, authors stress weakness, claiming they might interfere with desired learning outcomes and reinforce conventional preconceptions of teaching (Beitzel & Derry, 2009; Brophy, 2004).

Video-vignettes are a type of response-based simulations. Involvement in them requires having available an action framework describing steps teachers can take to tackle the specific situation (see for instance James, 2016; Chaplain, 2016). This action framework is considered a cognitive schema or script as discussed earlier. Student teachers elaborate and organize this schema in their cognitive system as a guide for action. Being involved in a series of video-vignettes is expected to consolidate and refine this schema/script that becomes part of the professional behavioral repertoire. Research emphasizes three factors influencing learning from video-vignettes (see Hatch et al., 2016):

1. the characteristics of the materials and resources, such as the content, length, quality, authenticity, degree of uncertainty, and/or level of relevant information;

2. the social and educational background of participants, i.e., the knowledge, experiences, and/or conceptions; and

3. the nature of the activities: online or offline, individually or in groups. We return to these factors when presenting the nature of the research intervention.

The present intervention focused on the use of video-vignettes through an online environment to immerse secondary mathematics student teachers in hypothetical real-life classroom situations. As a course assignment, participants were required to react via short or middle term planned actions. They entered a description of these actions in the online environment.

6.3 Methodology

This section includes information about the sample, the instrument and the procedure for the data collection and analysis.

6.3.1 Hypotheses

Building on the theoretical base, the following hypothesis was put forward : "Studying clinical simulations will boost the development of the feedback competence in student teachers as reflected in their video-question answers and their self-efficacy".

6.3.2 Sample

The sample consisted of 15 mathematics student teachers enrolled in the MDTTSE in the University of Oviedo (Spain). Prior to participating in this study, student teachers completed twenty-one weeks of their initial teacher education program. One student dropped out due to personal circumstances, resulting in data collected from 14 students (mean=25.93 years old, SD=3.54): 7 women and 7 men. Participants' academic background was distributed among three fields of knowledge: mathematics (n_1=3), physics (n_2=3), and a range of engineering degrees (n_3=8).

6.3.3 Instrument

Data were collected at the time of the pre-test and post-test administration:

- Marking student teachers' competence development was based on the analysis of their answers to the questions embedded in the pre-test and post-test video-clips.
- Student teachers' self-efficacy (SE) was measured by the administration of a SE scale, designed on the base of Bandura's guidelines (1986, 2006). He defines self-efficacy as the perception of one's capacities to successfully perform specific tasks. An 11-item self-efficacy questionnaire was developed, using a ten-point Likert scale (see Appendix G). The reliability of this scale was $\alpha = .823$ at the pre-test, and $\alpha = .922$ at the post-test.

6.3.4 Design of the video-vignettes

The video-vignettes were developed from video-recordings of lessons purposefully designed in collaboration with two mathematics teachers from two public secondary education schools. Each specific vignette – duration between 7-9 minutes – focused on feedback given during a different real-life classroom situation. Each vignette was based on a different type of learning activity: digital quiz, card game, group work, blended learning, regular lesson, and role play game. Building on the feedback model of Hattie and Timperley (2007) the teacher and the students were engaged in feed-up, feed-back, and feed-forward. Three cameras were used to videotape each situation. Each video-vignette consisted of a compilation of three shots, giving the viewer a holistic picture of the instructional setting.

At the start and during regular intervals, the online video was paused and student teachers were required to respond – in writing – to an open-ended question. When necessary, the video included a print of the exercise being focused upon. The video-questions focused on student teachers' feedback competence while exploring the two founding taxonomical levels described above: remembering (perception) and understanding (interpretation). Table 6.1 gives an outline of the questions put forward during a typical video-vignette. All video-vignettes were hosted on EDpuzzle®.

Table 6.1. Structure and content of a sample video-vignette.

Progress	Embedded question	Taxonomical level
Start	1. Imagine you have to teach (*content*) at (*grade*). How would you start the lesson?	Understanding
	2. How did the teacher start the lesson?	Remembering
	3. How would you respond to students' work?	Understanding
	4. How did the teacher respond to students' work?	Remembering
	5. How would you conclude the lesson?	Understanding
End	6. How did the teacher conclude the lesson?	Remembering

Note: Questions 1 and 6 were not included in the pre-test.

6.3.5 Procedure

The intervention consisted of three sessions of two hours each, and took place in the span of two consecutive weeks. Figure 6.2 gives a graphical representation of the procedure.

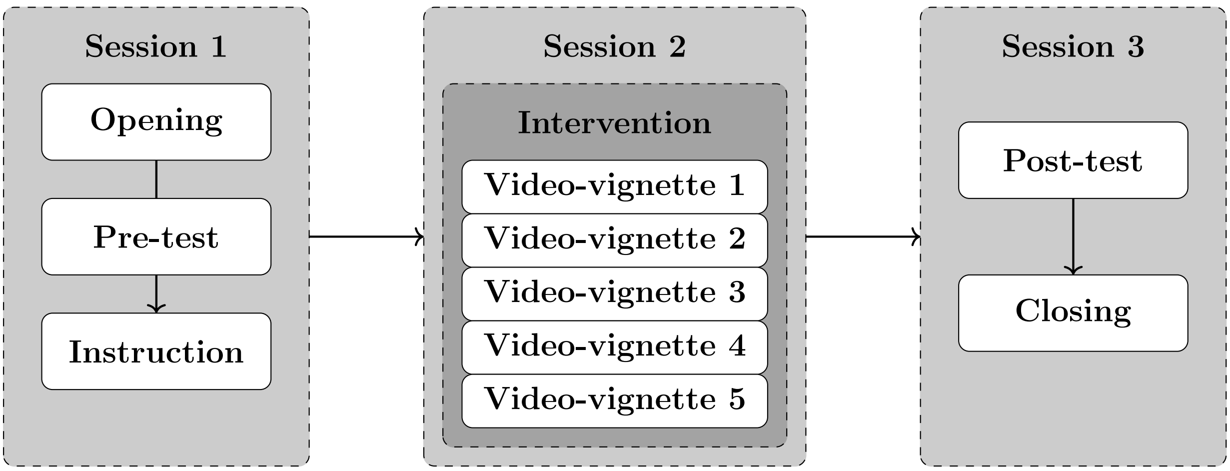

Figure 6.2. Structure and content of the intervention.

All sessions were set up in a computer room. Each student teacher was provided with computer access, Internet connection, and headphones.

Session 1

- **Opening.** A presentation was given about the research project and the intervention. At this point, informed consent was obtained from all participants.
- **Pre-test.** Participants watched a pre-test video and answered the pre-test questions (see Table 6.1). These questions were embedded in the video-vignette. Next, they filled-out the self-efficacy instrument.
- **Instruction.** Participants watched individually an instructional video-clip introducing the feedback model explained above. A print handout was provided as additional support. A list of questions was embedded in the video-clip in order to check participants' understanding.

Session 2

- **Intervention.** The intervention consisted of participants watching five consecutive video-vignettes with embedded questions (see Table 6.1).

Session 3

- **Post-test.** Participants watched the post-test video and answered the embedded questions (see Table 6.1). Next, they filled out the post-test version of the self-efficacy scale.
- **Closing.** Participants and researchers summarized and discussed key concepts of the feedback model. Participants were acknowledged for their participation and interest.

6.3.6 Data analysis

The feedback model and Bloom's revised taxonomy helped developing a coding rubric with a list of indicators (see Table 6.2). Weft QDA© was used to manage the data and coding.

Table 6.2. Coding matrix to map student teachers' feedback competence development.

Feedback perspective	(1) Feed-up, (2) Feed-back, (3) Feed-forward
Feedback level	(1) Task, (2) Process, (3) Self-regulation, (4) Self
Taxonomical level	(1) Remembering, (2) Understanding

The analysis focused on the evaluation of student teachers' responses to the pre-test and the post-test video-vignettes. Responses to each embedded question were considered as unit of analysis. Each unit of analysis was screened following the coding rubric. After coding, a cross-case analysis was carried out (Hsieh & Shannon, 2005). For each indicator, frequencies were calculated to compare pre-test and post-test results. In order to better understand the following analysis, the reader must notice that within each feedback perspective it is possible to consider feedback related to the four different levels. Similarly, it is feasible to provide feedback at the three different perspectives without a particular focus in any of the four levels.

6.4 Results

Table 6.3 summarizes the descriptive results relative to student teachers' feedback competence development and self-efficacy.

Overall, the results reflect a positive impact of the intervention on the development of student teachers' feedback competence. Differences in student teachers' reactions before and after the training can be identified. The structure of the table is followed when discussing the results.

Before the training, student teachers were able to better perceive and/or interpret feedback related to feed-forward (n=13) than to feed-up (n=4) or feed-back (n=18). This notable difference is settled after the training, especially at the feed-back perspective. A modest increase is observed at the feed-up (n=16) and feed-back (n=25) components, while the feed-forward (n=26) remains constant with quite positive outcomes. As to the feed-up, before the training, very few participants (n=4) perceived how the teacher started the lesson stressing the learning goal(s) of the unit to ensure that students focus on content related to this goal. After the training, despite a higher number of student

Table 6.3. Pre-test and post-test results relative to student teachers' feedback (FB) competence development and self-efficacy (N=14).

	Pre-test				**Post-test**			
	R	**U**	**R+U**	**SE - M (SD)**	**R**	**U**	**R+U**	**SE - M (SD)**
Feed-up	4	-	4	7.47 (2.17)	8	8	16	7.79 (1.42)
Feed-back	10	8	18	7.23 (1.96)	13	12	25	8.07 (1.76)
Feed-forward	-	13	13	7.07 (1.84)	13	13	26	8.07 (1.68)
FB perspective total	14	21	35		34	33	67	
Task	2	3	5	8.17 (1.95)	9	10	19	8.11 (1.71)
Process	13	12	25	8.53 (1.41)	12	12	24	8.21 (1.37)
Self-regulation	3	4	7	7.86 (1.46)	2	5	7	8.07 (1.39)
Self	5	8	13	7.40 (1.81)	1	7	8	8.07 (1.94)
FB level total	23	27	50		24	34	58	

Note: R = Remembering. U = Understanding. SE = Self-efficacy. M = Mean. SD = Standard Deviation.

teachers perceived the feed-up actions performed by the teacher, the results are still rather modest at both taxonomical levels (n=8). Regarding the feed-back perspective, despite a general awareness (n=10), the understanding level was attained at a lesser extent (n=8) before the training. After the training, student teachers were able to better perceive (n=13) and interpret (n=12) actions containing information about students' progress, such as "I would provide students information about their progress during the lesson" or "The teacher asks students what they have been learning up to this lesson in order to check what students know". The feed-forward component appears to be well developed both before and after the training. Student teachers' reactions seemed fairly adequate in relation to both taxonomical levels, see for instance, "I would ask students to design a similar activity for the next lesson including the concepts they consider more difficult about this unit" (pre-test) or "The teacher concludes the lesson using the information she gathered from the activity to decide which concepts need to be reviewed and reinforced in order to improve students' learning" (post-test).

Regarding the four levels, we observe the highest number of indicators in relation to feedback about the process both before (n=25) and after (n=24) the training. Before the training, this is second by a moderate focus on feedback related to the self (n=13).

This focus shifts towards feedback at the task level after the training (n=19). Nevertheless, very few student teachers referred to feedback at the self-regulation level both before (n=7) and after (n=7) the training. When looking separately at both taxonomical levels, slight variation is found at each feedback level due to the training. For instance, as to the task level, prior to the training student teachers were not able to perceive (n=2) nor interpret (n=3) actions that aim at distinguishing correct from incorrect answers, acquiring more or different information, or building surface knowledge. After the training, we observe a substantial increase in both the remembering (n=9) and the understanding (n=10) level. However, most of the indicators related to this level consist of correct/incorrect-answer feedback, instead of some other criterion related to task accomplishment. Feedback at the process level was perceived and interpreted at a large extent both before and after the training. Hardly differences are observed between both taxonomical levels. Student teachers were able to perceive and interpret actions containing information about the learning processes needed to understand or perform the task even before the training period. As mentioned before, self-regulation is the most overlooked feedback level. Before the training, student teachers barely perceived (n=3) how the teacher encourages students to monitor, self-control or self-assess their learning processes. Nor were they able to interpret this feedback level (n=4). After the training, the results remain rather negative at both taxonomical levels (n=2 and n=5, respectively). As to the self level, the overall decrease in the number of indicators is explained by a slighter emphasis on the remembering level after the training (from n=5 to n=1). Very small differences are observed at the understanding level (from n=8 to n=7).

Before the training, participants' answers mainly referred to other instructional activities, such as content review, participation encouragement, calling attention, or praise, see for instance "The teacher starts the lesson encouraging students' participation" or "The teacher makes a lot of questions in order to get students' attention and help them focus on the subject". Other answers remained very general: "The teacher starts the lesson making questions", redundant: "I would explain why the correct answer is right. I would explain why one of the incorrect answers is wrong", "I would congratulate the students who answer correctly. I would reward the students who answer correctly with symbolic prizes that reinforce their learning", or even irrelevant: "If all the students answer correctly, I would be happy", "I would encourage students to cooperate and help each other" or "I will respond to students' work making them feel good". Some student teachers shared their personal opinion about the behavior of the teacher, see for instance "The way the teacher starts the lesson is very appropriate" or "The teacher responds to students' work with and open and calm attitude". Respondents also referred to what the learners did instead of adopting the teacher's perspective: "Some students raise their hands. Although not all students responded, it seems that several know the answer".

The nature of the student teachers' reactions clearly changed during and after the intervention. Replies were more elaborate and referred to key concepts in the model, see for instance "I would start the lesson contextualizing and recalling the learning goals, evoking students' thinking, in order to know what they remember", "I would ask students about what they remember/know about the metric system in order to gather information about their current knowledge. I would make a schema from their answers and relate them with the learning goals of the unit", or

> "I would respond to students' work enhancing their confidence about their response (self-regulation level), using questions to check how they came up with the answer and what they should have done (process level), identifying what is the correct answer (task level) and making some comments about their personal work (self level, the least effective), all through questions, suggestions and directions, not directly".

