CREATIVE LITTLE SCIENTISTS:
Enabling Creativity through Science and Mathematics in Preschool and First Years of Primary Education

D2.2 Conceptual Framework
ADDENDUM 3 of 4:
Literature Review of Teacher Education

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The project CREATIVE LITTLE SCIENTISTS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 289081.

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SEVENTH FRAMEWORK PROGRAMME

The project CREATIVE LITTLE SCIENTISTS has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 289081.

Project Information
Project no. 289081
Project acronym: CreativeLittleScientists
Start date of project: 01/10/2011
Duration: 30 months
Project title:

Creative Little Scientists: Enabling Creativity through Science and Mathematics in Preschool and First Years of Primary Education

EU Strategic Objective
Funding scheme: FP7/ CP/ Capacities
Call ID: FP7-Science-In-Society-2011-1
Topic: SiS.2011.2.2.3-1 Science and mathematics-related activities carried out in pre-school and in the first years of primary school: their link to the development of creative skills

Information about the deliverable
Dissemination level: **PUBLIC**
Due date of deliverable: March 2012
Actual submission date: 31/03/2012
Deliverable title:

D2.2 Conceptual Framework

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A. Introduction

In many Member States of the European Union, the growing consensus about the crucial importance of teachers in education has led to renewed efforts to improve teacher education, initial teacher education as well as professional development. The crucial role teachers play in social and economic advancement is discussed in an article on teacher preparation and professional development by Hammond (2005) in which she states that, internationally, the importance of, and focus on education has increased at breathtaking speed as the new knowledge-based economy has emerged.

The systems of teacher education differs a lot in several countries, but they all face the dual challenge of helping teachers to optimally function in the current school contexts while at the same time mobilizing their contribution to the development of better schools in the future (Furlong, et al., 2000).

A.1. Teacher education: some definitions and structure of the review

One of the key premises of this review is that teachers hold a key role in promoting, encouraging, and nurturing creativity in classrooms. In order to encourage creativity, teachers need to be supported at every stage and in different ways. Teacher education is of major importance to help their students develop the imaginative, critical, and reflective processes that are essential to creativity. This review discusses two sub-areas of teacher education, namely the initial teacher education for preschool and primary school teachers and the continuous professional development for preschool and primary school teachers.

These two sub-areas are defined as follows:

- Initial teacher education for preschool and primary school teachers is the professional preparation organized by a college, university or specialized school in order to obtain the certificate to teach in preschool and primary school contexts.
- Continuous professional development for preschool and primary school teachers encompasses all professional inputs that are given to teachers, either to provide them with new insights or to improve their competences. This concerns both pre-service teachers still in training, who can be viewed as not yet qualified and in-service teachers who can be considered to be qualified.

'The development of teachers beyond their initial training can serve a number of objectives, including: to update individuals' knowledge of a subject in light of recent advances in the area; to update individuals' skills, attitudes and approaches in light of the development of new teaching techniques and objectives, new circumstances and new educational research; to enable individuals to apply changes made to curricula or other aspects of teaching practice; to enable schools to develop and apply new strategies concerning the curriculum and other

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aspects of teaching practice; to exchange information and expertise among teachers and others, e.g. academics, industrialists; and to help weaker teachers become more effective' (OECD, 2009).

In the following sections conceptual and practical issues in initial teacher education and professional development in general are reviewed as well as issues concerning learning and instruction of science and mathematics in early childhood and primary education. Both policy and research related topics are taken into consideration.

A2. Research method used

According to Collins and Fauser (2005) narrative reviews are generally comprehensive and cover a wide range of issues within a given topic, but they do not necessarily state or follow rules about the search for evidence. Contrary to sustained systematic reviews with rather narrow scope, typical narrative reviews barely reveal how the decisions were made about relevance of studies and the validity of the included studies.

Through the process of synthetic academic narrative review, the researchers locate, compare and combine available studies in order to create new interpretations across the multiple studies. The present review of both qualitative and quantitative research was used to synthesize the evidence regarding which content and didactical approaches best prepare pre- and in-service teachers to structure their thinking about science and mathematics teaching and learning for young children fostering creativity, by using mainly the inquiry approach.

This contribution is constructed as a 'synthetic academic narrative review study' and encompasses a number of building blocks.

A2.1. Scope review determined by task leaders

In task 2.4, literature review of teacher education for early year educators and primary teachers was carried out with a particular interest in the common ground and links between creativity and inquiry in early years science and mathematics education.

A2.2. Guidelines for international partners

The *Creative Little Scientists* consortium carried out research in a sample of nine European countries (Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania, and the UK) consisting of eleven partner institutes. Regarding teacher education review framing, each partner had to add e-materials in the online Dropbox system, had to develop bibliographic lists (policy and research) and had to develop rubric documents (policy and research). Each partner added the input they found in sub-folders and had to keep all these documents up-to-date. E-materials which were not in English but key or landmark policy or research documents were summarized in English.

A2.3. Bibliographic list

A broad set of literature within the review scope is written by each partner into one bibliographic list. Furthermore, partners were asked to

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indicate for every reference added if the rubric is completed (and in the rubric folder in Dropbox) and if they have collected e-material for that reference. This check list facilitated the revising work for the task leaders.

A2.4. Rubric per single publication

Each partner had to complete a separate rubric for every single reference they found in each area they are contributing to. The rubrics folder is divided into two subfolders – rubrics policy and rubrics research – each divided in 11 subfolders (the 11 partners). Both a blank document and an example of good practice made in an Excel-file were provided in Dropbox. Each research rubric is written in English and is based on the following ten categories: full bibliographic reference, country/region, sample, research questions, methodological approach, research methods, key findings, and other comments, reasons for inclusion or exclusion, and reviewer.

With the aim of facilitating interpretations during the process of expanding references into rubrics, key findings also included starting sentences to be filled in if possible: Learning science and mathematics is clearly related to … Teacher education interventions focus on … The relationship between theory and practice is seen as … Teacher trainers are supported by … Creativity is fostered by means of … Inquiry is fostered by means of...

Each policy rubric is written in English and is based on the following ten categories: full bibliographic reference, country/region, date, period, status (mandatory/guidance), age, key messages, and other comments, reason for inclusion or exclusion, and reviewer. Partners were asked to write a brief overview of policy developments in their countries using a template. These overviews of policy will help task leaders to make sense of the material the partners have included in the bibliographies and rubrics. Policy documents were restricted to content published between 1990 and 2011.

A2.5. Appraisal criteria determined by review team

Initially, the task 2.4 related e-materials as mentioned in the bibliographic list and rubrics were subject to two main criteria for inclusion in the narrative literature review (see sections B.3, C.3, D.4). Firstly, the research needed to focus on initial teacher education and/or professional development. Secondly, the research needed to focus on pre-school and/or primary school teachers in relation to science and/or mathematics education. The studies included were located through an extensive search in the Web of Science database. Research documents were restricted to content published between 1990 and 2011.

The bibliographical search on initial teacher education in particular was based on the following key words: 'pre-service teacher', 'teacher candidate', 'student teacher', 'prospective teacher', and/or 'teacher trainee' in combination with search filters related to specific (1)

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knowledge contents: 'science' and/or 'mathematics', and (2) audience age: 'kindergarten', 'early childhood', 'primary', 'elementary', and/or 'preschool'. In order to refine the searching strategy titles and abstracts of relevant journals were checked. This additional search led to the inclusion of the terms 'creativity' and/or 'inquiry'.

The review team consisted of three researchers, all enrolled in a teacher education program and experienced in research with regard to constructivist theory and how it can be implemented into practice by teachers. Through the critical appraisal exercise, the total amount of rubrics as mentioned in the bibliographic list and referring to the e-materials was evaluated by the three researchers working independently. Deciding on the targeted focus of the review and on an inter-rater screening, more than one hundred studies were identified. Disagreements on inclusion/exclusion between the reviewers were resolved through comparison and discussion. For example, in a number of studies in the field of science and mathematics education the terms 'creativity' and/or 'inquiry' were not clearly stated. However, those particular studies still provided contributions to the synthesis and were thus not excluded.

A2.6. Broad content issues in e-mindmap

The next phase of the review consisted of identifying and defining the common threads (concepts, practices and visions) with respect to teaching and learning in science and mathematics education emerging from the scrutinised literature. An initial mapping was made based on mostly didactic subject matters and subsequently refined by merging topics and themes emerging from the literature.

B. Initial teacher education for early years and primary teachers concerning mathematics and science

B1. Initial teacher education: some general issues

Initial teacher education for preschool and primary school teachers is the professional preparation organized by a teacher education institution in order to obtain the certificate to teach in preschool and primary school contexts. The length and content of the teacher preparation programmes can be different, but they all have the same goal – the education of teachers. To prepare their teacher candidates many of these teacher education programmes try to link theory to practice.

Five pedagogical traditions have been identified as influencing current teacher education programmes (Schepens et al., 2009): the academic, practical, technological, personal, and critical/social reconstruction tradition.

Historically the academic tradition, also known as the 'application of theory' approach, has been found dominant (Korthagen, 2010; Schepens

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et al., 2009; Zeichner, 2010). This academic tradition is described by Korthagen (2010) as follows: teacher education institutions provide the knowledge through various, often fragmented courses, while schools provide the setting where students are expected to apply those theories. Such traditionally structured programmes have been found to be ineffective in terms of preparing student teachers to the teaching profession (Korthagen and Kessels, 1999). Since the nineties, there is a pressure towards more school-based programmes and policies in many countries recommend that teacher education should be arranged in partnership between schools and higher education institutions (see section 2.2.).

In a recent meta-analysis of North-American research (Cochran-Smith and Zeichner, 2005) the AREA Research Panel on Teacher Education, concluded that in the U.S. the impact of teacher education on their students' practice is still limited. Despite these findings, they identified some aspects of teacher education programmes which have a positive impact on student teachers' pedagogical knowledge and beliefs. These are: strategies such as case studies and teaching portfolios, learning by doing, collaborative arrangements between university programmes and local school districts. Structured teaching formats, where instructional methods are demonstrated by teacher educators followed by guided and carefully mentored practice are also widely claimed as providing supportive trajectories toward application in classrooms (Clift and Brady, 2005; Risko et al., 2008; Zeichner, 2010).

The collaborative approach is supported by Zeichner (2010) who argues that a shift towards more democratic and inclusive ways of working with schools and communities is necessary for colleges and universities to fulfil their mission in the education of teachers. He uses the idea of third spaces; hybrid spaces in pre-service education programmes that bring together school and university-based teacher educators and practitioner and academic knowledge in new ways to enhance the learning of prospective teachers. These three spaces are less hierarchical than conventional school-university partnerships. Examples of these partnerships are: bringing teachers into campus-based teacher education, bringing a portion or all of a campus method course in the schools and connecting it to the practices and expertise of the teachers in the school, creating hybrid teacher educators (work of teacher educators takes place both in an elementary school and on a campus), incorporating knowledge from communities into pre-service teacher education.

In a document of Bezzina, Lorist, and van Velzen (2006) collaborative school-based education is described as collaborations between schools and institutes in order to improve school development and teacher education - it elaborates on the ideas of the professional development schools. According to Bezzina et al. these PDS schools are schools in which not only student-teachers are educated, but also a place where faculty and school staff can collaborate on research and development.

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Snoek, Uzerli, and Schratz (2008) under scribe these partnerships between schools and teacher education institutions - 'The potential benefits of partnerships between schools and teacher education institutions are increased when the benefits of all participants (student teachers, schools, teacher education institutions and the system) are taken into account and when there is flexibility in the specific design of the partnership, leaving room for adaptation to local needs and conditions. The partnership should not only focus on the education of student teachers, but also on the professional development of staff within schools, on curriculum innovation and on shared research.'

In their review, Wideen et al. (1998) argue that successful teacher education programmes do not merely change, but build upon student teachers' belief making use of systematic support and guidance of teacher educators and of cooperating teachers during teaching practice periods. These findings are confirmed by Schepens et al. (2009). Their study also confirms the importance of teacher education preparation for the roles and responsibilities of teachers in the present-day society. In line with this, Brouwer and Korthagen (2005) as well as Schepens et al. (2009) also plead for teacher education programs which are characterized by the integration of practical experiences and theoretical study. Teacher education should not only focus on changing behaviour, competencies or beliefs, but also take into account future teachers' identity (professional identity) and their mission as a teacher on a more profound level (Korthagen, 2004). This professional development is related to concepts of the self, to what is termed personal identity, to self-understanding and is influenced by conceptions and expectations of other people as well (Schepens et al., 2009). Social standards, conceptions and expectations of others (e.g. mentors) may conflict with what teachers (or student teachers) personally desire and experience as good teaching (Beijaard et al. 2004; Korthagen, 2004).

Korthagen et al. (2001) developed the so-called 'realistic approach' to teacher education, which takes into account the causes of the theory and practice divide. This realistic and holistic approach lays the emphasis on the student teachers' experiences, concerns, and existing gestalts. This new pedagogy is focused on helping student teachers to become good teachers who understand themselves as teachers involving personal and professional change. This approach starts from concrete practical problems and concerns experienced by student teachers in real contexts. It also aims at the promotion of systematic reflection by student teachers on their own and their pupils' wanting, feeling, thinking and acting, on the role of context, and on the relationships between those aspects. A realistic programme has a strongly integrated character. Two types of integration are involved: integration of theory and practice and integration of several disciplines.

In this holistic approach systematic reflection by the student teacher is highlighted. Also Bell (2004) sees the teacher as a reflective practitioner

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constantly constructing and reconstructing his or her working theories through action and research.

In his study, Korthagen (2010) discussed the problem of an extreme elaboration of the realistic approach. In alternative programmes, where the traditional approach of 'theory first, practice later' is replaced by the adage 'practice first, theory later', the balance seems to shift completely from an emphasis on theory to reliance on practical experiences but this also does not guarantee success.

The professionalism of the teacher educator is another important issue in effective teacher education, highlighted in policy as well as in research documents. Already in the late 1970s, Coonen (1978) pointed out that this professionalism of teacher educators directly influences the professional level of the programme and the level of the professional education of the student teacher. However, the need for professional development and training of teacher education staff and cooperating teachers, is often overlooked (Korthagen et al., 2001).

Some issues about initial early childhood teacher education in particular. In many countries around the world there is a great emphasis on early childhood education. In order to provide high-quality preschool education, policymakers and other stakeholders are increasingly requiring preschool teachers to have at least a Bachelor's degree (ETUCE, 2008). However, according to Early et al. (2007) 'policies focused solely on increasing teachers' education will not suffice for improving classroom quality or maximizing children's academic gains. Instead, raising the effectiveness of early childhood education likely will require a broad range of professional development activities and supports targeted toward teachers' interactions with children.' In line with this, Tarr (2006) cites Dr Sarah Farquhar, 'Given the young age of children and the particular complexity of teaching this age group both teacher education (including knowledge and pedagogical skills) and the teacher's personal characteristics matter.' Especially teachers who are working with the young children have to bring together the educational and care functions in order to enhance these children's learning.

In conclusion, Snoek and Žogla (2009) can be cited, 'teacher education institutes in the various European Countries face similar challenges, like how to support teachers identity, how to bridge the gap between theory and practice, how to find the balance between subject studies and pedagogical studies, how to contribute to a higher status of teachers, how to prepare teachers for the needs of pupils in the 21st century (European Commission, 2007)'

B2. Current policy issues concerning initial teacher education for early year and primary teachers

Teachers in Europe are educated in a wide variety of institutes and by a wide range of curriculum models. Initial teacher education for early years and primary teacher may take place in universities, university colleges, or specialist institutes. However, regardless of their nature, teacher

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education institutes in the various European Countries face similar challenges, as indicated in B1.

In the past decades curricula of European teacher education institutes have been influenced by European and national policy. In the sections below current policy issues in Europe and in different European countries are highlighted.

B2.1. Policy in Europe in general

Although educational policies are the domain of national governments, the European Commission exerts a strong influence by organizing exchanges of interesting policy practices between Member States and by establishing recommendations and benchmarks (Snoek and Žogla, 2009).