Notwithstanding, a couple of participants still referred to rather broad actions after the training, such as "I would start the lesson using very graphic and simple materials that serve to call their attention and strengthen their motivation".

The impact of this intervention was also measured in terms of student teachers' self-efficacy. Overall, participants believed they were suitably qualified for providing feedback even before the training. This perception supports the self-efficacy results at the time of the pre-test, but contrasts with the analysis of the responses given to the embedded questions. Table 6.3 shows a small increase in student teachers' self-efficacy to give and seek feedback after the training.

6.5 Discussion

The former results provide evidence about the effectiveness of video-vignettes on the development of secondary mathematics student teachers' feedback competence during their initial teacher education. These findings confirm previous research outcomes about the potential of this type of simulation-based activities to provide student teachers with the opportunity to experience dimensions of simulated practice reality (Hatch et al., 2016; Herbst et al., 2013). It is hypothesized that through their reflections on the real-life classroom situations, student teachers come to understand the realities of the future school environment (O'Donoghue & Brooker, 1996).

A clear increase in the number of indicators related to feedback at the feed-up and feedback perspectives and at the task level was observed after the training. Indeed, taking into account that around 90% of teachers' feedback are aimed at the task level (see Hattie & Timperley, 2007), it is surprising that only half of the student teachers reacted to the pre-test situation providing information about whether students' answers are correct or incorrect. The output related to feedback at the feed-forward perspective and the process and self-regulation levels, remained barely invariable after the training, while the emphasis on the self level decreased. The latter is not of concern taking into account that feedback at the self level is the least effective because it is too often not related to task performance (Hattie & Timperley, 2007). Of importance is the low amount of reactions referring to feedback at the self-regulation level, which appears to be largely effective. As learners monitor, self-control or self-assess their learning processes, they become more competent in view of seeking, accepting and accommodating feedback information from external factors (Hattie & Timperley, 2007). Besides, they become more proactive, self-motivated learners (Cleary & Zimmerman, 2004; Nicol & Macfarlane-Dick, 2006). In this sense, Zimmerman (2002) explains that teachers usually expect students to display their self-regulation skills outside the classroom. However, to be able to meet these expectations, teachers need to provide learners a wide repertoire of strategies to empower their self-regulation and self-assessment proficiencies. The student teachers in the present study also emphasized this level to a too limited extent. This feedback level should be reinforced during the training period, incorporating specific strategies that student teachers can use to boost their students' self-regulation. The examples proposed by Nicol and Macfarlane-Dick (2006) can be adopted in this context.

The video-vignette based intervention clearly resulted in changes in student teachers' knowledge, skills and attitudes about feedback at two founding taxonomical levels when observing and reflecting on real-life classroom situations. As to the first taxonomical level, remembering, we observe a higher number of indicators after the training. Also in relation to the understanding, the post-test results reflect a clear increase in the amount of indicators. Overall, slight differences exist between both levels. Indeed, the results suggest that both levels are attained at the same extent. Considering the existence of a sequential, hierarchical link between the taxonomical levels (Anderson & Krathwohl, 2001), the mastery of the two founding levels enables the development of competences in the higher levels of the taxonomy.

Previous research suggests that video-based experiences support student teachers' engagement during their initial education (Herbst et al., 2013). During the implementation of the intervention the research team could observe an increase in student teachers' motivation as compared to the traditional courses they were used to. Throughout the different sessions, all participants seemed focused when watching the different video-vignettes, and when reflecting on the real-life classroom situations, and suggesting solutions to move forward. This implies that the affective-motivational dimension – put forward in the model of Blömeke et al. (2015) – has been boosted. Student teachers' engagement was also mirrored in the in-depth and lively discussions that came up along each session. In this way, using an online environment can also been considered as a prompting mechanism (Georgouli et al., 2008; Szabo & Schwartz, 2011).

The design of the video-based intervention combined an instructional video about the feedback model (Hattie & Timperley, 2007) with a series of video-vignettes in which was put into practice what was learned earlier. This combination fosters the much needed link between theory and practice in initial teacher education (Allen & Wright, 2013; Korthagen & Kessels, 1999). The data collected at the post-test reflect this changed reality. Besides, student teachers participating in the study valued the potential of video-vignettes to link theory and practice.

After the training, student teachers were able to better Perceive and Interpret core concepts related to the feedback model and about their relevance for the learning process. Participants' responses appear to have changed when looking at their personal reflections during the intervention. Therefore, the research team believes this approach expands and deepens student teachers' understanding of the theoretical concepts and improves their ability to appropriately react to feedback situations. According to Schwartz and Bransford (1998), when learners have little familiarity with a theory or concept, providing them with illustrative representations of such theory or concept can prepare them to learn about it. On the other hand, throughout the intervention, their perceptions and interpretations became more accurate, i.e., student teachers answered in a more focused, in-depth, and analytical way about specific issues related to feedback.

Some limitations of the present study have been acknowledge. First, only a small student sample from one Spanish university was involved. This methodological constraint calls for a more representative sample at the national level involving student teachers from other universities. Besides, the impact of this intervention should also be examined at a later stage and not only right after the training. Further research should explore the effects of a long-term intervention and compare the outcomes with the results obtained in this study. Finally, it could be of interest to include group discussions during the intervention procedure. Dotger (2013) stresses this could, on the one hand, help to "cool down" after a stressful experience and, on the other hand, deepen the perception and reflection practice by sharing experiences. Teacher educators could join in and use their valuable experience to bring up potential issues related to each specific classroom situation. Such discussions would provide a complete portrayal of the ideas generated during the analysis of the video-vignettes.

This study contributes to initial teacher education policy and practice. The results of this intervention can be used to inform policymakers and teacher educators about specific learning experiences that enhance student teachers' competence development. Many initial teacher education programs are still largely based on traditional teaching methods (Akrawi, 2010). This intervention moves towards a more student-centered environment and provides an opportunity to integrate theory and practice in initial teacher education. This research can be extended by implementing alternative interventions relative to additional teaching competences. To that end, a similar design could be adopted, but representing different real-life classroom situations.

CHAPTER 7

Conclusions and perspectives

The main aim of this dissertation was to gain insight into the nature and the quality of initial education programs for future secondary mathematics teachers in Spain. In order to achieve this purpose, five different studies were conducted. The results helped to identify different shortcomings, particularly regarding the mathematical content knowledge and competences of future teachers. As a consequence, this research also attempted to overcome the perceived deficiencies by proposing practical alternatives to be implemented in the MDTTSE in the specialty of mathematics. This concluding chapter presents an integrated overview of the most relevant findings of this research, aligned with the research objectives of this dissertation. The limitations of the different studies are next described, together with the implications for theory, practice and policy. Finally, directions for future research and recommendations for initial teacher education in Spain are suggested.

7.1 Introduction

Initial education programs play a central role in the preparation of future teachers (Darling-Hammond et al., 2005) and, as a consequence, in student achievement (Darling-Hammond, 2000). Initial teacher education is becoming increasingly complex and multi-faceted. The challenge of implementing a quality teacher education system is being experienced internationally (Levine, 2006). As stated in the introductory chapter, different factors influence – directly or indirectly – the extent to which initial teacher education programs accomplish their purpose, i.e., provide future teachers the knowledge, skills and attitudes necessary to perform effectively as teachers. The literature highlights the recruitment system (Bokdam et al., 2014; OECD, 2005), the content of the program (Darling-Hammond et al., 2005; Levine, 2006), the theory-practice linkage (Allen & Wright, 2013; Korthagen & Kessels, 1999), the existence of well-defined standards (Darling-Hammond, 2006; Kleinhenz & Ingvarson, 2007), or the preparation of teacher educators (Buchberger et al., 2000; Koster & Korthagen, 2001) as some of these factors. More specifically, previous research points at future teachers' subject-matter content knowledge and competences as key elements in the preparation of future teachers (European Commission, 2013; Osana et al., 2006; Rowan et al., 2002).

In Spain, the quality of initial teacher education programs at secondary education level has been recurrently questioned. Despite the last reform in initial teacher education in the academic year 2009-2010, still many issues are to be addressed, such as the heterogeneity between programs at the national level (Muñiz-Rodríguez et al., 2016a; Palarea, 2011), the disconnection between the different modules and subjects and between theory and practice (Santos & Lorenzo, 2015), the lack of a competence framework (Font, 2013; Muñiz-Rodríguez et al., 2017), the narrow subject-matter content knowledge of student teachers (López et al., 2013), the limited partnership between universities and secondary education schools (Valle & Manso, 2011), or the short experience and expertise of some teacher educators and mentors (Viñao, 2013).

The research carried out in the context of this dissertation dealt with initial teacher education programs for future teachers in secondary education in Spain, but focused on the particular case of future mathematics teachers. The center of attention was the mathematical background of student teachers who enter into an initial education program, and on the pursuance and attainment of teaching competences. Other significant factors – such as student teachers' motivation for teaching mathematics and teacher educators and mentors' experience and expertise – were also examined. On the basis of the results, one specific strategy to improve the acquisition of teaching competences was designed, implemented and evaluated by means of an intervention study.

This dissertation built on different theoretical frameworks which conceptualize the mathematical knowledge, pedagogical skills, and personal and professional attitudes that mathematics teachers should have for an effective teaching. A number of reliable research instruments were also designed and validated. These instruments comprise a wide range of variables, such as student teachers' academic background, initial teacher education programs' characteristics, student teachers' motivation for teaching mathematics, level of pursuance and attainment of competences for teaching mathematics in secondary education, or student teachers' competence related self-efficacy. Various research methods were combined, as well as data collection and analysis techniques. Considerable emphasis was placed on the online approach, by conducting online surveys or setting online assignments. Reflections and conclusions about the feasibility and success in the adoption of the theoretical, instrumental, and methodological frameworks are presented in the following sections, together with the main results of each research study.

7.2 Overview of the main results related to the research objectives

The general purpose of this dissertation was covered by five specific research objectives that guided the different studies of this research:

- **Research objective 1 (RO1).** To identify the principal strengths and weaknesses of initial education programs for future secondary mathematics teachers in Spain.
- **Research objective 2 (RO2).** To develop and validate a competence framework for secondary mathematics student teachers in Spain.
- **Research objective 3 (RO3).** To design and validate an instrument to assess the knowledge and competences of future secondary mathematics teachers.
- **Research objective 4 (RO4).** To assess the knowledge and competences of future secondary mathematics teachers in Spain.
- **Research objective 5 (RO5).** To design, implement and evaluate an intervention to enhance the development of a specific teaching competence – *giving constructive, purposeful and timely feedback* – during an initial education program.

In this section, the main findings in relation to each research objective are discussed. Further information has been provided in each of the preceding chapters.

7.2.1 RO1: The principal strengths and weaknesses of initial education programs for future secondary mathematics teachers in Spain

The study reported in Chapter 2 explored the organizational characteristics of initial education programs for future teachers in secondary education in sixteen countries, including Spain. The results show clear differences regarding the structure, the duration, the admission requirements, the level of the degree awarded at the completion of the program, and the existence of a competence framework (see also Muñiz-Rodríguez et al., 2016a). Some of these dissimilarities are of relevance because they can influence the extent to which initial teacher education programs prepare student teachers for their future role (OECD, 2014).

The principal strengths of initial teacher education in Spain lie in the professionalizing nature of the program and the significant weight of the practical component. Although the structure and the duration of the program have been a matter for debate at the national level (Santos & Lorenzo, 2015; Valdés & Bolívar, 2014), they are still considered adequate. In Spain, as in many other countries, initial teacher education programs follow a consecutive model, with an overall length of 4 (subject-matter training) + 1 (pedagogical training) years. Considering the specialist nature of mathematics teachers in secondary education, the structure of the program seems to be quite appropriate (Eurydice, 2012; OECD, 2014). Increasing the duration of the program to 2 years would allow student teachers to gain a deeper pedagogical – content – knowledge, but it would delay with one additional year the access to the labor market. The latter can be viewed as a discouragement by student teachers.

The major weaknesses of initial education programs for future secondary mathematics teachers in Spain relate to the broad structural differences between programs at the national level, the heterogeneous – and in some cases inappropriate – admission requirements, and the lack of a competence framework. First, the distribution of ECTS credits across the three different modules – generic, specific, and internship – is unequal from one program to another. This questions the extent to which contents are covered to the same extent. Second, the autonomy of Spanish universities to determine the bachelor degrees that allow candidates to enter directly into an initial teacher education program in mathematics leads to a significant variance in the mathematical background of student teachers. Moreover, some universities establish direct admission bachelor degrees with too limited mathematical content knowledge, which are, therefore, inadequate for becoming a mathematics teacher in secondary education. In third place, the ministerial order that regulates initial teacher education programs in Spain establishes very general competences required for the accreditation of the MDTTSE. Such competences seem slightly inaccurate and are common to all specialties. Besides, no benchmark information is available at the national/regional level. Appropriate measures should be introduced in order to overcome these deficiencies. The following research objectives pursued to tackle the perceived shortcomings.

7.2.2 RO2: Development and validation of a competence framework for secondary mathematics student teachers in Spain

The existence of comprehensive and specific frameworks of teaching competences has significant practical implications for initial teacher education (Erebus International, 2008; European Commission, 2013; Kleinhenz & Ingvarson, 2007). As stated earlier, the ministerial order that regulates the MDTTSE does not specify which knowledge, skills and attitudes secondary mathematics student teachers should demonstrate by the time they graduate from initial teacher education. This explains why the main aim of the study described in Chapter 3 was to develop and validate a competence framework for secondary mathematics student teachers, grounded in the Spanish context.