B2.1.1. Common European principles on teacher competences and qualifications

'The improvement of the education of teachers and trainers was identified as one of the key objectives to improve the overall quality of the education and training systems in the EU. In 2002 the Commission established an expert group with representatives of Member States, social partners and other stakeholders to support the implementation of this objective, notably through identifying key issues and exchanging best practices. In 2004, the Commission was given the mandate by the Council of Ministers to begin the development of Common European Principles on Teacher Competences and Qualifications, a common framework to support policy reforms on teacher education in the Member States. The expert group developed a set of common principles which were presented in 2005, but it was not until August 2007 that the Commission formally presented the results of its work on teacher education (ETUCE, 2008).

The Commission suggests a number of policy steps. These include ensuring that teachers have the skills to identify the needs of each individual learner and support them to be fully autonomous learners, to work in multicultural settings, and to help young people acquire the key competences. Teachers should moreover be encouraged to continue to reflect on their own practice in a systematic way and to engage in classroom-based research. Furthermore, the Commission recommends that teacher education programmes should be available in the Master and Doctorate (as well as Bachelor) cycles of higher education' (ETUCE, 2008).

In 2011 the Council of the European Union stated that education and training are key factors to achieve the 'Europe 2020' goals. In the conclusions of the Council of the European Union (2011) on the role of education and training in the implementation of the 'Europe 2020' we notice that there is a call at the education and training area to provide a right mix of skills and competences, to ensure a sufficient supply of science, mathematics and engineering graduates, to equip people with basic skills and the motivation and capacity to learn, to foster the

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development of transversal competences, including those that enable the use of modern digital technologies, to promote sustainable development and active citizenship, and to encourage creativity, innovation and entrepreneurship.

B2.1.2. Inquiry in science and mathematics

In the report of the European Commission (2007) it is stated that inquiry, by definition, is the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments (Linn, Davis, and Bell, 2004). Although this is a very broad definition, the problem arises that when talking about inquiry teaching approaches: a lack of clarity in terminology pops up (European Commission, 2011a).

In mathematics teaching, the education community often refers to 'Problem-Based Learning' (PBL) rather than to IBSE (European Commission, 2007). In science education we see that the term Inquiry refers to at least three distinct categories of activities. First to what scientist do (e.g., conducting investigations using scientific methods), secondly to how students learn (e.g., actively inquiring through thinking and doing into a phenomenon or problem, often mirroring the processes used by scientists), and finally to pedagogical approach that teachers employ (e.g., designing or using curricula that allow for extended investigations)' (European Commission, 2011b).

B2.1.3. Creativity

The European parliament and the Council of the European Union announced 2009 as the year of creativity and innovation (2008). They subscribed creativity as related with innovation as a personal quality that should be spread across the entire population. The full development of the potential for innovation and creativity of European citizens built on European culture and excellence in science is a key factor for future growth. Therefore the education systems had to ensure they could support this development. (European Parliament and the Council of the European Union, 2008). Since 2002 the EURAB recommends the introduction of Creative Science Teaching modules in the formal training period of all primary school teachers (EURAB, 2002).

B2.1.4. Features of the professionalism of the teacher educator

In a recent study, Smoke et al. (2010) analysed European policy documents to search for information on the status of the profession of teacher educator and for actions and measurements to improve teacher educators' professionalism. The study was restricted to 6 main policy documents that consider the issues of the teacher education from a European perspective. These are:

- Teachers Matter (OECD, 2005)
- Common European Principles for Teacher Competences and Qualifications (European Commission, 2005)

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- Improving the Quality of Teacher Education (European Commission, 2007)
- The Council Conclusions (European Council, 2007)
- The Quality of Teachers (ATEE, 2006)
- Teacher Education in Europe (ETUCE, 2008)

Smoke et al. (2010) concluded that the documents gave no information about the current status of the teacher educator profession. They found that these documents pay limited attention to the professionalism of teacher education. If teacher educators are mentioned, it is to express concerns about their quality. The researcher finds this quite disturbing because there are reasons to assume that the quality of teacher educators is one of the most prominent factors predicting the quality of teachers. They plead for policymakers, researchers and teacher educators to work together to develop concepts for the induction and further development of teacher educators.

In the ETUCE report (2008) the group of teacher educators is defined as follows: 'academic staff in higher education institutes who are teachers of education or teaching subjects; education researchers; other teachers of didactics or general courses; supervisors of practice in schools closely linked to initial teacher education institutes; trained and experienced teachers supervising practice in other schools; tutors (counsellors, coordinators, mentors, guides etc.) supervising prospective teachers at the 'on-the-job' qualifying phase; networks of supporters in the 'on-the job' qualifying phase.'

B2.2. Policy in the participating countries *Creative Little Scientists*

Initial teacher education for preschool and primary school teachers is part of a country's educational system. The levels of teacher education programmes in the different European countries differ, by means of length and academic degree. In the participating European countries, teacher education programmes (especially primary education) have been adapted to the bachelor-master framework, as recommended by the European Commission. However, in only a few countries all teachers' qualifications are at Master's level (Portugal, Finland). In Malta and Flanders the level of qualification for teachers in early years and primary is under discussion, with the possibility of having teachers at Master's level following the model in Finland.

In most of the EU countries, initial teacher education for early childhood education takes place at the tertiary level. In Malta, this is currently not in place and kindergarten teachers are usually BTEC National Diploma graduates in Care. By 2015 policy is that all teachers even in age range of 3-5 years are to have a degree.

In Belgium, France, Cyprus, Portugal and the UK, teacher education for early childhood education is similar to study for teaching at primary level. In most countries, staff without formal teaching qualifications can be employed as childcare assistants, who play a valuable role that is distinct from that of the teacher (ETUCE, 2008)

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In Germany the regulation of the initial teacher education lies with the federal state and is different from Land (=federal state) to Land.

In Romania, according to the Law 387/2009 there are two tracks for the initial training for early age educators (preschool and primary school): a. 'those graduating with a diploma exam at a pedagogical university colleges, teaching high school or equivalent schools followed by graduation with a diploma of higher education institutions long-term or short-term or completion of first cycle studies at the Bachelor's degree or completion or graduation, followed by a specific course in the psycho-pedagogical and methodological field; b. those completing the first cycle diploma of Bachelor's degree or second cycle of university studies or job-masters in teaching high school graduation, followed by graduation from an institution of higher education in the short or long term teaching profile'. Some Universities are offering a Master degree on early age (e.g. 'Ovidius' University form Constanta; Faculty of Psychology and Educational Sciences, University of Bucharest) or primary education.

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Country		**length**	**degree**	**institution**
Greece	Early childhood and primary education	4 years	Bachelor	State University
UK/England and Wales	Early childhood and primary education	3 or 4 years	All teachers must have a degree and Qualified Teacher Status (QTS) gained through Bachelor degree plus QTS or Bachelor degree (3 years) followed by either *Professional* graduate certificate in education (Bachelor level – 1 year) or *Postgraduate* certificate in education (Master level)	University – in varied partnerships with schools
UK/Scotland	Nursery (3-5) and primary education (5-12)	4 years or 1 year	The four year Bachelor of Education (BEd) degree course in Primary Education or the one-year Professional Graduate Diploma in Education (PGDE) course.	University – in varied partnerships with schools
Portugal	Early childhood and primary education	5 years	Master	University and Higher Education Schools

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Belgium	Early childhood and primary education	3 years	Bachelor	University colleges
Finland	Early childhood education	3 years	Bachelor	University
	Primary education	5 years	Master	University
France	Early childhood education	5 years	Master	First three years university; last two years -‘‘University Institutes of Teacher education’’ IUFM (which will be gradually integrated into the universities).
	Primary education	5 years	Master	First three years university; last two years -‘‘University Institutes of Teacher education’’ IUFM (which will be gradually integrated into the universities).
Malta	Early Childhood education 2 – 8 years		BTEC - National diploma graduates Bachelor	University of Malta
	Primary education 5 to 11 years		Bachelor	University
Germany, Different from State to State	Early Childhood education	Minimal 3 years	National diploma	specific Berufsschulen (vocational schools) New in some federal states: University
	Primary education	Minimal 5 and a half years	State examination	University In some federal states: ‘Pädagogische Hochschule’ (University of Education)

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B2.2.1. The recruitment of student teachers' candidates

In Finland there is a three phase entrance test: literature based test, interview and group assessment. As stated by McKinsey (2010) the system in Finland, like Korea and Singapore, recruits 100% of his teacher corps from the top third of the academic cohort and then screen for other important qualities as well. According to this report, this central strategy is one of reasons why the school system in Finland belongs to the world's top performing school systems.

In Wales and England all applicants for programmes of initial teacher education must at least have a grade C at GCSE (exams in year 11) in English, mathematics and science. Applicants for 1 year teaching qualifications (after their first degree) generally require also a good degree, and some experience of schools. Interview processes often include tests in mathematics and English. Students must have a criminal records check and be interviewed to check suitability in terms of intellectual capability, communication skills, qualities, attitudes and values expected of a teacher and have met health and physical requirements.

In Scotland: Three Highers (or equivalent) including English at grade C or above. Acceptable alternative qualifications include GCSE English language and literature at grade C or above; two Standard Grades (or equivalent) including mathematics at Credit level or Intermediate 2. Acceptable alternative qualifications include GCSE mathematics at Grade B and above; a degree from a UK university (or equivalent degree from outside of the UK).

In Greece Pan-Hellenic examinations are held at the end of the final grade of secondary education.

In Germany, the standing Conference of Ministers of Education and Cultural Affairs (KMK 2005) adopted guidelines and definitions for Bachelor's and Master's degrees in Primary teacher education courses. Admission requirements to initial teacher education courses are: higher education entrance qualification (Abitur); First State Examination is required for the entrance to the preparatory courses in school (in-service training).

In Portugal, according to legislation, to apply for access to higher education through the National Competition, students must prove their capacity to attend higher education. This demonstration is made through entrance examinations and in some cases, pre-requisites. The entrance examinations are currently implemented through national exams for secondary school.

In Belgium students and foreign nationals must have successfully completed a secondary education course or qualification or foreign equivalent.

In France students must have the degree of 'Licence' (obtained at the end of the first 3 years of university studies). After, examination is

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required for the entrance to the IUFM where students follow a two-year vocational training.

In Romania, admission to the initial training program includes the assessment of communication and artistic skills and a stage of files analysis: 50% average of the baccalaureate marks and 50% average of marks during the high school years study (example from Faculty of Psychology and Educational Sciences, University of Bucharest (http://admitere.unibuc.ro/infoadmitere/studii-universitare-de-licenta/psihologie-si-stiintele-educatiei).

B2.2.2. Qualification as a teacher

In several countries in Europe, a Bachelor's or Master's degree is not enough to qualify as a teacher. In Greece teachers must participate in an examination held by the Supreme Council for Civil Personnel Selection (ASEP) and being registered in a chart of provisional supplementary teachers. Apart from their success in the written exams, the following are being taken into account: a) Degree grade, b) Postgraduate degrees, c) PhDs, d) past experience in the field. In Wales and England students must have a first degree before being awarded Qualified Teacher Status (QTS). Also in France student teachers have to pass a state assessment before a teaching license can be obtained.In Portugal the ownership of the professional qualification for teaching general, in pre-school and on the 1st and 2nd cycles of basic education is given to those who have a degree in Elementary Education and a Masters in Education.

B2.2.3. Competences/standards to be reached in initial teacher education

In several of the participating countries the autonomy of the institutions providing initial teacher education, is restricted by minimum standards or competences required of teachers at the end of initial training. Still there are some differences between these countries. According to the study of the University of Jyväskylä (2009) in the European Member States there are three kinds of models to define teachers' skills and competences in teacher education.

- In the first model, teachers' skills and competences in teacher education have been defined in a fairly centralised way at national level. Germany and the UK belong to these countries. The Government or the Ministry or a governmental body, such as a Teaching Council or similar, quite strictly regulates the competences which must be included in teacher education curricula or other teacher education documents.
- In the second model, the Government or the Ministry sets a broad framework for defining competences for teacher educators, but does not define the skills and competences the teachers should acquire during teacher educators courses. In several of the participating countries the second model is applied: Belgium, France, Portugal, Romania

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- In the third model, which is applied in Finland, Greece and Malta, the definition of skills and competences for teacher education has not been documented at all at national level.

Although in some countries research skills and competences are specifically stated in official documents, the research component in teacher education in the majority of EU countries is far from adequate (ETUCE, 2008). Yet, these skills and competences are necessary to develop new knowledge and to be innovative, for example to bring in new methods of inquiry, to develop a creative learning environment for children integrating science and mathematics.

B2.2.4. The standards/competences in detail

In Portugal, the general profiles of competence of teachers and educators first cycle of primary education are defined by Decree-Law No. 241/2001 of 30 August. (See due to its length profiles in: http://dre.pt/pdf1sdip/2001/08/201A00/55695572.pdf)

In England the current standards comprise 3 main areas: professional attributes; professional knowledge and understanding; professional skills. These will be replaced be new standards from September 2012 - 1) Set high expectations which inspire, motivate and challenge pupils 2) Promote good progress and outcomes by pupils 3) Demonstrate good subject and curriculum knowledge (which includes 'if teaching early mathematics, demonstrate a clear understanding of appropriate teaching strategies') 4) Plan and teach well structured lessons 5) Adapt teaching to respond to the strengths and needs of all pupils 6) Make accurate and productive use of assessment 7) Manage behaviour effectively to ensure a good and safe learning environment 8) Fulfil wider professional responsibilities.

The current standards require that students are aware of the approaches promoted by the government for mathematics and English. The new standards require that students are taught systematic synthetic phonics to teach reading and unspecified 'appropriate teaching approaches' for mathematics which have yet to be disclosed.

In Wales the current standards consist of: professional values and practice – endeavour to personalise learning to meet diverse needs; demonstrate professionalism; ability to communicate with others; promote the school in the community; reflect on own practice and take responsibility for development; knowledge and understanding – subjects and curriculum; make good use of national guidance; special needs; behaviour strategies; teaching – planning, teaching, assessing, behaviour management; promote sustainable development and global citizenship.

In Germany the regulation of the initial teacher education lies with the federal states. According to the Eurybase summary (2011), following KMK (2008), primary teacher-training students should gain: compatible content knowledge; subject-related cognitive and working methods; compatible subject-related teaching methods. Furthermore, the in-service school training is intended to provide future teachers with the ability to: plan and structure subject-related learning; deal with complex teaching situations; promote sustainable learning; manage subject-specific performance assessment.

In Flanders a new decree on teacher education was adopted (December 2006). The decree redefined the learning outcomes of teacher education curricula (early childhood, primary and secondary education). The learning outcomes of teacher education are described as basic competences. There are 3 groups and 10 subgroups of basic competences:

- the teacher as a guide of learning- and development processes;
- the teacher as an educator;
- the teacher as a (subject - content) expert;
- the teacher as an organizer;
- the teacher as an innovator / researcher;
- the teacher as a partner of parents;
- the teacher as a partner of the school team;
- the teacher as a partner of the external community;
- the teacher as a member of the educational community;
- the teacher as a participant of the cultural community.

Within these ten competences the decree stated to have special attention for: perfect mastering of the Dutch instruction language, taking into account the idea that all teachers should be language teachers; ability to communicate with non-native speakers; problems related to the metropolitan context (truants, aggression, language…).

In the French Community of Belgium the decree adopted on 12 December 2000 defines thirteen competencies to be developed as part of initial training for pre-primary, primary and lower secondary teachers: using knowledge of the human sciences for an accurate interpretation of situations encountered inside and outside class and for better adaptation to the school population; maintaining effective partnership relations with institutions, colleagues, and pupils' parents; understanding their role within the school and functioning in the profession as defined by the relevant laws; internalising the disciplinary and interdisciplinary knowledge that underpins teaching work; mastering the disciplines' didactics, which guide teaching work; demonstrating a broad general culture in order to awaken pupils' interest in the cultural world; developing the relational skills commensurate with the profession's requirements; understanding the ethical issues associated with day-to-day teaching practice; working in a team in the school; developing, testing, evaluating and refining teaching aids; maintaining a critical and autonomous relationship with past and future scientific knowledge; planning, managing and evaluating learning situations; maintaining a

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reflective view of one's own practice and organising one's own continuing training.

In France, in 2007, the new specifications for IUFM driven by the Ministry of Education increases the presence of trainees with students during their training, transforms the professional report written by professionals determined locally by schools, and establishes the concept of life skills to the trainee. These ten skills that the young teacher must necessarily control are: 1 acting ethically and responsibly; 2 master the French language to teach and communicate; 3 mastering the disciplines and have a good general knowledge; 4 designing and implementing teaching; 5 organise the work of the class; 6 take into account the diversity of students; 7 evaluate students; 8 mastering information technology and communications (repository C2i teacher - the C2i corresponds to a certain level of computer skills, assessed by a test); 9 teamwork and cooperation with parents and school partners. 10. train and innovate.