The first step to tackle this purpose consisted of a literature review about the most transcendent theories conceptualizing the knowledge and competences of – mathematics – teachers in secondary education. Starting from Shulman's notion of *pedagogical content knowledge* (1986, 1987), some other conceptual models were examined, such as the TPACK model (Koehler & Mishra, 2009), the MKT model (Ball et al., 2008), the DMK model (Godino, 2009), and the MTSK model (Carrillo et al., 2013). From this eclectic theoretical perspective, a first layer of the competence framework was drawn up.

The second step was based on a search of the academic literature about available and validated competence frameworks developed by teacher education organizations in a set of countries, such as the NCATE (2008) and the NCTM (2012) in the United States, the AAMT (2006) in Australia, the TA (Department for Education, 2011), the GTCS (2012), the EWC (Welsh Government, 2011) and the GTCNI (2011) in the United Kingdom, or the NPST in China (Wu, 2014). These frameworks were employed as a proxy for the development of the competence framework object of this study. As a result, thirty-two preliminary competences – classified into twelve different clusters – were defined.

The third and last step led to the validation of the competence framework. This was done by means of an expert panel consultation process: the Delphi method (Linstone & Turoff, 1975). During the consecutive rounds, some of the preliminary competences were modified or removed according to the suggestions given by the experts. Through this technique, a framework of thirty-three competences for secondary mathematics student teachers was validated (see also Muñiz-Rodríguez et al., 2017). These competences address mathematical content knowledge, mathematical pedagogical knowledge, teaching and learning processes, classroom management, lesson planning, assessment and mentoring, developmental psychology, inclusion and diversity, technology knowledge, communication skills, contribution to school organization, and personal commitment. During the consultation process, four competences did not achieve consensus. However, the research team did not find a logical explanation for their exclusion (see Chapter 3 for more detail). Still, they were labeled as *debatable competences* and carefully analyzed in a subsequent study of the present research. The results of the pilot study – described in Chapter 4 – support their relevance to be included in the final version of the competence framework. This decision was based on the relatively high level of importance that recently graduate secondary mathematics teachers gave to these competences. The development and validation of this framework laid a sound foundation for the assessment of competence development and acquisition during the MDTTSE in mathematics.

7.2.3 RO3: Design and validation of an instrument to assess the knowledge and competences of future secondary mathematics teachers

After an exhaustive search in the academic literature, no research instrument fully fitting the purpose of this dissertation was found. This explains why the study in Chapter 4 focused on the design and validation of a data collection instrument to assess the knowledge and competences of future secondary mathematics teachers. More specifically, the instrument aimed at measuring (1) the mathematical knowledge of those who enter into the MDTTSE in mathematics, and (2) the extent to which teaching competences are pursued and attained during the MDTTSE in mathematics.

The instrument was first designed building on available reliable measures. The items relative to future teachers' mathematical background and motivation for teaching mathematics were taken from the TEDS-M instrument (Brese & Tatto, 2012). The level of pursuance and attainment of teaching competences was examined using the framework of thirty-three competences designed and validated in the preceding study. Besides, one open-ended question concerning the opinion about the questionnaire was added as a source of feedback in view of the validation process. The preliminary version of the instrument is available in Appendix B. The instrument was designed in view of an upcoming study which intended to scope a national, representative sample in a cost-efficient way. This explains why an indirect measurement system – based on the perceptions of future teachers – was chosen (Blanton et al., 2006).

The instrument was next validated by means of a pilot online survey involving recently graduate secondary mathematics teachers from different Spanish universities (see also Muñiz-Rodríguez et al., 2016c). The results of the psychometric analysis indicate high reliability of the instrument. Notwithstanding, some indications for improvement were suggested by participants. In particular, they recommended to include a more detailed description of the items used to measure the mathematical background of future teachers. This suggestion was accepted and, as a consequence, a new version of the instrument was developed (see Appendix D). This instrument was next used to pursue the subsequent research objective.

In order to make a preliminary evaluation of the MDTTSE in the specialty of mathematics, the collected data were also analyze using descriptive statistics. The results show, on the one hand, gaps in certain areas of future teachers' mathematical knowledge and, on the other hand, basic competences weakly pursued and/or attained during the MDTTSE. These findings were supported by the results of the subsequent empirical study.

7.2.4 RO4: Assessment of the knowledge and competences of future secondary mathematics teachers in Spain

The study reported in Chapter 5 is considered the backbone of this dissertation. Building on the CIPO model (Scheerens, 1990, 2015), a number of quality indicators relative to the MDTTSE were analyzed, including the profile and mathematical background of future secondary mathematics teachers, the profile of teacher educators teaching in the MDTTSE and mentors supporting field experiences in secondary education schools, and the perception of the four stakeholder groups (i.e., student teachers, teacher educators, mentors, and recently graduate teachers) about the extent to which professional teaching competences are pursued and attained during the MDTTSE in the specialty of mathematics. To this end, the research instrument designed and validated in the preceding study was employed. An adapted version was developed for teacher educators and mentors (see Appendix E and Appendix F). The study was conducted by means of an online survey. Below, the most significant findings are summarized.

There is a strong motivation of future secondary mathematics teachers for the profession. Overall, internal or vocational reasons (such as loving mathematics, having a talent for teaching, liking to work with young people, or seeing teaching as a challenging job) prevail over external or professional reasons to become a mathematics teacher in secondary education. This is promising because motivation ensures dedication and enthusiasm, among other personal attitudes necessary to perform effectively as a teacher (Bakker, 2005).

The level and depth of mathematical knowledge of those who enter into the MDTTSE in mathematics is, in some cases, insufficient. The problem comes from the admission requirements established by certain universities. Bachelor degrees with poor mathematical content are sometimes accepted to enter directly into the program (see Muñiz-Rodríguez et al., 2016a). Considering the influence of teachers' mathematical knowledge on student mathematical achievement (Hill et al., 2005), this is a critical issue in initial teacher education in Spain. Moreover, the low or average marks in university of future secondary mathematics teachers suggest that Spanish universities do not always recruit outstanding aspirants.

Regarding teacher educators and mentors, the results point at the limited experience and expertise of both sample groups. The lack of strict criteria for selecting teacher educators and mentors in Spain poses an additional weakness of the initial teacher education system. A number of research studies explain that teacher educators as well as mentors play an essential role in the preparation of future teachers (Even & Krainer, 2014; Murray & Male, 2005). Besides, few programs and courses are being conducted to help teacher educators and mentors to effectively train future teachers for the profession.

On the one hand, the perceptions of student teachers, teacher educators, mentors and recently graduate teachers reflect that teaching competences are pursued to a moderate extent during the MDTTSE in mathematics, both in theory and practice. On the other hand, student and recently graduate teachers perceive that teaching competences are attained to a small or moderate extent. In fact, their perceptions are significantly below the mastery learning benchmark (Zimmerman & Dibenedetto, 2008), put forward at the 80% level. As a consequence, the four stakeholder groups qualified the MDTTSE as moderately effective in view of preparing future secondary mathematics teachers for the profession. These findings suggest that there is little assurance that the MDTTSE train future secondary mathematics teachers towards the mastery of teaching competences and, consequently, towards the teaching career. The former suggests the need to implement new strategies which provide student teachers the opportunity to develop teaching competences to the fullest extent. The following – and last – research objective of this dissertation undertakes this research initiative.

7.2.5 RO5: Design, implementation and evaluation of an intervention to enhance the development of a specific teaching competence during an initial education program

The results of the preceding study indicate that some teaching competences are hardly pursued – and consequently scarcely achieved – during the MDTTSE in mathematics. Giving constructive, purposeful and timely feedback to students is one of such competences. As previously described in Chapter 6, this dissertation tackles the general research problem in an innovative way with the design, implementation and evaluation of a competence development intervention involving secondary mathematics student teachers in the MDTTSE. The intervention aimed at exploring the potential of video-vignettes as a response-based simulation strategy to develop secondary mathematics student teachers' feedback competence. According to the literature, watching and analyzing real-life classroom situations provide student teachers with the opportunity to evolve, reflect on and improve their teaching practices (Bogo et al., 2013; Jeffries & Maeder, 2004).

The design of the intervention built on an integrated theoretical perspective. The model of Blömeke et al. (2015) laid a sound foundation for the overall conceptual framework. In particular, this model helped to characterize the developmental stages of teaching competences. The feedback model of Hattie and Timperley (2007) was first introduced as a cognitive schema to develop the feedback competence. This was done by means of an instructional process during the implementation of the intervention. Next, student teachers' feedback competence was assessed using a list of indicators related to the three feedback perspectives (i.e., feed-up, feed-back, and feed-forward) and the four feedback levels (i.e., task, process, self-regulation, and self). Besides, Blooms' revised taxonomy (Anderson & Krathwohl, 2001) was also used to screen student teachers' reflections. The focus of attention was on the two founding levels: remembering and understanding.

The intervention was implemented as an online course assignment within the MDTTSE in the specialty of mathematics. Student teachers were invited to react to different real-life classroom situations depicted in the video-vignettes by answering open-ended questions. The video-vignettes were previously designed on the base of video-recordings of lessons prepared for the purpose of this study. A number of questions were embedded during regular intervals in each video-vignette in order to focus student teachers' attention of particular features of instruction and, subsequently, explore their feedback competence. The intervention consisted of three sessions, structured as follows: opening, pre-test, instruction, training, post-test, and closing.

The impact of the intervention was studied according to student teachers' feedback competence development. To this end, student teachers' responses to the questions embedded in the pre-test and post-test video-vignettes were analyzed. A self-efficacy scale was also used to measure their related self-perceived feedback competence (see Appendix G). Overall, the results reflect a positive impact of the intervention on the development of student teachers' feedback competence. Participants' competence to provide feedback at the feed-forward perspective and at the process level seemed to be well-developed already before the training and remained invariable afterwards. A significant increase in the number of indicators related to feedback at the feed-up and feed-back perspectives and at the task level clearly reflects development in student teachers' competence. Reactions related to feedback at the self-regulation level were scarce before and after the training. This is troubling. In view of a future implementation of the intervention, stronger emphasis should be given to this feedback level by, for instance, providing student teachers with specific strategies that foster self-regulation in the classroom (see Nicol & Macfarlane-Dick, 2006). A moderate decrease was observed in the number of references related to feedback at the self level.

The latter was not considered a deterioration taking into account that feedback at this level is the least effective (Hattie & Timperley, 2007). Besides, the overall feedback competence development was observed at both taxonomical levels: remembering and understanding. The intervention also resulted in a number of additional achievements. For instance, student teachers' motivation was strengthen as a consequence of interacting with the video-vignettes in an online environment. Also, the combination of an instructional video with a series of real-life classroom situations fostered the link between theory and practice. In general, the findings support the potential of video-vignettes as an effective strategy for the development of teaching competences during initial teacher education. This provides a strong foundation for the implementation of this kind of clinical response-based simulation strategies in the MDTTSE, not only to pursue student teachers' feedback competence, but some other teaching competences.

7.3 Limitations

In this section, an overview of the limitations of this dissertation is provided. The reader should bear in mind that theoretical, instrumental, and methodological choices were made considering the feasibility of the research.

The first limitation concerns the sample sizes of the five research studies. In total, seven different sample groups were involved in the development of this research: the expert panel (n=31) who helped validating the competence framework, the group of graduate teachers (n=51) who participated in the validation of the instrument to assess the knowledge and competences of future secondary mathematics teachers, the student teachers (n=95), teacher educators (n=95), mentors (n=96), and graduate teachers (n=29) who took part in the online survey, and another group of student teachers (n=14) who engaged in the intervention. The sample sizes were, in some cases, relatively small. In particular, very few student teachers participated in the intervention study. Besides the limited size, a convenience sampling technique was used in all the studies. So another limitation relates to the voluntary nature of the participants. Both constraints are explained by the difficulty to get access to a database of the target population groups (see page 31 of this dissertation for more detail). Also, the comprehensiveness of the competence framework resulted in a long questionnaire, especially for student and graduate teachers. The latter increased the risk of dropout, leading to a smaller sample.

In the particular case of the intervention, engaging universities in this endeavor proved to be extraordinarily difficult. Because of time, money and practical limitations, the involvement of larger samples was unfeasible. As a consequence, the results cannot directly be generalized to other educational levels, specialties, or countries. Moreover, this limitation affected the applicability of more advanced statistical techniques. Notwithstanding, the reader may note that a relatively high number of universities (n=47) and secondary education schools (n=86) were represented (see Appendix C for more detail). Still, it was impossible to examine sample representativeness due to the nature of the data source. Future research may pay more attention to rigor in the sampling procedure. This limitation also suggests the need to start developing a public, centralized and comprehensive database of the profile of student teachers, teacher educators, mentors, and recently graduate teachers in Spain. In particular, the findings of the intervention study can be further enhanced by involving additional or larger sample groups. For instance, a higher number of student teachers could help to compare the effects of the experimental group with a control group. Also, it could be of interest to include a sample of teacher educators in order to stimulate a group discussion after each video-vignette based on student teachers' reactions.

The second limitation concerns the use of an indirect measurement method to assess future secondary mathematics teachers' subject-matter content knowledge and competences. Despite a multi-actor perspective was adopted, perceptions were used as the base for collecting and analyzing data. This choice was made considering the characteristics of the context and the purpose of the studies. Although helpful in some regards (for instance determining the adequacy of a list of competences), self-report data have obvious limitations. Indirect measurement methods suffer from validity problems. As a consequence, it is difficult to know whether the results reflect exact appraisals of future teachers' subject-matter content knowledge and competences. Through perceptions, participants tend to under- or over-estimate their knowledge and competences and respond to socially desirable answers. This constraint also explains the emphasis placed on the quantitative approach. The employment of additional direct measurement methods (such as interviews, focus groups, or observations of student teachers' behaviors) could help to interpret the research findings at a deeper level. In this sense, future research may consider the adoption of a mixed method research design, including qualitative data.