In Romania, the standard for primary school teachers issued in 1999 defines 23 competences grouped in six fields of competences as such: 1.communication (teacher-student communication; teacher-teacher communication); 2.curriculum (educational material providing, accomplishment of the didactic project, learning activity programming); 3.professional development (professional development); 4. assessment (assessment of student's results, development of the assessment tools, evaluation of student's results, registration of student's results); 5. student personal development (development of communication skills, building the exact thinking, development of learning skills, development of social behaviour, development and encouragement of artistic skills, training of practical skills, formation of the fundamental tools of communication, training in sciences, organization and preparation of learning space); 6. the relationship: family-school-society (coordination of extracurricular activities, family involvement in formative - educative activities, development of the family - school relationship). The current standard for preschool teachers issued also in 1999 is structured also in the same six fields of competencies, two of them having less competence units: 4. assessment (pupil's evaluation) and 5. student personal development (coordination of didactic games, coordination of games and leisure - creative activities, training of general skills, teaching of basic knowledge).

B2.2.5. Curriculum content

In the study of University of Jyväskylä (2009) two basic models, concerning the level of decision-making at which key decisions are made about the content of initial teacher education curricula, are identified:

1) In 24 countries the national documents, laws and regulations provide general guidelines and frameworks on how teacher education has to be organised in teacher education institutions,

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with the institutions designing their teacher education curricula quite independently.

2) Only in three countries, in Greece, Luxembourg and Malta, are the teacher education institutions quite independent and define the structure and the contents of initial teacher education curricula autonomously.

This means that the institutions in the participating countries are designing their teacher education curricula quite independently. As such, there are great differences between institutions in Europe and even within each country. Innovation in these institutions is possible.

In general, teacher education curricula consist of the following four elements (European Commission, 2007):

- extensive subject knowledge;
- a good knowledge of pedagogy;
- the skills and competences required to guide and support learners;
- an understanding of the social and cultural dimension of education.

According to the Eurydice report on science education (European Commission, 2011a) 'knowing and being able to teach the official mathematics/science curriculum' is the most important competence emphasised during the initial education of teachers of mathematics/science.

Along with observations from Eurydice, countries which have a strategic framework for the promotion of science education normally include the improvement of science teacher education. However, only a few European countries have such strategic framework. Countries which have a general, overall strategy are Germany, Spain, France (since March 2011), Ireland, the Netherlands, Austria, the United Kingdom and Norway. In Malta, a strategy for mathematics, science and technology is currently developed (European Commission, 2011a).

In most of the participating European countries there are no references made in legislation regarding Inquiry Based (Science) Education. Although in several countries in teacher education institutions a trend exists that points to focus on IB(S)E. In Greece most universities have a section devoted to IBSE as part of the Didactics of Science module.

In Malta IB(S)E is promoted in the new policy document 'vision for science education in Malta'. The focus on inquiry-based learning is present in the training courses focusing on science as part of the Bachelor of Education courses in both primary and early years.

In England the closest statement is 'build on prior knowledge, develop concepts and processes, enable learners to apply new knowledge, understanding and skills and meet learning objectives'. In Wales the closest match is S3.3.3. They teach clearly structured lessons or sequences of work which interest and motivate learners and which: (c) promote active and independent learning that enables learners to think for themselves, and to plan and manage their own learning.

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B2.2.6. Teacher education pedagogy

In most of the participating countries there are no specific approaches for teacher education pedagogy (teaching activities) stated in the initial education policies, apart from school practices.

In some countries, tests and assessments are defined by the government. For example, in Germany, primary student teachers have to pass through two State Examinations; a First State Examination, which has to be passed before the preparatory course and a Second State Examination, the prerequisite for permanent employment in a teaching career. Student teachers must pass a central exam in mathematics in Greece, France and the United Kingdom (European Commission, 2011b).

B2.2.7. Involvement of schools in initial teacher education

In many European countries the role of field experiences in schools has been reconsidered. In recent years the amount of teaching practice in teacher education curricula as been increased (OECD, 2005). In Europe two dominant models exist to link theory and practice: the concurrent model and the consecutive model. In the concurrent model, the theory and practice are combined during the initial education. Whereas in the consecutive model the teaching qualification is achieved by undertaking pedagogical studies/training after the initial education is completed. The latter is used in the system in Germany. The initial teacher education of primary school teachers is divided into 2 parts: a course of higher education (focus on theory) which takes place at universities, Technische Hochschulen, colleges of education or colleges of art and music; a practical pedagogical training (focus on practice) which takes place at training schools. Also, practical preparatory courses during the first part take place in schools. The preparatory course usually lasts between 12 – 18 months; it differs from Land to Land. Kindergarten teachers are usually trained in vocational schools and Kindergarten classes at the same time, combining theory and practice.

In Portugal the initial training of teachers and professors have a component of initiation into professional practice that includes observation and intervention in situations of education and training, supervised practice in the classroom and school.

In Greece, all trainees are required to attend school days as observers, teach a number of supervised or 'trial' lessons and during the final two semesters teach on their own for a number of days depending on the University requirements (e.g. for the University of Athens it is one week)

In Malta, during a 6 week period students take a class in hand and are required to teach during this period. However, currently there is a debate about the number of classrooms available for students to observe and carry out teaching practice since there is saturation of classes as the pupil population has gone down over the past 10 years.

In England the government favours putting initial teaching education more under control of the schools, taking more of an apprenticeship

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approach. Teaching schools are being promoted. Schools are involved in the selection process, training and assessment; minimum requirements set for time in schools (32 weeks for 4 year undergraduate; 24 weeks for 3 year undergraduate; 18 weeks for post-graduate); mentoring while in schools. There is an increased emphasis on school-based training routes for example Graduate Teacher education Programme (GTP) – a competence-based route largely based in school. The trainee needs to be based in a school and has an individualised programme devised and assessed by an accredited provider. Teach First – a programme for graduates with very good degrees (1st or 2.1 grades). After a short induction training period of 6 weeks they take on the role of the class teacher in school – assessed and supported by Higher Education Institution and school mentors.

In Wales all providers must work in partnership with schools and actively involve them in: planning and delivering initial teacher education; selecting trainee teachers; assessing trainee teachers for QTS. The minimum requirements set for time in schools (32 weeks for 4 year undergraduate; 24 weeks for 3 year undergraduate; 18 weeks for post-graduate); mentoring while in schools

In Finland teaching practices are carried out at university practice school (3 times during studies Orientation practice 3 ects, Basic practice 7 ects and Advanced practice 8 ects) and at normal school (once during the studies Applied practice 4 ects).

In Flanders a new decree on teacher education was adopted (December 2006). The decree increased the pre-service/in-classroom training: each student has to pass a minimum number of study points of practical teaching classes, which can be up to half of the teacher education programme. The decree also introduced a new mentoring system.

In France there are 2 types of training: 'Training of observation' where students are present in pairs in the class of a teacher; and 'Training of responsibility' where students take full responsibility for a class. The duration of training is less than 40 days and cannot exceed six weeks.

B2.2.8. Teacher educator characteristics

In the section below information is given about the teacher educator working in teacher education institutions.

In Portugal the teacher trainer, in accordance with Article 35 of the Basic Law of the Portuguese education system, 'Qualification for teachers of higher education' has the degrees of doctor or teacher. They can also be licensees who have provided educational aptitude and scientific capacity, and may begin teaching other known qualified individuals.

In Greece a relevant PhD is required from all members of teaching staff. No standard amount of school experience is mentioned as a requirement. Teacher educators in Finland also need to have a doctoral degree and in addition two year teacher experience and teacher qualification.

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In Malta teacher-trainers for courses offered at tertiary level would involve academic staff at the Department of Primary at the Faculty of Education, University of Malta. The teacher-trainers are thus at minimum with masters level and higher level academics possessing a doctorate in their area of teaching. Although there are not stipulated times of teaching experience required, all need to be teachers with warrant and a degree of experience of teaching in schools. The latter is assured when recruiting teacher-trainers at the University of Malta. In the case of staff teaching BTEC National Diplomas at the vocational institute, Malta College of Arts, Science and Technology (MCAST), these tend to have a Masters degree, and if currently still with just a first degree, the college is investing in their professional development.

Since teacher education for early years and primary is provided by University colleges, the teacher educators in Flanders have to have at least a bachelor degree.

In Wales and England there are no legal explicit requirements. In most cases teacher educators will have qualified teacher status (QTS) and have experience teaching in the relevant age phase. Most institutions prefer tutors to have higher degrees (masters or doctorates) but this is not a legal requirement. In Wales, spoken and written Welsh are an advantage.

In France teachers trainers are teachers IUFM. First they can be master trainers: teachers or school teachers who have passed the CAFIMF (certificate of proficiency as a teacher educator master) or CAFIPEMF (certificate of proficiency as a school teacher of master trainer) these trainers continue to teach in their class, but intervene in IUFM for a discharge time of instruction. Secondly the can be aggregate or certified teachers from the secondary (PRAG, ESRP) or school teachers from the primary (PREC) and seconded teachers or time-sharing (working both in the classroom and in the IUFM). These teachers involved provide training in the disciplines of primary or secondary, but also in philosophy of education and sometimes in other sciences for education; They can also be lecturers: assistant professors and university professors; Finally they can be outsiders: people from diverse backgrounds who bring expertise in a particular field.

B3. Research studies on initial teacher education for early years and primary teachers concerning math and science

In this section of the review, key findings from research studies concerning initial teacher education for early years and primary teacher in the domains of science and mathematics are synthesized. The results are structured in three themes: characteristics of the student teacher, initial teacher education interventions (including content/method courses, field experiences and reflective practices) and the teacher educator.

Research articles as well as books, containing research data, are selected, using the methodology described in section 1.2. The articles can

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be divided into studies focusing on instructional design with or without effect study, reviews, studies focusing on beliefs, views, opinions, attitudes, conceptions, … of the learner (student teacher) and studies focusing on conceptual frameworks. The articles provide data in the field of early childhood, primary and elementary pre-service teacher educations. Elementary, in a large part of the documents, stands for preschool and primary school pre-service teacher education. In the synthesized results, data of these two levels are not separated.

Only a few studies combine science and creativity, mathematics and inquiry, mathematics and creativity, or science/mathematics, inquiry and creativity.

An overview of the characteristics of the selected studies is presented in Table 1 (see appendix).

B3.1. Key findings related to characteristics of the learner = the student teacher

Research in the field of science and mathematical education, points out that beliefs and attitudes towards science and mathematics of pre-service teachers play an important role in the development of their teaching practices, and accordingly their influence on students (pupils) attitude and interests (Downing and Filer, 1999; Yilmaz-Tuzin, 2007; Zacharos et al., 2007).

In the planning and development of courses for student teachers, it is therefore necessary to take these views, conceptions, beliefs and attitudes towards mathematics, science, mathematical and science teaching into account (Loughran, 2008; Zacharos et al., 2007) as well as student teachers understanding of science- and mathematics-related knowledge (Gago et al., 2004; European Commission, 2011a;2011b).

The study of Howes (2002) recommends teacher research as a powerful way to get to know the student teachers' skills, attitudes, and beliefs. She suggests how science teacher educators might draw on the strengths (characteristics) of their teacher's students to support teaching practices. As described before, this is also emphasised in the realistic approach of Korthagen et al. (2001).

In the section below key findings extracted from the included studies focusing on attitude, conceptions, views, beliefs, subject knowledge … of the student teacher towards science, mathematics, science or mathematics teaching, are presented.

B3.1.1. Key findings concerning characteristics of student teachers in the domain of science and science teaching

Garbett (2003) highlights the problem of inadequate science content knowledge of elementary pre-service teachers. Early childhood student teachers are also unaware of how much they don't know and how this might affect their ability to provide appropriate science experiences for young children (Garbett, 2003).

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In their study Skamp and Mueller (2001) examined the factors which are influencing student teachers conceptions of effective primary science practice. They reported a pattern of influencing factors (starting with entry influences), however student teachers' own practice often supersedes most other influences. This was also stated by Loughran (2008). Student teachers are influenced by their school experiences and try to teach in the same way they experienced science teaching, it is difficult for them to adopt alternative approaches.

The results of Downing and Filer (1999) also indicate the impact former teachers have on students' achievement and attitude towards science. Student teachers with positive attitudes towards science believed that their former science teachers perceived them as being capable of doing and learning science. Downing and Filer also noticed that these student teachers performed well in using science process skills. According to Eick and Stewart, student teachers with positive attitudes towards science, inquiry and inquiry based science teaching, also appear to have additional dispositions that support teaching of inquiry based science (Eick and Stewart, 2010). These supportive dispositions included curiosity and questioning, investigating first-hand, learning together, and active learning.

Amirshokoohi (2010) explored elementary pre-service teachers' environmental literacy and views toward science, technology, and society issues. The results of the study indicate low levels of environmental literacy, low levels of personal interest in science, technology and society issues but slightly better scores of participants' views towards teaching science, technology and society.

Bleicher (2009) distinguishes four different categories in a group of pre-service elementary teachers: fearful, disinterested, successful and enthusiastic science learners. The study indicates that the four categories increased differently in their science content knowledge, understanding of the Learning Cycle, science teaching self-efficacy and confidence to learn science, following a science method course. Fearful science learners were less confident to learn science and demonstrated less increases in science content knowledge and understanding of the Learning cycle than the other three categories. Disinterested teachers only showed fewer gains in science content knowledge.

In their study, Sundberg and Ottander (2008) found that one full year of exposure to activities was needed for sceptical attitude towards science to change.

Scientific subjects seem to influence the emotions of pre-service primary teachers (Brigido et al., 2010) and these emotions seems to play an influential role throughout their professional growth. In physics and chemistry, the emotions are mostly negative in women, both in learning and in teaching, while men recall negative emotions in learning, but positive in teaching. In nature sciences, the emotions of both men and women are very positive, both in learning and teaching.

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Yilmaz-Tuzin (2007) noticed a significant correlation among elementary student teachers' confidence level with assessment techniques, classroom management, teaching methods and science content knowledge and number of science methods and science content courses taken. The pre-service teachers in this study however felt more comfortable teaching biology concepts than teaching chemistry concepts and/or physics concepts.

The findings of Hechter (2011) reveal that science method courses can increase pre-service elementary teachers' level of science teaching self-efficacy. However the number of postsecondary science courses completed and prior school science experiences can have a significant main effect on personal science teaching efficacy but not on science teaching outcome expectancy of pre-service elementary teachers.

Ucar and Sanalan (2011) noticed that programmes with higher science method course hours, seems to be superior in terms of students' SVAS (student views about science) scores.

Newton and Newton (2011) identified that primary pre-service teachers' conceptions of creativity in science lessons are narrow. Their conceptions of creativity in science focused mainly on practical investigations of matter of facts, and included misconceptions. These student teachers saw creativity as centred more on the arts and they omit the significant opportunities for creativity involving, for example, the imaginative processing of scientific information and the constructing and testing of explanations. These authors (Newton and Newton, 2011) also noticed that beginning pre-service teachers have narrow conceptions of engaging children in science lessons. The aim of their pedagogies was most commonly that of gaining a willing, attentive participation in a science lesson, using hands-on experiences. However, these approaches are not always feasible, appropriate or effective. One kind of instruction may not be suitable for all learners and may not recognize individualized instruction.

Also, Ergül (2009) found that pre-service primary teachers would like to teach science classes with the emphasis on experiments and practice.

B3.1.2. Key findings concerning characteristics of student teachers in the domain of mathematics and mathematics teaching

The findings of Zacharos et al. (2007) revealed the negative attitude of a group of student teachers of early childhood education towards mathematics. Furthermore, the epistemological views on mathematics and its instruction of these teachers did not constitute a single and solid conceptual system.

Brady and Bowd (2005) noticed that the anxiety associated with teaching mathematics experienced by many of the pre-service teachers in their study, can be described as a cyclical phenomenon. 'Negative experiences with formal mathematics instruction led many participants to discontinue their study of the subject, or discouraged them from pursuing formal

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mathematics instruction beyond that which was necessary to fulfil high school graduation or university admission requirements. This led to the perception on the part of many respondents that their mathematics education had not prepared them to teach the subject confidently, a condition that has the potential to be replicated in their students' (Brady and Bowd, 2005: 45).