A third limitation concerns the variables used to assess future teachers' subject-matter content knowledge. Student and graduate teachers' mathematical knowledge was measured considering (1) the nature of their bachelor degree and (2) whether they had ever studied a list of mathematics topics prior to entering into the MDTTSE. However, previous research criticizes that having studied a bachelor degree does not assure that a person understands and is able to explain the related subject-matter (Diamond et al., 2013; Goldhaber & Brewer, 2000). Further, the second factor originates from self-report data, which may have caused bias in the results. Future research should explore in detail the effects of alternative selection processes. This would be an important step in assuring that candidates who enroll in the MDTTSE have a deep subject-matter content knowledge.

7.4 Implications

In this section, the theoretical, empirical, and practical implications of this dissertation to the field of initial teacher education are presented.

The theoretical relevance of this dissertation is reflected in several ways. The results of the first study (see Chapter 2) add to the state of the art on the identification of factors influencing the quality of initial teacher education programs in Spain. This helps to explain differences between countries in the preparation of future teachers in secondary education. The second study (see Chapter 3) succeeded in developing and validating a competence framework for future secondary mathematics teachers, grounded in sound theoretical models and international research literature. As such, it has potential consequences both at the national and the international level. On the one hand, this competence framework provides a strong foundation to measure teaching knowledge and competences. Therefore, it can now be implemented in the curriculum of the MDTTSE in the specialty of mathematics. On the other hand, the validated framework can also be adapted and improved for use in subsequent studies, whether in other specialties or countries. In the last study (see Chapter 6), a competence development intervention based on a combination of conceptual and theoretical frameworks was designed. This design can subsequently be used to target similar interventions aiming at developing additional teaching competences. Besides, the intervention study contributes to the literature by proving that student teachers' knowledge, skills and attitudes can be influenced by video-based intervention programs.

Besides the theoretical relevance, this dissertation contributes to the research literature through the development and disposal of validated instruments. First, reliable measures and scales were developed for the assessment of student teachers' mathematical knowledge and competences. Previous research has already adopted valid direct and indirect measurement methods, but these were often limited to a small number of competences. The research instrument developed in Chapter 4 scopes a wide range of mathematical knowledge domains and teaching competences. Although it targets the specifics of the MDTTSE in the specialty of mathematics, this instrument can be adapted and employed in survey studies, involving nationwide, representative samples, in a cost-efficient way. Besides, this instrument was designed in four different versions, in order to gain the perceptions of four stakeholder groups: student teachers, teacher educators, mentors, and recently graduate teachers. Second, a reliable self-efficacy scale was also developed to capture student teachers' self-efficacy about their competence to provide and seek feedback to/from students. This scale is grounded on a theoretical construct and can be implemented in future research studies.

From an empirical point of view, this dissertation provides accurate data sets on factors related to the initial education of future secondary mathematics teachers in Spain. Up to know, there was a lack of nationwide, empirical evidence documenting the subject-matter knowledge and competences of future secondary mathematics teachers. While prior research has focused on primary student teachers, less attention has been paid to secondary student teachers. Remember that the Spanish participation in the TEDS-M was limited to future mathematics teachers in primary education because of special difficulties anticipated in collecting data from future teachers in secondary education. The study described in Chapter 5 is, as far as the author of this dissertation knows, the first major exploratory, nationwide study about secondary mathematics initial teacher education in Spain. In this sense, this dissertation is considered pioneering at the national level. The results provide valuable evidence about a number of factors, such as the mathematical background and motivation for teaching of future secondary mathematics teachers, the experience and expertise of teacher educators and mentors, and the perceptions of the four groups about the level of pursuance and attainment of teaching competences during the MDTTSE in mathematics. The key achievement was the involvement of a relatively large number of universities and secondary education schools, both in the public and the private sector.

This dissertation is also relevant for the educational practice and policy. From the practical point of view, the most significant contribution is the development of an intervention to foster the acquisition of teaching competences during initial teacher education. Besides, the use of video-vignettes was used as a way to bridge the perceived theory-practice gap and increase the opportunities to observe and reflect on real-life classroom situations. Future research studies attempting to establish feedback competence development activities can benefit from the available materials and experiences. In particular, the author of this dissertation encourages teacher educators and initial teacher education institutions in Spain to implement this approach in the MDTTSE.

In addition, this dissertation intends to inform policymakers and educational leaders about the urgent need to reformulate different elements of initial education programs for future secondary mathematics teachers in Spain. As previously mentioned, in the academic year 2009-2010 the Spanish Ministry of Education and Science implemented the MDTTSE. The findings of the different studies reveal that, eight years later, the new initial teacher education program has barely achieved its initial purpose. Responsibility for the later is, to some extent, placed in the hands of policymakers and educational leaders.

First, the ministerial order that regulates the MDTTSE puts forward rather general competences required for the accreditation of initial education programs. These competences are common to all specialties and, in some cases, redundant. Besides, important gaps can be identified. Therefore, the author of this dissertation advocates policymakers and educational leaders to actualize the broadly formulated competences of the ministerial order and establish a clear description of a mastery level that student teachers are expected to achieve. In this sense, this dissertation proposes a competence framework for future secondary mathematics teachers which can be implemented in the curriculum of the MDTTSE in the specialty of mathematics. Initial teacher education institutions should explore the value of this framework for assessing and guiding initial teacher education programs. The later would improve the quality of initial teacher education at the national level. Although benchmark information has not yet been provided, this framework can already play a valuable role in the accreditation of student teachers.

Another policy implication concerns the direct admission bachelor degrees established by the different universities offering the MDTTSE in mathematics. The results of the studies conducted in the context of this dissertation illustrate that certain degrees seem inadequate for becoming a mathematics teacher in secondary education, mainly because of their limited mathematical content. Authority to change the admission requirements is assigned to policymakers and educational leaders. The definition and implementation of a common national framework of direct admission bachelor degrees is a demanded requirement in this field.

Another suggestion concerns the lack of preparation of teacher educators and mentors on how to prepare future teachers for the profession. In this sense, policymakers and educational leaders should design and implement training programs and courses to help these stakeholder groups to undertake their work more effectively.

Finally, taking into account the negative perceptions of student teachers, teacher educators, mentors, and recently graduate teachers about the level of pursuance and attainment of teaching competences, policymakers and educational leaders should encourage and financially support initial teacher education institutions to employ alternative, effective strategies which provide student teachers opportunities to better develop teaching competences. A number of concrete proposals are suggested in the following section.

7.5 Directions for future research

Considering the overall results of the different studies, it is possible to discuss some directions for future research that go beyond the specific research objectives of this dissertation. As previously mentioned, particular features of initial teacher education in Spain demand immediate, practical reforms. The following proposals concern three courses of action: (1) the design and validation of an alternative recruitment system of future secondary mathematics teachers, (2) the development and implementation of a training program for teacher educators and mentors, and (3) the formulation and evaluation of additional effective strategies to promote competence development during initial teacher education. Following, a brief explanation of each perspective is outlined.

7.5.1 Design and validation of an alternative recruitment system of future secondary mathematics teachers

In some Spanish universities, the current admission requirements to enter into an initial education program for future secondary mathematics teachers represent a major problem. The results of this dissertation suggest that a possible short-term measure consists of limiting the variety of direct admission bachelor degrees. The findings described in Chapter 5 suggest that only a degree in mathematics or statistics provides an adequate mathematical background. However, this measure could result in the exclusion of potential candidates because of a too narrow selection policy. Therefore, the design and validation of an alternative recruitment system, common to all Spanish universities, is proposed.

Across countries, there is a multiplicity of criteria to enter into an initial teacher education program, such as diploma requirements, *numerous clausus* policies, competitive examinations, standardized tests, or personal interviews (OECD, 2014). However, no consensus exists on which is the best route into teaching (see Heinz, 2013). In Finland – where initial teacher education is considered a highly competitive field – a proficiency test in mathematics and science has been proven to be a relevant criteria to select student teachers with quality mathematical knowledge (see Kaasila, Hannula, Laine, & Pehkonen, 2008). Using this as an example, the author of this dissertation suggests to conduct an experimental study to compare the effects of the selection criteria currently established in Spain (control group) with a competitive examination (experimental group). This aims at identifying patterns of association between student teachers' condition to enter into the MDTTSE and their performance during teaching practice. Undertaking this study will entail a number of processes.

First, it would be necessary to design an entrance exam about mathematical contents. The exam will consist of eight mathematics problems. A total of eight experts (including teacher educators, mentors, and secondary mathematics teachers) will perform this task. Each expert will first suggest one mathematics problem for each specific domain: discrete structures and logic, geometry, continuity and functions, and probability and statistics. For each category, experts will be asked to rank the proposed mathematics problems. Next, the aggregate ranking for each category will be computed based on a suitable technique (see Pérez-Fernández, Rademaker, & De Baets, 2017). Finally, in order to select a total of eight problems, the two highest ranked problems in each category will be selected. The exam can be tested by means of a pilot study with a random group of secondary mathematics student teachers.

The experimental condition will be set up in six Spanish universities offering an initial education program for future secondary mathematics teachers. Prior to the enrollment process, candidates will be required to undertake the entrance exam previously designed for the purpose of this research. The exams will be subsequently grade by the same expert group. Only candidates who achieved at least 80% of the total grade will be selected to enter into the MDTTSE in mathematics. Data about selected candidates' bachelor degree and marks in university will also be stored.

At the same time, the control condition will be applied in six different Spanish universities offering an initial education program for future secondary mathematics teachers. Candidates will be selected following the existing procedure in each university. No additional requirements will be imposed. Data about student teachers' bachelor degree and marks in university will be collected.

During regular intervals during the initial teacher education program, student teachers participating in the study will be asked to complete an online task in which they have to demonstrate both their mathematical content knowledge and their mathematical pedagogical knowledge. The same group of experts will assess student teachers performance on each task by providing grades representing their teaching practice.

Finally, statistical analysis will be performed combining the three data sets. The results will allow to identify patterns of association between student teachers' bachelor degree, student teachers' marks in university, student teachers' exam grade, and student teachers' performance during teaching practice. As a consequence, it will be possible to decide on a better recruitment system of future secondary mathematics teachers.

7.5.2 Development and implementation of a training program for teacher educators and mentors

In Spain, as in many other countries, becoming a teacher educator – or a mentor – without having received special preparation for training student teachers is a reality (see Chapter 5). However, previous research explains that teacher educators as well as mentors have a significant influence on the preparation of future teachers (Even & Krainer, 2014; Murray

& Male, 2005). Thus, the development and implementation of a training program for teacher educators and mentors is imperative. This initiative pursues a number of specific research objectives: determine the competences and standards that teacher educators and mentors need to accomplish, develop an accurate assessment system of those standards, and design strategies to help teacher educators and mentors to attain those standards.

A first approach to the first research objective consists of a search of the academic literature about studies relative to the professional competences of teacher educators and mentors. In this sense, the Association of Teacher Educators (ATE, 2002) puts forward seven core standards for teacher educators that can be summarized as follows: (1) model professional practices, (2) apply cultural competence and promote social justice in teacher education, (3) inquiry and contribute to scholarship that expands the knowledge base related to teacher education, (4) inquire into, reflect on, and improve own practice, and commit to continuous professional development, (5) provide leadership in developing, implementing, and evaluating teacher education programs, (6) collaborate with relevant stakeholders to improve teaching, research, and student learning, and (7) serve as informed, constructive advocates for high quality education. Building on these standards, a first overview of teacher educators and mentors' competences can be developed.

A second step in this study goes through a consultation process (such as the Delphi method) involving teacher educators, mentors, and novice teachers who recently graduate from an initial teacher education program. Several reasons explain the adoption of a mixed sample group. On the one hand, Koster et al. (2005) explain the relevance of making the target group responsible for developing the content of their own professional profile. On the other hand, novice – but recently graduate – teachers have been exposed to a wide range of teacher educators and mentors during their initial teacher education. Therefore, they have shaped opinions about quality requirements for these stakeholder groups (Smith, 2005). Besides, they should be aware about what it means to be a teacher. Thus, the second part of the study aims at exploring participants' answers to open-ended questions about required competences of skilled teacher educators and mentors.

On the basis of the combined results from the ATE standards and participants' responses, a first version of a professional profile of teacher educators and mentors can be outlined. In particular, participants' responses will provide valuable feedback in order to develop specific indicators of each standard. Following the structure of a consultation process, the three sample groups will be able to give their opinion on the adequacy of each competence described in the preliminary version. A subsequent data analysis will lead to determine the competences and standards that teacher educators and mentors need to accomplish.

In view of the second research objective, focus group interviews can be conducted to explore the way in which the consensual standards might be assessed. The sampling will consist of groups of five to eight people who are teacher educators themselves or experts in teacher education research. The later will help to develop an accurate assessment system of those standards. This outcome can also be used as a starting point for the implementation of a recruitment system for teacher educators and mentors, which is currently missing in Spain.

The last research objective pursues the development of a professional development program for teacher educators and mentors building on the agreed standards. It has been criticized that teacher educators are often unaware of the real problems of teaching to the same extent mentors are not acquainted with the theoretical instruction student teachers receive during an initial education program. Quality teacher education would require a system that promotes a close, successful partnership between teacher educators and mentors, and therefore, between universities and schools (Darling-Hammond, 2006; Korthagen & Kessels, 1999). Therefore, an intervention study to examine the effects of a training workshop in which teacher educators and mentors work together is proposed. The idea is to expose participants to a real-life classroom situation depicted in a short sketch. Next, they are asked to individually construct a portfolio containing a description of how they would prepare student teachers to react to that specific situation from their professional perspective as teacher educators or mentors. Each teacher educator participating in the workshop is next paired off with a mentor. Each couple is requested to discuss their reactions and provide feedback to each other using the standards as reference points. Finally, participants are asked to add the outcomes of the peer discussion in their preliminary portfolios. This initiative fits the Community Learning Model (CLM). Content analysis of the written portfolios will be conducted in order to explore the effects of the intervention.