The results of Isiksal et al. (2009) indicate the negative relationship between mathematical anxiety and mathematical self-concept of elementary school teachers, which is also reported by others as mentioned in their study.

Bolden et al. (2010) noticed that pre-service primary teacher conceptions of creativity in mathematics teaching are narrow, predominantly associated with the use of resources and technology. Pre-service teachers themselves indicate that the facilitation of students' creativity is included in the teachers' role, but they do not feel well-trained and confident to realize this (Kampylis, 2009).

B3.1.3. Advices for the design of initial teacher education programmes or courses

Although most of the studies mentioned above focus on characteristics of the student teacher, several of them formulate advices.

- It could be useful to link the word 'creativity' with 'productive thoughts' in science education to draw attention to a wider view of what creativity in science can offer (Newton and Newton, 2009).
- It is important to include and emphasize science process skills and to foster positive attitudes toward science in teacher education programmes (Downing and Filer, 1999).
- Dominant attitudes, norms and behaviours of the pre-school professional culture (nurturing) may clash with developing science teaching skills (structured learning activities). It may be important that preschool teacher education programmes communicates about these contradicting cultures (Sundberg and Ottander, 2008).
- The features of engagement of pre-service teachers could be used as starting point for teacher education programmes, to widen student teachers' conceptions of engagement and increase their repertoire of teaching behaviours (Newton and Newton, 2011).
- The study of emotions is important in the context of initial teacher education (Brigido et al., 2010).
- Conceptions of creativity in mathematic teaching need to be addressed and developed directly during pre-service teacher education (Bolden et al., 2010).
- Data of Bleicher (2009) advice to develop different instructional interventions to prepare all pre-service teachers, also the fearful ones.
- Science method courses should provide opportunities to learn about different methods and practice them as appropriate. More

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field experiences might increase pre-service teachers' confidence in handling the issues learned in their courses (Yilmaz-Tuzun, 2007).

- Pre-service teachers should have positive, meaningful and engaging experiences in postsecondary science courses leading up to the methods courses. To do this, there must be a collaboration between the teacher education department and the science department (Hechter, 2011).

B3.2. Key findings related to initial teacher education interventions

Several of the included studies focus on instructional design of initial teacher education interventions.

The primary research function of these studies however differs - design of an intervention, description of an intervention, evaluation of an intervention in terms of changed competences of the learner or strengths or weakness of the intervention. Accordingly, the research strategies in these studies are different - case studies, action research, ethnography, evaluation research, design research ... In the majority of the studies an intervention is evaluated. Educational design research, however, as described by Plomp and Nieveen (2010), with active participation of different stakeholders as co-researchers (such as the student teachers) and the description of several iterative loopings, is not detected in the included studies.

In one of the studies a new approach is evaluated - the dual vision methodological process, using dual vision critical incident vignettes (Howitt and Venville, 2009), provides the researcher with an opportunity to move into the reality of the pre-service teacher.

The interventions studied in the included articles can be divided into 'interventions' focusing on:

- specific methods, lessons or tools used in a science and/or mathematics method or content course to improve knowledge and skills or change attitudes, beliefs, … of student teachers
- field experiences, mastery experiences and/or vicarious experiences as part of a science and/or mathematics method course to improve mathematics and science teaching skills and confidence of student teachers
- reflective practices of student teachers to improve reflective skills of student teachers
- integrated approaches

In the section below, each of these interventions are discussed per subheading.

In a relevant number of the selected studies, the interventions are part of a mathematics or science method course. In several of these method courses class lecturers, discussions and demonstrations are combined with scientific laboratory activities and field experiences. In a study of Schwarz (2009), results indicate that pre-service elementary teachers are

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most likely to advance their science knowledge and practices within a coherent approach that focus on a core scientific practice such as modelling-centred inquiry, which provides opportunities to unpack and apply robust tools such as reform-based instructional frameworks, and addresses their perceived problems of practice.

Many of the included science method courses not only have an impact on student teachers' pedagogical skills but also on their science content knowledge (Bleicher, 2006; Bleicher, 2009; Haefner and Zembal-Saul, 2004). Palmer (2008) confirms the effectiveness of a combination of content and methods courses. Science content courses focusing on science discipline knowledge only appears to be unsuccessful in improving student teachers' attitudes (Schoon and Boone, 1998). This is supported by Hechter (2011) who advises collaborations between educational departments and science departments to have a more holistic approach in science content courses, prior to science method courses. Goulding, Rowland, and Barber (2002) noticed a relationship between subject knowledge and planning and teaching, and they also stress on the importance of both subject knowledge and pedagogical knowledge in teaching mathematics.

According to Gago et al. (2004): 'The subject knowledge that primary school teachers require to teach the elements of the SET cluster of disciplines does not require them to have an academic background in any of these subjects. Nevertheless, to teach science well, primary school teachers must be able to explain potentially complex scientific principles in an interesting and simple way to their pupils, and relate these principles to their personal experiences and to salient contemporary issues.'

However Gago et al. stress on the importance of teachers having an authentic picture of what scientists do and how the scientific mode to explain and analyse the world looks. He suggests an integration of projects during the teachers' pre-service or in-service training, carried out through networks of co-operation between teacher education and research institutes or researchers at university to involve student teachers in authentic science projects. For example, future teachers could be involved in research projects as some kind of 'reporter', to know about it, to understand how and why it is done, and to present and explain it to non-scientists.

In some of the included studies, laboratory practices and partnerships with experts are evaluated.

Only a few of the included studies integrate science and mathematics. Jones et al. (2003), however, present some sound reasons for integrating science and mathematics method classes in early childhood teacher preparation programmes. They stress on the fundamental goal in early childhood education to deliver a curriculum in developmentally appropriate ways. They suggest also developing joint assignments, such as integrated science and mathematics lesson plans and integrated

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reflective journals. Palmer (2008) investigated innovative practices in initial teacher education programmes in Australia, these innovations included integration of science and mathematics courses.

Research studies combining science and creativity or maths and creativity are scarce (Broderick and Hong, 2005; Etherington, 2011; Koray, 2009; Palmer, 2009; Tselfes and Paroussi, 2009).

In a majority of the included studies the samples are too small or the interventions are only tested on one location, so there is no possible statistical generalization from sample to population. The researchers strived to generalize (a part of) the results to a broader theory. Several researchers formulated 'instructional design principles'. But in this context it is good to cite Tjeerd-Plomp (2010): 'each context has unique characteristics that justifies that the design principles should be used as 'heuristic' statements: they provide guidance and direction, but do not give 'certainties'.

B3.2.1. Interventions focusing on specific methods, lessons or tools used in science and/or mathematics method or content courses

A number of the studies focus on the understanding of the nature of science. Akerson, Morrison, and McDuffie (2006) used a reflective science method course to improve and retain new views of the nature of science. They suggest a combination of metacognitive teaching strategies coupled with explicit reflective nature of science instruction would be fruitful. Abd-el-khalick, and Akerson (2004) found also that the effectiveness of an explicit reflective instructional approach was mediated by motivational, cognitive and worldview factors.

A significant number of studies are focusing on inquiry based and problem based learning and teaching. The findings of Weld and Funk (2005) suggest that when pre-service elementary teachers are taught science as inquiry (using inquiry teaching strategies), they recognize not only how much more there is to know about a science discipline, but also how much there is to know about teaching it effectively. And more importantly, the pre-service teachers adopted the characteristics of life-long learning. Similar conclusions are drawn by Haefner and Zemba-Saul (2004), scientific inquiry supported the development of more appropriate understandings of science and scientific inquiry. Isabelle and de Groot (2008) evaluated the Itakura method, an inquiry-based teaching method, also known as the hypothesis-experiment-instruction method, to successfully mediate alternate science conceptions 'preconceptions' of pre-service teachers in an integrated mathematics, science, and technology methods course. The integration of Web-based archived data into inquiry-based instruction can be used to effectively promote conceptual change among pre-service teachers (Ucar, Trundle and Krissek, 2011). ICT-tools such as video games can also support student's scientific understanding, especially when they are integrated with hands-

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on activities, with each activity informing the other (Anderson and Barnett, 2011).