7.5.3 Formulation and evaluation of additional effective strategies to promote competence development during initial teacher education

This dissertation has already succeed in the design, implementation and evaluation of an effective strategy to enhance the development of a specific teaching competence (see Chapter 6). However, the negative results regarding the pursuance and attainment of teaching competences during initial teacher education programs in Spain strongly encourage to provide additional, practical alternatives to be implemented in the MDTTSE. In particular, *participate actively in school decision making* (CSO3) was perceived as one of the weakest pursued and attained competences (see Chapter 5). As previously explained, simulation-based activities are emerging as a latent tool in initial teacher education (Cioffi, 2001; Dotger, 2013). The study described in Chapter 6 explored the effects of video-vignettes as a response-based simulation strategy to develop secondary mathematics student teachers' feedback competence. The third proposal for future research aims at examining the potential of a process-based simulation to promote decision-making competence development during initial teacher education.

To design this simulation, the study of Dotger et al. (2014) will be used as an example. Secondary mathematics student teachers enrolled in the MDTTSE in mathematics in a number of Spanish universities will be the target population of this study. Besides, three actors from theater organizations will be encouraged to voluntarily participate in the simulation. They will be carefully trained to perform as standardized students for the purpose of this study. Two sets of documents – a Teacher Interaction Protocol and a Standardized Individual Protocol – will be carefully designed. The Teacher Interaction Protocol provides each secondary mathematics student teacher substantial background and contextual information about the simulated environment which, in this case, will focus on a school decision-making situation. The Standardized Individual Protocol serves as a training guide for the standardized students. As such, it gives specific triggers that each standardized student will issue during the simulation.

The implementation of the intervention will take place in three similar examination studios looking as a teacher's room. Two cameras and two microphones will be installed to videotape each simulation. One student teacher and one standardized patient will enter into an examination room to subsequently start the simulated performance. Three simulations – one per actor – will be run simultaneously. Afterwards, each student teacher will be allowed to watch the video of his/her performance. The research team will next select some critical episodes in order to conduct a semi-structured group debriefing. Data will be analyzed through content analysis techniques, using the videos of student teachers' performance and researchers' notes from the group debrief session. The results will provide valuable feedback for the evaluation of the process-based simulation strategy.

The latter is just one example of a possible alternative to enhance competence development during initial teacher education. Comparable strategies should be designed regarding other weakly pursued and attained teaching competences, such as *contribute in the design of the comprehensive education plan and common school activities* (CSO2), or *know relevant findings from teaching mathematics research* (MPK4).

7.6 Final conclusion

Initial teacher education represents a fundamental but complex field. This complexity is largely explained by the demands of today's society, who requires teachers to demonstrate a full range of competences right from the start of their career. Effectiveness in teaching does not simply resides in the knowledge a teacher has accrued, but in how this knowledge is efficiently used in classrooms. Despite the already mentioned limitations, this dissertation provides extensive evidence about different shortcomings regarding initial education programs for future secondary mathematics teachers in Spain. The perceptions of student teachers, teacher educators, mentors, and recently graduate teachers are too important to be neglected. Future secondary mathematics teachers seem to have a strong motivation for teaching mathematics, but the MDTTSE falls short of providing them with the necessary competences to become effective teachers. Similarly, it is essential to better understand and strengthen the position of teacher educators and mentors in this context. Therefore, improving initial teacher education becomes a major challenge for Spanish institutions, policymakers and educational leaders.

Conclusiones y líneas futuras

Esta investigación tiene por objetivo analizar los programas de formación inicial para el futuro profesorado de matemáticas en Educación Secundaria en España. Con esta finalidad se han realizado un total de cinco estudios de carácter tanto descriptivo y exploratorio como experimental, que buscan conceptualizar y evaluar los conocimientos y competencias del futuro profesorado de matemáticas en Educación Secundaria. A continuación, y a la luz de los resultados obtenidos, se presentan las principales conclusiones de esta tesis doctoral, que han permitido dar respuesta a los objetivos y preguntas de investigación planteadas. Asimismo, se describen futuras líneas de investigación que posibilitan dar continuidad a estos estudios.

En primer lugar, se pretende identificar las principales fortalezas y debilidades de los programas de formación inicial para el futuro profesorado de matemáticas en Educación Secundaria en España. Para ello, en primer lugar, se realiza una comparativa internacional que permite contrastar las similitudes y diferencias entre España y otros países. Los resultados muestran claras diferencias en cuanto a la estructura, la duración, los requisitos de acceso, la titulación obtenida al finalizar el programa, y la existencia de un marco de competencias (véase Muñiz-Rodríguez et al., 2016a). Algunas de estas diferencias son relevantes ya que pueden influir en la medida en que los programas de formación inicial preparan al futuro profesorado de cara al desarrollo de la labor docente (OECD, 2014).

Por un lado, las principales fortalezas del contexto español residen en el carácter profesionalizante del programa, así como en la acentuación de la componente práctica en comparación con el modelo anterior. Si bien la estructura (de naturaleza consecutiva) y la duración (de 1 año) del programa parecen adecuadas, estos aspectos han sido objeto de debate a nivel nacional (Santos & Lorenzo, 2015, Valdés & Bolívar, 2014), ya que algunos investigadores abogan por un programa de 2 años con un mayor vínculo entre la formación disciplinar y la pedagógica.

Por otro lado, las principales debilidades encontradas están vinculadas a (1) las diferencias estructurales entre los programas de formación, (2) la heterogeneidad de los requisitos de acceso a la especialidad de matemáticas entre las distintas universidades, y (3) la falta de un marco de competencias a nivel nacional. En primer lugar, la distribución de los créditos ECTS en los diferentes módulos (genérico, específico y práctico) es desigual de un programa a otro. Esto cuestiona la medida en que el alumnado matriculado en los distintos programas recibe la misma formación y al mismo nivel de desarrollo. En segundo lugar, la autonomía de cada una de las universidades españolas para determinar qué titulaciones dan acceso directo a la especialidad de matemáticas, da lugar a un heterogéneo – y en algunos casos limitado – conocimiento matemático del profesorado en formación. En tercer lugar, si bien la orden ministerial que regula los programas de formación inicial docente en España establece un listado de competencias para la acreditación del título, estas son imprecisas, redundantes y comunes a todas las especialidades.

En consecuencia, y en línea con el segundo objetivo de investigación, el siguiente paso fue definir y validar un marco de competencias para el futuro profesorado de matemáticas en Educación Secundaria, adaptado al contexto español. La fase de diseño se llevó a cabo a partir de una revisión de la literatura sobre, por un lado, modelos teóricos que buscan conceptualizar el conocimiento del profesor – como el conocimiento pedagógico del contenido de Shulman (1986), el modelo TPACK (Koehler & Mishra, 2009), el modelo MKT (Ball et al., 2008), el modelo del conocimiento didáctico-matemático (Godino, 2009), o el modelo MTSK (Carrillo et al., 2013) – y, por otro lado, marcos de competencias disponibles en otros países – como Estados Unidos (NCATE, 2008; NCTM, 2012), Australia (AAMT, 2006), Reino Unido (Department for Education, 2011; GTCNI, 2011; GTCS, 2012; Welsh Government, 2011) o China (Wu, 2014). Lo anterior dió lugar a un marco preliminar de treinta y dos competencias, clasificadas en doce áreas.

La fase de validación de dicho marco consistió en un proceso de consulta a expertos, durante el cual algunas de las competencias inicialmente definidas fueron modificadas o eliminadas de acuerdo a las sugerencias proporcionadas por los participantes. A través de esta técnica, fue posible validar un marco de treinta y tres competencias para el futuro profesorado de matemáticas en Educación Secundaria (véase Muñiz-Rodríguez et al., 2017). Estas competencias se clasifican en doce áreas: conocimiento matemático, conocimiento didático matemático, procesos de enseñanza y aprendizaje, gestión del aula, planificación de las enseñanzas, evaluación y tutoría, desarrollo personal del estudiante, inclusión y atención a la diversidad, tecnología de la información y la comunicación, habilidades comunicativas, participación en la comunidad educativa, y ética profesional. Durante el proceso de consulta a expertos, cuatro de las treinta y tres competencias no lograron consenso. Sin embargo, el equipo de investigación no encontró una explicación lógica para su exclusión. Por ello, estas competencias fueron etiquetadas como *discutibles* y, en consecuencia, analizadas con detalle en un estudio posterior. Los resultados del sucesivo estudio piloto corroboran su pertinencia para ser incluidas en la versión final del marco de competencias. Esta decisión se justifica debido al elevado nivel de importancia que los recién titulados en la especialidad de matemáticas de un programa de formación inicial docente otorgan a estas competencias. El diseño y la validación de este marco constituye un instrumento fundamental para la evaluación del desarrollo y adquisición de competencias durante el periodo de formación inicial.

Así, tomando lo anterior como referente, fue posible diseñar y validar un instrumento para medir los conocimientos y las competencias del futuro profesorado de matemáticas. Más específicamente, se elaboró un cuestionario para examinar (1) el conocimiento matemático del alumnado que accede a la especialidad de matemáticas de un programa de formación inicial docente, y (2) el nivel de desarrollo y adquisición de las competencias durante el periodo de formación. Dicho instrumento fue diseñado tomando como referencia variables y escalas previamente validadas (véase por ejemplo Brese & Tatto, 2012) así como el marco de competencias previamente elaborado. Además, con vistas a ser utilizado para recoger información sobre muestras representativas y de suficiente tamaño, se optó por un método de medición indirecta basado en la percepción de los sujetos participantes.

A continuación, el instrumento fue validado mediante un estudio piloto en el que participaron recién titulados en la especialidad de matemáticas de un programa de formación inicial docente en diferentes universidades españolas (véase Muñiz-Rodríguez et al., 2016c). Los resultados del análisis psicométrico indican una alta fiabilidad del instrumento. No obstante, algunos participantes sugirieron indicaciones de mejora, como la inclusión de una descripción más detallada de los elementos utilizados para medir el conocimiento matemático del futuro profesorado. Esta sugerencia fue aceptada y, como consecuencia, se desarrolló una nueva versión del instrumento, que fue utilizada con vistas a la consecución del tercer objetivo de investigación.

El siguiente estudio, considerado el eje vertebral de esta investigación, pretende evaluar los programas de formación inicial para el futuro profesorado de matemáticas en Educación Secundaria en España, centrándose en el nivel de desarrollo y adquisición de competencias. Con esta finalidad, se lleva a cabo un estudio a nivel nacional, en el que participan profesores de matemáticas en formación, formadores de profesores de matemáticas, tutores de prácticas en centros de Educación Secundaria, y recién titulados en la especialidad de matemáticas de un programa de formación inicial, de diferentes universidades españolas. Para la recogida de datos se utilizó el instrumento diseñado y validado en la fase anterior, que permite conocer el perfil y conocimiento matemático del futuro profesorado, el perfil de los formadores de profesores de matemáticas y tutores de prácticas, así como la percepción de los cuatro grupos muestrales acerca del nivel de desarrollo y adquisición de competencias durante el programa de formación inicial docente. El estudio se llevó a cabo mediante una encuesta en línea.

Los resultados confirman que el futuro profesorado de matemáticas tiene vocación para la docencia. En general, las razones de naturaleza intrínseca prevalecen sobre las razones meramente profesionales. Esto es alentador ya que la motivación asegura dedicación y entusiasmo, entre otras aptitudes personales necesarias para el desempeño docente (Bakker, 2005). Sin embargo, el conocimiento matemático de aquellos que acceden a la especialidad de matemáticas de un programa de formación inicial docente es, en algunos casos, insuficiente. La causa de este problema radica en la naturaleza de los requisitos de acceso establecidos por ciertas universidades. En ocasiones, se aceptan titulaciones con un escaso contenido matemático para entrar en el programa y, en consecuencia, para enseñar matemáticas en Secundaria. Teniendo en cuenta la influencia del conocimiento matemático de un docente sobre el rendimiento matemático del alumnado (Hill et al., 2005), este es un aspecto crítico de los programas de formación inicial docente en España.

Con respecto a los formadores de profesores y tutores de prácticas, los resultados ponen de manifiesto una limitada experiencia y formación para preparar al futuro profesorado. La ausencia de criterios para la selección de formadores de profesores y tutores de prácticas en España plantea una debilidad adicional del sistema de formación inicial docente. Investigaciones previas explican que tanto los formadores de profesores como los tutores de prácticas desempeñan un papel esencial en la preparación de futuros docentes

(Even & Krainer, 2014; Murray & Male, 2005), motivo por el cual es necesario desarrollar e implementar programas y cursos de formación para capacitar a estos profesionales.

Por último, las percepciones de los profesores de matemáticas en formación, formadores de profesores, tutores de prácticas, y recién titulados en la especialidad de matemáticas reflejan un bajo nivel de desarrollo de las competencias durante el periodo de formación, tanto en la componente teórica como en la práctica. Además, los profesores de matemáticas en formación y los recién titulados en la especialidad de matemáticas perciben un débil nivel de adquisición de las competencias. En consecuencia, los cuatro grupos muestrales cuestionan la eficacia de los programas de formación inicial en España para preparar al futuro profesorado de matemáticas en Educación Secundaria para la profesión. Estos hallazgos sugieren la necesidad de implementar nuevas estrategias que proporcionen al profesorado en formación la oportunidad de desarrollar las competencias en mayor medida.

El último objetivo de investigación planteado en esta tesis doctoral pretende impulsar esta iniciativa, para lo cual se propone el diseño, implementación y evaluación de una intervención, que tiene por finalidad explorar el impacto del uso de vídeo-clips en los programas de formación inicial docente como herramienta para potenciar el desarrollo de competencias. Para ello, se seleccionó aquella competencia que, en base a los resultados del estudio anterior, está siendo desarrollada y adquirida en menor medida, esto es: *proporcionar retroalimentación constructiva, útil y oportuna al alumnado, a sus familias, y a otros profesionales del centro.*

La intervención fue diseñada a partir de diferentes modelos teóricos que caracterizan las etapas de desarrollo de competencias (Blömeke et al., 2015) y de la experiencia de varios profesores de matemáticas en Educación Secundaria, para que, desde su punto de vista como expertos, facilitaran ejemplos de casos reales en los que se trabaja la competencia seleccionada. Para analizar si el uso de vídeo-clips mejora o no el desarrollo y la adquisición de competencias, se optó por un estudio experimental de tipo pretest-postest, con una fase de formación intermedia, en el que participaron profesores de matemáticas en formación. En cada vídeo-clip se incluyeron una serie de preguntas para focalizar la atención de los participantes en determinados aspectos de la situación de aula, para así explorar, posteriormente, su competencia para proporcionar retroalimentación.

Los resultados obtenidos demuestran el potencial de esta herramienta didáctica para proporcionar al futuro profesorado la oportunidad de experimentar distintas dimensiones de la práctica docente. En particular, el análisis de datos refleja cambios en los conocimientos, las habilidades, y las actitudes del profesorado en formación a la hora de reaccionar ante situaciones de aula en las que hay un intercambio de retroalimentación entre el profesorado y el alumnado. La intervención también proporcionó una serie de logros adicionales. Por ejemplo, se percibió un aumento en la motivación del profesorado de matemáticas en formación como consecuencia de la interacción con los vídeo-clips en un entorno digital. Además, la inclusión de una fase de formación, dentro de una actividad de carácter mayoritariamente experimental, fomentó el vínculo entre la componente teórica y la práctica dentro de los programas de formación inicial docente. En general, estos resultados proporcionan una fundamentación sólida para la implementación de este tipo de herramientas en los programas de formación inicial docente, no sólo para promover la competencia seleccionada, sino también otras competencias.

Los programas de formación inicial para el futuro profesorado de matemáticas en Educación Secundaria en España exigen reformas inmediatas. A partir de los resultados de los diferentes estudios es posible plantear algunas orientaciones para futuras investigaciones que vayan más allá de los objetivos de investigación específicos de esta tesis doctoral. Las propuestas de la autora de esta memoria giran en torno a tres líneas de acción: (1) diseño y validación de un sistema alternativo de acceso a los programas de formación inicial docente, (2) desarrollo e implementación de un programa de capacitación para formadores de profesores y tutores de prácticas, y (3) formulación y evaluación de estrategias adicionales para promover el desarrollo y la adquisición de competencias durante el periodo de formación.

La formación inicial docente es un campo complejo a la par que prioritario para garantizar la calidad de la educación en todos los niveles educativos. Esta complejidad se explica en gran medida por las exigencias de la sociedad actual, en la que los docentes deben demostrar una completa gama de competencias desde el comienzo de su carrera. La eficacia en la enseñanza no reside simplemente en el conocimiento disciplinar del docente, sino en cómo este conocimiento se utiliza de manera eficiente en el aula. A pesar de las posibles limitaciones de la investigación, esta tesis doctoral proporciona suficiente evidencia sobre las carencias detectadas en los programas de formación inicial para el futuro profesorado de matemáticas en Educación Secundaria en España. Las percepciones de los profesores de matemáticas en formación, los formadores de profesores, los tutores de prácticas, y los recién titulados en la especialidad de matemáticas son demasiado importantes para ser ignoradas. El futuro profesorado de matemáticas en Educación Secundaria parece tener una fuerte motivación para enseñar matemáticas, sin embargo los programas de formación inicial docente no les proporcionan las competencias necesarias para desempeñar de manera eficaz su futura labor profesional. Del mismo modo, es esencial mejorar la situación de los formadores de profesores y tutores de prácticas en este contexto. Así, el mejoramiento de la formación inicial docente es un gran reto para las instituciones españolas y los responsables de la política educativa.

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Appendix A

Items of the Delphi questionnaire (round 1)

Respondent profile

What is your gender?

☐ Female ☐ Male

In which university/school/institution do you work?

____

What is your current academic rank?

☐ Teacher in secondary education ☐ Professor ☐ Associate professor
☐ Assistant professor/Senior lecturer ☐ Lecturer ☐ Instructor/Tutor
☐ Other: ____________

Which of the following fields better describes your area of specialization?

☐ Mathematics ☐ Education/Psychology ☐ Mathematics education

How many years of experience do you have in the profession?

____________ years

Competences for teaching mathematics at secondary education

Consider the following competences for teaching mathematics at secondary education. Indicate the extent to which you consider that each of them is adequately defined.

	Not adequate	Slightly adequate	Adequate	Very adequate	Extremely adequate
MCK1	☐	☐	☐	☐	☐
MCK2	☐	☐	☐	☐	☐
MPK1	☐	☐	☐	☐	☐
⋮	⋮	⋮	⋮	⋮	⋮
PC1	☐	☐	☐	☐	☐
PC2	☐	☐	☐	☐	☐
PC3	☐	☐	☐	☐	☐

Do you consider that any of the previous competences is unnecessary or redundant?

☐ Yes ☐ No

If yes, indicate which one(s): ____________________

Do you consider that there is any competence for teaching mathematics at secondary education that is missing in the previous framework?

☐ Yes ☐ No

If yes, indicate which one(s): ____________________

Propose a suggestion for those competences whose definition you consider not or slightly adequate, according to your answers to the first question of this section.

____

What is your general opinion about the above competence framework for teaching mathematics at secondary education?

____

Appendix B

Items of the pilot study questionnaire

Respondent profile

How old are you?

_______________ years

What is your gender?

☐ Female ☐ Male

What is your bachelor degree?

____

In university, what were the average marks that you received?

☐ Fail [0-5) ☐ Pass [5-7) ☐ Remarkable [7-9) ☐ Outstanding [9-10]

In which university did you study the Master Degree in Teacher Training in Secondary Education?

____

In which academic year did you complete the Master Degree in Teacher Training in Secondary Education?

☐ 2009-2010 ☐ 2010-2011 ☐ 2011-2012 ☐ 2012-2013
☐ 2013-2014 ☐ 2014-2015 ☐ 2015-2016

Which specialty did you study in the Master Degree in Teacher Training in Secondary Education?

☐ Mathematics ☐ Other: ____________

Which of the following routes did you follow to enter into the Master Degree in Teacher Training in Secondary Education?

☐ Direct admission university degree ☐ University degree with additional training
☐ Access test ☐ Other: ____________

Consider the following mathematics topics. Indicate whether you have ever studied each topic before entering into the Master Degree in Teacher Training in Secondary Education.

	Yes	No
Numbers and operations (e.g., integers, rational, real and complex numbers, ways of representing numbers, relationships among numbers, operations)	☐	☐
Linear algebra (e.g., vector spaces, matrices, dimensions, eigenvalues, eigenvectors)	☐	☐
Set theory	☐	☐
Abstract algebra (e.g., group theory, field theory, ring theory, ideals)	☐	☐
Foundations of geometry or axiomatic geometry (e.g., Euclidean axioms)	☐	☐
Analytic or coordinate geometry (e.g., equations of lines, curves, conic sections, rigid transformations or isometrics)	☐	☐
Non-euclidean geometry (e.g., geometry on a sphere)	☐	☐
Differential geometry (e.g., sets that are manifolds, curvature of curves, and surfaces)	☐	☐
Topology	☐	☐
Introduction to calculus (e.g., limits, series, sequences)	☐	☐
Calculus (e.g., derivatives and integrals)	☐	☐
Multivariate calculus (e.g., partial derivatives, multiple integrals)	☐	☐
Advanced calculus, real analysis or measure theory	☐	☐

	Yes	No
Differential equations (e.g., ordinary differential equations and partial differential equations)	☐	☐
Theory of real functions, theory of complex functions or functional analysis	☐	☐
Discrete mathematics, graph theory, game theory, combinations or boolean algebra	☐	☐
Probability	☐	☐
Theoretical or applied statistics	☐	☐
Mathematical logic (e.g., truth tables, symbolic logic, propositional logic, set theory, binary operations)	☐	☐

To what extent does each of the following identify your reasons for becoming a teacher?

	An extremely minor reason	A very minor reason	A minor reason	A moderate reason	A major reason	A very major reason	An extremely major reason
I love mathematics	☐	☐	☐	☐	☐	☐	☐
I believe I have a talent for teaching	☐	☐	☐	☐	☐	☐	☐
I like working with young people	☐	☐	☐	☐	☐	☐	☐
I am attracted by teacher salaries	☐	☐	☐	☐	☐	☐	☐
I see teaching as a challenging job	☐	☐	☐	☐	☐	☐	☐
I seek the long-term security associated with being a teacher	☐	☐	☐	☐	☐	☐	☐

On a scale from (1) *I will probably not seek employment as a teacher* to (7) *I expect it to be my lifetime career*, how do you see your future as a mathematics teacher?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Are you working or have you ever worked as a secondary mathematics teacher after finishing the Master Degree in Teacher Training in Secondary Education?

☐ Yes ☐ No

Competences for teaching mathematics at secondary education

Consider the following competences for teaching mathematics at secondary education. Indicate the extent to which you consider that each of them is important for the teaching profession as a secondary mathematics teacher:

	To an extremely small extent	To a very small extent	To a small extent	To a moderate extent	To a large extent	To a very large extent	To an extremely large extent
MCK1	☐	☐	☐	☐	☐	☐	☐
MCK2	☐	☐	☐	☐	☐	☐	☐
MPK1	☐	☐	☐	☐	☐	☐	☐
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
PC1	☐	☐	☐	☐	☐	☐	☐
PC2	☐	☐	☐	☐	☐	☐	☐
PC3	☐	☐	☐	☐	☐	☐	☐

Consider the following competences for teaching mathematics at secondary education. Indicate the extent to which you consider that each of them is pursued during the Master Degree in Teacher Training in Secondary Education:

	To an extremely small extent	To a very small extent	To a small extent	To a moderate extent	To a large extent	To a very large extent	To an extremely large extent
MCK1	☐	☐	☐	☐	☐	☐	☐
MCK2	☐	☐	☐	☐	☐	☐	☐
MPK1	☐	☐	☐	☐	☐	☐	☐
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
PC1	☐	☐	☐	☐	☐	☐	☐
PC2	☐	☐	☐	☐	☐	☐	☐
PC3	☐	☐	☐	☐	☐	☐	☐

Consider the following competences for teaching mathematics at secondary education. Indicate the extent to which you consider that each of them is attained by the time student teachers graduate:

	To an extremely small extent	To a very small extent	To a small extent	To a moderate extent	To a large extent	To a very large extent	To an extremely large extent
MCK1	☐	☐	☐	☐	☐	☐	☐
MCK2	☐	☐	☐	☐	☐	☐	☐
MPK1	☐	☐	☐	☐	☐	☐	☐
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
PC1	☐	☐	☐	☐	☐	☐	☐
PC2	☐	☐	☐	☐	☐	☐	☐
PC3	☐	☐	☐	☐	☐	☐	☐

Questionnaire assessment

What is your opinion about this questionnaire? Add any suggestion or comment you would like to share with us (adequacy of the questions, wording mistakes that disrupt comprehension, response time, among other difficulties that may arise during the survey).

Appendix C

Participant universities and secondary education schools

Universities

The student teachers, teacher educators, and recently graduate teachers who participated in the study 4 (see Chapter 5) belonged to the following Spanish universities:

University	Autonomous Community	Nature
University of Alicante	Valencian Community	Public
University of Alcalá	Community of Madrid	Public
Alfonso X El Sabio University	Community of Madrid	Private
University of Almería	Andalucía	Public
Antonio de Nebrija University	Community of Madrid	Private
Autonomous University of Barcelona	Catalonia	Public
Autonomous University of Madrid	Community of Madrid	Public
University of Barcelona	Catalonia	Public
University of Burgos	Castilla y León	Public
University of Cantabria	Cantabria	Public
University of Castilla – La Mancha	Castilla – La Mancha	Public
Catholic University of Ávila	Castilla y León	Private

University	Autonomous Community	Nature
Catholic University St Vincent Martyr	Valencian Community	Private
Complutense University of Madrid	Community of Madrid	Public
University of Córdoba	Andalucía	Public
University of Extremadura	Extremadura	Public
Francisco de Vitoria University	Community of Madrid	Private
University of Granada	Andalucía	Public
International University of La Rioja	La Rioja	Private
International University Isabel I	Castilla y León	Private
Valencian International University	Valencian Community	Private
University of the Balearic Islands	Balearic Islands	Public
Jaume I University	Valencian Community	Public
University of La Laguna	Canarias	Public
University of La Rioja	La Rioja	Public
University of León	Castilla y León	Public
University of Málaga	Andalucía	Public
Miguel Hernández University	Valencian Community	Public
University of Murcia	Region of Murcia	Public
University of Navarra	Navarra	Private
University of Oviedo	Principality of Asturias	Public
Pablo de Olavide University	Andalucía	Public
University of the Basque Country	Basque Country	Public
Polytechnic University of Catalonia	Catalonia	Public
Pompeu Fabra University	Catalonia	Public
Comillas Pontifical University	Community of Madrid	Private
Public University of Navarre	Navarra	Public
King Juan Carlos University	Community of Madrid	Public
University of Salamanca	Castilla y León	Public
CEU San Pablo University	Community of Madrid	Private
University of Santiago de Compostela	Galicia	Public
University of Seville	Andalucía	Public
Madrid Open University	Community of Madrid	Private
National Distance Education University	Community of Madrid	Public
University of Valencia	Valencian Community	Public

University	Autonomous Community	Nature
University of Valladolid	Castilla y León	Public
University of Zaragoza	Aragón	Public

Secondary education schools

The mentors who participated in the study 4 (see Chapter 5) belonged to the following Spanish secondary education schools:

Secondary education school	Autonomous Community	Nature
Alfonso II	Principality of Asturias	Public
Alonso Cano	Andalucía	Public
Alonso Quijano	Castilla – La Mancha	Public
Aramo	Pricipality of Asturias	Public
Astures	Principality of Asturias	Public
Augusto González Linares	Cantabria	Public
Azkoitiko Ikastola – Xabier Munibe	Basque Country	Public
Azuer	Castilla – La Mancha	Public
Batalla de Clavijo	La Rioja	Public
Bembézar	Extremadura	Public
Benlliure	Valencian Community	Public
Berenguela de Castilla	Castilla – La Mancha	Public
Blas de Otero	Community of Madrid	Public
Callosa d'en Sarrià	Valencian Community	Public
Carlos III	Community of Madrid	Public
Clavero Fernández de Córdoba	Castilla – La Mancha	Public
Damià Campeny	Catalonia	Public
David Vázquez Martínez	Principality of Asturias	Public
Don Bosco – Salesianos	Valencian Community	Private
Eduardo Primo Marqués	Valencian Community	Public
El Caminàs	Valencian Community	Public
Emilio Alarcos	Principality of Asturias	Public

Secondary education school	Autonomous Community	Nature
Félix Rodríguez de la Fuente	Andalucía	Public
Fernández Vallín	Principality of Asturias	Public
Fernando de Herrera	Andalucía	Public
Francesc Macià	Catalonia	Public
Fray Luis de León	Castilla y León	Public
Fuente de San Luis	Valencian Community	Public
Gabriel Alonso de Herrera	Castilla – La Mancha	Public
Gilabert de Centelles	Valencian Community	Public
Gonzalo Anaya	Valencian Community	Public
Gregori Maians	Valencian Community	Public
Gregorio Marañón	Community of Madrid	Public
Henri Matisse	Valencian Community	Public
Izpisúa Belmonte	Castilla La Mancha	Public
Jaume I	Valencian Community	Public
Joan Fuster	Valencian Community	Public
José del Campo	Cantabria	Public
José Navarro y Alba	Andalucía	Public
José Vilaplana	Valencian Community	Public
Juan de Garay	Valencian Community	Public
Justo Millán	Castilla – La Mancha	Public
L'Alzina	Catalonia	Public
La Inmaculada – Marillac	Community of Madrid	Private
La Inmaculada – Padres Escolapios	Community of Madrid	Private
La Mola	Valencian Community	Public
Las Lagunas	Valencian Community	Public
Las Llamas	Cantabria	Public
Lloixa	Valencian Community	Public
Los Montecillos	Andalucía	Public
Luis de Lucena	Castilla – La Mancha	Public
Macarena	Andalucía	Public
Maestro Diego Llorente	Andalucía	Public
María Blasco	Valencian Community	Public
Marqués de Santillana	Community of Madrid	Public

Secondary education school	Autonomous Community	Nature
Miguel Hernández	Valencian Community	Public
Mirabal	Community of Madrid	Private
Miralcamp	Valencian Community	Public
Modesto Navarro	Castilla – La Mancha	Public
Número 1	Principality of Asturias	Public
Número 1 – Universidad Laboral	Andalucía	Public
Número 3	Valencian Community	Public
Padre Feijoo	Principality of Asturias	Public
Peñalar	Community of Madrid	Private
Professor Manuel Broseta	Valencian Community	Public
Puçol	Valencian Community	Public
Ramón Giraldo	Castilla – La Mancha	Public
Ribera del Tajo	Castilla – La Mancha	Public
Salvador Gadea	Valencian Community	Public
San Blas	Valencian Community	Public
San Francisco	La Rioja	Public
San Isidro	Castilla – La Mancha	Public
San Juan Bosco	Castilla y León	Private
Santa Eulalia	Extremadura	Public
Santa María de Alarcos	Castilla – La Mancha	Public
Sierra de San Jorge	Andalucía	Public
Sivera Font	Valencian Community	Public
Sixto Marco	Valencian Community	Public
Suárez de Figueroa	Extremadura	Public
Torre del Rey	Andalucía	Public
Torres Villaroel	Castilla y León	Public
Torrevilano	Community of Madrid	Private
Vega de Toranzo	Cantabria	Public
Villa de Aspe	Valencian Community	Public
Virgen de las Nieves	Andalucía	Public
Virgen del Castillo	Andalucía	Public

Appendix D

Items of student and graduate teachers' questionnaire

Respondent profile

How old are you?

________________ years

What is your gender?

☐ Female ☐ Male

In which university are you studying or did you study the Master Degree in Teacher Training in Secondary Education?

____

In which academic year?

☐ 2009-2010 ☐ 2010-2011 ☐ 2011-2012 ☐ 2012-2013
☐ 2013-2014 ☐ 2014-2015 ☐ 2015-2016

Which specialty are you studying or did you study in the Master Degree in Teacher Training in Secondary Education?

☐ Mathematics ☐ Other: ______________

What is your bachelor degree?

____

In university, what were the average marks that you received?

☐ Pass [5-7) ☐ Remarkable [7-9) ☐ Outstanding [9-10]

Which of the following routes did you follow to enter into the Master Degree in Teacher Training in Secondary Education?

☐ Direct admission university degree ☐ University degree with additional training
☐ Access test ☐ Other: ______________

Consider the following mathematics topics. Indicate whether you have ever studied each topic before entering into the Master Degree in Teacher Training in Secondary Education.

	Yes	No
Number and operations (e.g., integers, rational, real and complex numbers, number representations, relationships among numbers, operations)	☐	☐
Linear algebra (e.g., vector spaces, matrices, dimensions, eigenvalues, eigenvectors)	☐	☐
Set theory (e.g., basic elements, equivalence relations, quotient set, applications)	☐	☐
Abstract algebra (e.g., group theory, field theory, ring theory, ideals)	☐	☐
Foundations of geometry or axiomatic geometry (e.g., Euclidean axioms)	☐	☐
Analytic or coordinate geometry (e.g., equations of lines, curves, conic sections, rigid transformations or isometrics)	☐	☐
Non-Euclidean geometry (e.g., spherical geometry)	☐	☐
Differential geometry (e.g., local theory of curves and surfaces)	☐	☐
Topology (e.g., metric spaces, topological spaces, homeomorphisms, compactness, connection)	☐	☐
Introduction to calculus (e.g., limits, series, sequences)	☐	☐

	Yes	No
Single variable calculus (e.g., derivatives and integrals)	☐	☐
Multivariate calculus (e.g., partial derivatives, multiple integrals)	☐	☐
Advanced calculus, real analysis or measure (e.g., measurable and integrable functions)	☐	☐
Differential equations (e.g., ordinary differential equations and partial differential equations)	☐	☐
Complex functions or functional analysis (e.g., analytic functions, isolated singularities, residue theorem, normed space, Hilbert space)	☐	☐
Applied or discrete mathematics (e.g., graph theory, game theory, combinatorics or Boolean algebra)	☐	☐
Introduction to probability (e.g., Laplace theory, conditional probability, independence)	☐	☐
Stochastic processes (e.g., modeling, discrete and continuous time process)	☐	☐
Descriptive statistics (e.g., data management, central tendency, dispersion and position measures, two-dimensional variables, simple lineal regression)	☐	☐
Sequence of random variables (e.g., convergence, law of large numbers, Central limit theorem)	☐	☐
Inferential statistics (e.g., statistic, point estimation, interval estimation)	☐	☐
Mathematical logic (e.g., truth table, symbolic logic, propositional logic, set theory, binary operations)	☐	☐

To what extent does each of the following identify your reasons for becoming a teacher?

	An extremely minor reason	A very minor reason	A minor reason	A moderate reason	A major reason	A very major reason	An extremely major reason
I love mathematics	☐	☐	☐	☐	☐	☐	☐
I believe I have a talent for teaching	☐	☐	☐	☐	☐	☐	☐
I like working with young people	☐	☐	☐	☐	☐	☐	☐
I am attracted by teacher salaries	☐	☐	☐	☐	☐	☐	☐
I see teaching as a challenging job	☐	☐	☐	☐	☐	☐	☐
I seek the long-term security associated with being a teacher	☐	☐	☐	☐	☐	☐	☐

On a scale from (1) *I will probably not seek employment as a teacher* to (7) *I expect it to be my lifetime career*, how do you see your future as a mathematics teacher?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Have you ever worked as a secondary mathematics teacher?

☐ Yes, before starting the Master Degree in Teacher Training in Secondary Education
☐ Yes, after starting the Master Degree in Teacher Training in Secondary Education, but I am not currently working
☐ Yes, after starting the Master Degree in Teacher Training in Secondary Education, and I am currently working
☐ No

On a scale from (1) *Very ineffective* to (7) *Very effective*, how effective is the Master Degree in Teacher Training in Secondary Education to prepare future secondary mathematics teachers for the teaching profession?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Competences for teaching mathematics at secondary education

Consider the following competences for teaching mathematics at secondary education. On a scale from (1) *To an extremely small extent* to (7) *To an extremely large extent*, indicate the extent to which each competence is pursued during the Master Degree in Teacher Training in Secondary Education, from a theoretical and a practical point of view:

	Theory					Practice				
	1	2	···	6	7	1	2	···	6	7
MCK1	☐	☐	···	☐	☐	☐	☐	···	☐	☐
MCK2	☐	☐	···	☐	☐	☐	☐	···	☐	☐
MPK1	☐	☐	···	☐	☐	☐	☐	···	☐	☐
⋮	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋱	⋮	⋮
PC1	☐	☐	···	☐	☐	☐	☐	···	☐	☐
PC2	☐	☐	···	☐	☐	☐	☐	···	☐	☐
PC3	☐	☐	···	☐	☐	☐	☐	···	☐	☐

Consider the following competences for teaching mathematics at secondary education. On a scale from (1) *To an extremely small extent* to (7) *To an extremely large extent*, indicate the extent to which each competence is attained during the Master Degree in Teacher Training in Secondary Education, from a theoretical and a practical point of view:

	Theory					Practice				
	1	2	···	6	7	1	2	···	6	7
MCK1	☐	☐	···	☐	☐	☐	☐	···	☐	☐
MCK2	☐	☐	···	☐	☐	☐	☐	···	☐	☐
MPK1	☐	☐	···	☐	☐	☐	☐	···	☐	☐
⋮	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋱	⋮	⋮
PC1	☐	☐	···	☐	☐	☐	☐	···	☐	☐
PC2	☐	☐	···	☐	☐	☐	☐	···	☐	☐
PC3	☐	☐	···	☐	☐	☐	☐	···	☐	☐

Appendix E

Items of teacher educators' questionnaire

Respondent profile

What is your gender?

☐ Female ☐ Male

In relation with the Master Degree in Teacher Training in Secondary Education, in which university do you work?

____

What is your current academic rank?

☐ Professor ☐ Associate professor ☐ Assistant professor/Senior lecturer
☐ Lecturer ☐ Instructor/Tutor ☐ Other: _____________

How many years of experience do you have in the profession?

_____________ years

How many years of experience do you have as a teacher educator?

_____________ years

Have you ever received special preparation for training student teachers?

☐ Yes, I received special preparation prior to start working as a teacher educator
☐ Yes, I received special preparation after starting to work as a teacher educator
☐ No, I have never received any special preparation for working as a teacher educator

On a scale from (1) *Very ineffective* to (7) *Very effective*, how effective is the Master Degree in Teacher Training in Secondary Education to prepare future secondary mathematics teachers for the teaching profession?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Competences for teaching mathematics at secondary education

Consider the following competences for teaching mathematics at secondary education. On a scale from (1) *To an extremely small extent* to (7) *To an extremely large extent*, indicate the extent to which each competence is pursued during the Master Degree in Teacher Training in Secondary Education:

	1	2	3	4	5	6	7
MCK1	☐	☐	☐	☐	☐	☐	☐
MCK2	☐	☐	☐	☐	☐	☐	☐
MPK1	☐	☐	☐	☐	☐	☐	☐
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
PC1	☐	☐	☐	☐	☐	☐	☐
PC2	☐	☐	☐	☐	☐	☐	☐
PC3	☐	☐	☐	☐	☐	☐	☐

Appendix F

Items of mentors' questionnaire

Respondent profile

What is your gender?

☐ Female ☐ Male

In relation with the Master Degree in Teacher Training in Secondary Education, in which school do you work?

____

What is your current academic rank?

☐ Secondary mathematics teacher ☐ Other: ____________

How many years of experience do you have in the profession?

____________ years

How many years of experience do you have as a mentor?

____________ years

Have you ever received special preparation for training student teachers?

☐ Yes, I received special preparation <u>prior</u> to start working as a teacher educator
☐ Yes, I received special preparation <u>after</u> starting to work as a teacher educator
☐ No, I have <u>never</u> received any special preparation for working as a teacher educator

On a scale from (1) *Very ineffective* to (7) *Very effective*, how effective is the Master Degree in Teacher Training in Secondary Education to prepare future secondary mathematics teachers for the teaching profession?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Competences for teaching mathematics at secondary education

Consider the following competences for teaching mathematics at secondary education. On a scale from (1) *To an extremely small extent* to (7) *To an extremely large extent*, indicate the extent to which each competence is pursued during the Master Degree in Teacher Training in Secondary Education:

	1	2	3	4	5	6	7
MCK1	☐	☐	☐	☐	☐	☐	☐
MCK2	☐	☐	☐	☐	☐	☐	☐
MPK1	☐	☐	☐	☐	☐	☐	☐
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
PC1	☐	☐	☐	☐	☐	☐	☐
PC2	☐	☐	☐	☐	☐	☐	☐
PC3	☐	☐	☐	☐	☐	☐	☐

Appendix G

Items of self-efficacy questionnaire

The following questions are designed to help us gain a better understanding of your competence to provide and seek feedback to/from students. Please rate your degree of confidence in doing the tasks described below, using the following scale:

1	2	3	4	5	6	7	8	9	10
Cannot do at all				Moderately can do					Highly certain can do

	1	2	3	4	5	6	7	8	9	10
Establish specific learning goals	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Indicate whether students work is correct or incorrect	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Identify what students understand	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Detect when students make errors	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Detect when students have misconceptions	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Provide praise, rewards, and punishment	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Provide information about what is or what is not understood	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Indicate that more information is needed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Indicate alternative strategies to complete the task	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Use assessment data to plan future instruction	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Academic output

Publications in journals listed in the ISI Web of Knowledge

Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2016). Is there a gap in initial teacher education in Spain compared to other countries? *Revista de Educación, 372*, 106-132. doi: 10.4438/1988-592X-RE-2015-372-317

Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2017). Developing and validating a competence framework for secondary mathematics student teachers through a Delphi method. *Journal of Education for Teaching, 43*(4), 383-399. doi: 10.1080/02607476.2017.1296539

Publications in proceedings listed in the ISI Web of Science

Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2016). Are future mathematics teachers ready for the profession? A pilot study in the Spanish framework. *Procedia – Social and Behavioral Sciences, 16*, 735-745. doi: 10.15405/epsbs.2016.11.76

Publications in conference proceedings

Muñiz-Rodríguez, L., Alonso, P., Fernández-Blanco, T., Rodríguez-Muñiz, L. J., & Valcke, M. (2015). ¿Cuál es el perfil de los futuros profesores de matemáticas en

Educación Secundaria? In C. Fernández, M. Molina, & N. Planas (Eds.), *Investigación en Educación Matemática XIX* (p. 575). Alicante: SEIEM.

Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2015). Validación de un marco de competencias para futuros profesores de matemáticas en Educación Secundaria. In R. Pérez, A. Rodríguez-Martin, & E. Álvarez-Arregui (Eds.), *Innovación en la Educación Superior. Desafíos y propuestas* (pp. 219-226). Oviedo: Ediciones de la Universidad de Oviedo.

Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2016). Validación de un instrumento para evaluar el Máster en Formación del Profesorado: Estudio piloto en la especialidad de matemáticas. In J. A. Macías, A. Jiménez, J. L. González, M. T. Sánchez, P. Hernández, C. Fernández, F. J. Ruiz, T. Fernández, & A. Berciano (Eds.), *Investigación en Educación Matemática XX* (pp. 377-386). Málaga: SEIEM.

Other conference contributions

Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2015, September). Análisis de los programas de formación inicial para futuros profesores de matemáticas en Secundaria en España. Paper presented at XIX Simposio de la Sociedad Española de Investigación en Educación Matemática (SEIEM), Alicante (Spain).

Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2015, September). Initial teacher education for secondary mathematics teachers: is Spain an outlier in the international framework? Paper presented at European Conference on Educational Research (ECER), Budapest (Hungary).

Muñiz-Rodríguez, L. (2016, December). La formación inicial del profesorado de matemáticas en Educación Secundaria en España con respecto a otros países. Paper presented at Seminario FORPROMAT: Perspectivas en la formación inicial de profesores de matemáticas, Castro Urdiales (Spain).

Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2017, July). La retroalimentación en la mejora del proceso de enseñanza y aprendizaje de las matemáticas. Paper presented at VIII Congreso Iberoamericano de Educación Matemática (CIBEM), Madrid (Spain).

Research grants or proyects

Economical aid of the Campus of International Excellence for doctoral students of the University of Oviedo to undertake a joint PhD with a foreign university (9 months). Campus of International Excellence of the University of Oviedo (Spain).

Project *La formación inicial del futuro profesorado de matemáticas en Secundaria en Asturias y su influencia en el proceso de enseñanza-aprendizaje* (2 years). Collaboration agreement between the University of Oviedo and the Ministry of Education, Culture and Sport (Spain).

Erasmus+ Internship Mobility Programme (3 months). Univeristy of Oviedo (Spain).

BOF Finalizing PhD Grant (10 months). Ghent University (Belgium).

Data storage fact sheets

Data Storage Fact Sheet 1

Name/identifier study: Chapter 2 (study 1)
Author: Laura Muñiz-Rodríguez
Date: 12 July 2017

1. Contact details

1a. Main researcher
- name: Laura Muñiz-Rodríguez
- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
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1b. Responsible Staff Member (ZAP)
- name: Martin Valcke (supervisor PhD research)
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- e-mail: Martin.Valcke@UGent.be

If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the data sets to which this sheet applies

* Reference of the publication in which the data sets are reported:
Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2016). Is there

a gap in initial secondary mathematics teacher education in Spain compared to other countries? *Revista de Educación, 372*, 111-140. doi: 10.4438/1988-592X-RE-2015-372-317

* Which data sets in that publication does this sheet apply to?
All data sets used in the study.

3. Information about the files that have been stored

3a. Raw data
* Have the raw data been stored by the main researcher? ☒ Yes / ☐ No
If No, please justify:

* On which platform are the raw data stored?
☒ researcher PC
☐ research group file server
☐ other (specify): ...

* Who has direct access to the raw data (i.e., without intervention of another person)?
☒ main researcher
☒ responsible ZAP
☒ all members of the research group
☐ all members of UGent
☐ other (specify): ...

3b. Other files
* Which other files have been stored?
☒ file(s) describing the transition from raw data to reported results. Specify: The coding scheme used for the content analysis of the different initial teacher education programs curricula and policy documents.
☒ file(s) containing processed data. Specify: SPSS-data set file containing the set of variables.
☒ file(s) containing analyses. Specify: SPSS-output file and reports about the results of the data analysis.
☐ files(s) containing information about informed consent
☐ a file specifying legal and ethical provisions
☐ file(s) that describe the content of the stored files and how this content should be

interpreted. Specify: ...
☐ other files. Specify: ...

* On which platform are these other files stored?
☒ individual PC
☐ research group file server
☐ other: ...

* Who has direct access to these other files (i.e., without intervention of another person)?
☒ main researcher
☒ responsible ZAP
☒ all members of the research group
☐ all members of UGent
☐ other (specify): ...

4. Reproduction

* Have the results been reproduced independently?: ☐ Yes / ☒ No

* If yes, by whom (add if multiple):
- name:
- address:
- affiliation:
- e-mail:

Data Storage Fact Sheet 2

Name/identifier study: Chapter 3 (study 2)
Author: Laura Muñiz-Rodríguez
Date: 12 July 2017

1. Contact details

1a. Main researcher
- name: Laura Muñiz-Rodríguez

- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
- e-mail: Laura.MunizRodriguez@UGent.be

1b. Responsible Staff Member (ZAP)
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If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the data sets to which this sheet applies

* Reference of the publication in which the data sets are reported:
Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2017). Developing and validating a competence framework for secondary mathematics student teachers through a Delphi method. *Journal of Education for Teaching, 43*(4), 383-399. doi: 10.1080/02607476.2017.1296539

* Which data sets in that publication does this sheet apply to?
All data sets used in the study.

3. Information about the files that have been stored

3a. Raw data
* Have the raw data been stored by the main researcher? ☒ Yes / ☐ No
If No, please justify:

* On which platform are the raw data stored?
☒ researcher PC
☐ research group file server
☐ other (specify): ...

* Who has direct access to the raw data (i.e., without intervention of another person)?
☒ main researcher
☒ responsible ZAP
☒ all members of the research group

☐ all members of UGent
☐ other (specify): ...

3b. Other files
* Which other files have been stored?
☒ file(s) describing the transition from raw data to reported results. Specify: The coding scheme used to analyze the survey data.
☒ file(s) containing processed data. Specify: Weft QDA project file and SPSS-data set file.
☒ file(s) containing analyses. Specify: SPSS-output file and reports about the results of the data analysis.
☐ files(s) containing information about informed consent
☐ a file specifying legal and ethical provisions
☐ file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
☐ other files. Specify: ...

* On which platform are these other files stored?
☒ individual PC
☐ research group file server
☐ other: ...

* Who has direct access to these other files (i.e., without intervention of another person)?
☒ main researcher
☒ responsible ZAP
☒ all members of the research group
☐ all members of UGent
☐ other (specify): ...

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* Have the results been reproduced independently?: ☐ Yes / ☒ No

* If yes, by whom (add if multiple):
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- address:
- affiliation:
- e-mail:

Data Storage Fact Sheet 3

Name/identifier study: Chapter 4 (study 3)
Author: Laura Muñiz-Rodríguez
Date: 12 July 2017

1. Contact details

1a. Main researcher
- name: Laura Muñiz-Rodríguez
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- e-mail: Laura.MunizRodriguez@UGent.be

1b. Responsible Staff Member (ZAP)
- name: Martin Valcke (supervisor PhD research)
- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
- e-mail: Martin.Valcke@UGent.be

If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the data sets to which this sheet applies

* Reference of the publication in which the data sets are reported:
Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., & Valcke, M. (2016). Are future mathematics teachers ready for the profession? A pilot study in the Spanish framework. *Procedia – Social and Behavioral Sciences, 16*, 735-745. doi: 10.15405/epsbs.2016.11.76

* Which data sets in that publication does this sheet apply to?
All data sets used in the study.

3. Information about the files that have been stored

3a. Raw data
* Have the raw data been stored by the main researcher? ☒ Yes / ☐ No
If No, please justify:

* On which platform are the raw data stored?
☒ researcher PC
☐ research group file server
☐ other (specify): ...

* Who has direct access to the raw data (i.e., without intervention of another person)?
☒ main researcher
☒ responsible ZAP
☒ all members of the research group
☐ all members of UGent
☐ other (specify): ...

3b. Other files
* Which other files have been stored?
☒ file(s) describing the transition from raw data to reported results. Specify: SPSS-syntax file.
☒ file(s) containing processed data. Specify: SPSS-data set file containing the set of variables.
☒ file(s) containing analyses. Specify: SPSS-output file and reports about the results of the data analysis.
☐ files(s) containing information about informed consent
☐ a file specifying legal and ethical provisions
☐ file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
☐ other files. Specify: ...

* On which platform are these other files stored?
☒ individual PC
☐ research group file server
☐ other: ...

* Who has direct access to these other files (i.e., without intervention of another person)?
☒ main researcher
☒ responsible ZAP
☒ all members of the research group
☐ all members of UGent
☐ other (specify): ...

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* Have the results been reproduced independently?: ☐ Yes / ☒ No

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- address:
- affiliation:
- e-mail:

Data Storage Fact Sheet 4

Name/identifier study: Chapter 5 (study 4)
Author: Laura Muñiz-Rodríguez
Date: 12 July 2017

1. Contact details

1a. Main researcher
- name: Laura Muñiz-Rodríguez
- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
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1b. Responsible Staff Member (ZAP)
- name: Martin Valcke (supervisor PhD research)
- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
- e-mail: Martin.Valcke@UGent.be

If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the data sets to which this sheet applies

* Reference of the publication in which the data sets are reported:

* Which data sets in that publication does this sheet apply to?
All data sets in the study.

3. Information about the files that have been stored

3a. Raw data
* Have the raw data been stored by the main researcher? ☒ Yes / ☐ No
If No, please justify:

* On which platform are the raw data stored?
☒ researcher PC
☐ research group file server
☐ other (specify): ...

* Who has direct access to the raw data (i.e., without intervention of another person)?
☒ main researcher
☒ responsible ZAP
☒ all members of the research group
☐ all members of UGent
☐ other (specify): ...

3b. Other files
* Which other files have been stored?
☒ file(s) describing the transition from raw data to reported results. Specify: SPSS-syntax file.
☒ file(s) containing processed data. Specify: SPSS-data set file containing the set of variables.
☒ file(s) containing analyses. Specify: SPSS-output file and reports about the results of the data analysis.
☐ files(s) containing information about informed consent
☐ a file specifying legal and ethical provisions
☐ file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
☐ other files. Specify: ...

* On which platform are these other files stored?
☒ individual PC

☐ research group file server
☐ other: ...

* Who has direct access to these other files (i.e., without intervention of another person)?
☒ main researcher
☒ responsible ZAP
☒ all members of the research group
☐ all members of UGent
☐ other (specify): ...

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* Have the results been reproduced independently?: ☐ Yes / ☒ No

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- name:
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- affiliation:
- e-mail:

Data Storage Fact Sheet 5

Name/identifier study: Chapter 6 (study 5)
Author: Laura Muñiz-Rodríguez
Date: 12 July 2017

1. Contact details

1a. Main researcher
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- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
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- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
- e-mail: Martin.Valcke@UGent.be

If a response is not received when using the above contact details, please send an email to data.pp@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the data sets to which this sheet applies

* Reference of the publication in which the data sets are reported:

* Which data sets in that publication does this sheet apply to?
All data sets in the study.

3. Information about the files that have been stored

3a. Raw data
* Have the raw data been stored by the main researcher? ☒ Yes / ☐ No
If No, please justify:

* On which platform are the raw data stored?
☒ researcher PC
☐ research group file server
☐ other (specify): ...

* Who has direct access to the raw data (i.e., without intervention of another person)?
☒ main researcher
☒ responsible ZAP
☒ all members of the research group
☐ all members of UGent
☐ other (specify): ...

3b. Other files
* Which other files have been stored?
☒ file(s) describing the transition from raw data to reported results. Specify: The coding scheme used for the analysis of the online assignment and the SPSS-syntax file.
☒ file(s) containing processed data. Specify: Weft QDA project file and SPSS-data set file.

☒ file(s) containing analyses. Specify: SPSS-output file and reports about the results of the data analysis.
☒ files(s) containing information about informed consent
☐ a file specifying legal and ethical provisions
☐ file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
☐ other files. Specify: ...

* On which platform are these other files stored?
☒ individual PC
☐ research group file server
☐ other: ...

* Who has direct access to these other files (i.e., without intervention of another person)?
☒ main researcher
☒ responsible ZAP
☒ all members of the research group
☐ all members of UGent
☐ other (specify): ...

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