Lu, Tsai and Hong (2008) examined the Root Cause Analysis teaching strategy on pre-service primary teachers and their ability to apply the strategy in primary classrooms. The strategy can improve the shortcoming of tackling a problem on the surface and not at the root.

Carin, Bass, and Contant (2005) proposed the 5-E Model of science instruction relevant to teaching science as inquiry (Engagement, Exploration, Explanation, Elaboration, and Evaluation). In the first Engagement phase, the teacher engages activities and stimulates curiosity. Exploration: Students have a concrete physical experience, observe properties, establish relationships, and ask questions. The teacher guides and coaches. Explanation: descriptions, explanations, questions by students, introduction of scientific explanation. Elaboration: Teacher facilitates students in developing understandings of concepts, students engage in cooperative group work. Evaluation: Assessment of what has been learned. The 'engage, explore and explain' model was also used in the study of Howitt and Venville (2009). Moreover the learning experiences of pre-service early childhood teachers were also characterized by placement within an authentic early childhood context; discussion of children's view of science and learning within a social constructivist environment.

Leonard, Boakes, and Moore (2009) showed that it is necessary to improve student teacher conceptions of inquiry prior to influence their practices. Also Etherington (2011) mentioned the need for discussion about previous conceptions learned in high schools, before starting an open inquiry course. They designed a problem-based learning approach, as a pedagogical mode of learning open inquiry science, and found a positive impact on pre-service teachers' motivation to teach science ideas within a real world context. They found that the PBL mode of learning and the scientific method of inquiry helped to define, frame and recognize what is required of an open-inquiry learner. This open inquiry approach can be seen as a method of teaching and practicing science wherein curiosity and the desire to understand the world are nurtured and talents, interests, creativity and skills are fostered.

The research of Vacc and Bright (1999) reveals that elementary school teacher's belief about teaching and learning mathematics can be changed significantly using Cognitive Guided Instruction, an approach correlated with problem-based learning, during a mathematics method course. However, they noticed that the student teachers were unable to use the tenets of CGI in their teaching. In CGI classrooms students spend most of their mathematics instruction time solving various problems by creating their own solutions instead of following a set of procedures provided by an outside source (instructor or textbook).

Etherington (2011) stresses the importance of time in science courses, time to move pre-service teachers from passive learners to active doers

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in science. In this problem- and inquiry-based science course, pre-service teachers were provoked to produce authentic and innovative prototypes that would solve an authentic problem.

The item of time is also highlighted by Luera and Otto (2005), sufficient time and a variety of learning opportunities are needed to increase the belief of a pre-service teacher in his or her ability to teach science.

The influence of multiple experiences on pre-service teachers understanding of inquiry-based science instruction is also noticed by others. Varma, Volkmann, and Hanuscin (2009) found that when multiple inquiry-based experiences, from guided to open, are integrated into a science course, pre-service teachers develop not only an understanding of inquiry-based science instruction but also an appreciation for the benefits of teaching and learning science of inquiry in a constructivist environment. Plevyak (2007) saw how preschool pre-service teachers' ideas and understandings about science education and implementation of inquiry learning change as a result of implementing an inquiry-based curriculum, including demonstrations and experiments in physical science, inquiry projects with butterflies, crustaceans and plants or integration of other subject areas. However, he also found that inquiry projects are not enough to ensure that pre-service teachers feel confident to use inquiry in their own classrooms.

In one study, mathematics, science, inquiry, and creativity are integrated. Broderick and Hong (2005) focused their study on methods of inquiry that guide adult learners' to construct inquiry-teaching practices that they can transfer to their work with children. In the development of the method they relied on literature regarding the Reggio Emilia approach as well as on Creativity theory. Through the usage of their cycle of inquiry and Concept Materials (= term to relate the idea of conceptual thinking to the planning of materials to promote higher level representations and incorporate inquiry experiences) they promote higher level reasoning and creativity, as teacher candidates learn to reflect on and question the big ideas they observe in play to develop practice that extends learning along a conceptual continuum of inquiry. These researchers refer to creativity as being fluent, flexible, elaborate, original, complex, able to take risk, imaginative, and curious in pursuing goals rather than end products. They see flexible teachers as being open minded enough to allow the course of an investigation to follow the children's understanding, different than giving the right answers.

In different studies, stories are used to engage the student teachers in science/mathematics or science/mathematics teaching. Harkness and Portwood (2007) designed a lesson to help pre-service early childhood teachers to consider a nonstandard real-world contextual problem as a mathematical activity, to create an opportunity for participants to mathematise and to unpack mathematical big ideas related to measurement and similarity. They used a picture book as context to present a quilting problem, Sweet Clara and the Freedom Quilt by

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Deborah Hopkins (1993). The pre-service teachers had to replicate an original quilt but with different lengths. In the study of Howitt and Venville (2009) a pre-service early childhood teacher experienced the fun of science through literacy and simplicity; she saw science with fresh eyes. Through the story and the 'fun' component, necessary to teach science for young children, science had been taken off its pedestal of professors, theories and formulas. In the same method course, student teachers are shown how easily science can be incorporated into story books.

Frisch (2010) examined, during a science content-based course for pre-service elementary teachers, two strategies of writing stories to demonstrate physical science concepts. She found that without guidance, many student teachers struggled to find ways to integrate science within a story. However with guidance, participants wrote stories that included more narrative elements and the group of student teachers felt the stories helped them to develop a more scientific understanding. Moreover, these stories, written by student teachers, helped the instructor see where students were confused or unclear about the concept. The researcher concludes that 'teaching the stories of science is using the science content in context'

In his study, Wagler (2010) concludes that the use of case narratives is a simple and efficient way to evaluate student teachers' level of acceptance of science inquiry teaching within a science method course.

In two studies, links were made between arts and science/mathematics. In the study of Palmer (2009) mathematics courses for early childhood student teachers involved aesthetic workshops including mathematics/music, mathematics/dance, mathematics/visual arts. This course which adopts a feminist post-structural approach based on critical pedagogy and deconstructive theory and includes an interdisciplinary approach to investigate mathematics, changed student teachers understanding of their own mathematical subjectivity. The student teachers became much more positively inclined to the subject of mathematics. Tselfes and Paroussi (2008) designed a cross-disciplinary (science and theatre education) approach. Student teachers of early childhood education were asked to study extracts from Galileo's Dialogue Concerning the Two Chief World Systems, Ptolemaic and Copernican, to focus on a subject that the Dialogue's 'interlocus' forcefully disagree about and to theatrically represent what they consider as being the central idea of this clash of opinions. This approach leads to a satisfactory understanding of ideas to the content and methodology of the natural sciences. The authors of this study believe that the theatrical narrative based on images can present advantages over the unavoidable oral or laboratory approaches of scientific issues. However this is a hypothesis which they want to further explore.

In a limited number of studies, laboratory practices and partnerships with experts are evaluated. The laboratory practices are reported as effective

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on the development of student teachers' self-regulation skills (Aktamiș and Acar, 2010). Laboratory practices are seen as very important places where students can learn by doing and living. A creative and critical thinking based laboratory method seems also to be more effective than traditional activities in improving logical and creative thinking abilities of prospective teachers (Koray and Köksal, 2009).

Bers and Portsmore (2005) designed an innovative approach which involves the creation of partnerships between pre-service early childhood and engineering students to conceive, develop, implement and evaluate curriculum (project work) in the area of mathematics, science and technology, by using robotics and the engineering design process. Three different forms of partnership models were evaluated: the collaborator's model, the external consultant's model and the developer's model. The collaborator partnerships showed most successful, indicating that the approach should be presented to students as more of a joint project where students from each discipline are expected to contribute to the classroom curriculum and the technology. This study of Bers and Portsmore demonstrates the power of partnerships between students in different disciplines – the early childhood student teachers saw the potential offered by technology, they were also able to design with the safety net of experts (engineering students).

A number of studies focus on instructional, curriculum materials. The adaptation of existing science curriculum material by pre-service teachers, to plan and enact inquiry-based science lessons, is studied by Forbes (2011). He notices that field placement contexts, as teacher-specific factor, have a critical impact on these curricular adaptations. The results of Davis (2006) indicate that pre-service elementary teachers held a sophisticated set of criteria for critiquing instructional materials. However, even with explicit support, the student teachers did not engage in substantive critique about how scientific content is represented. The student teachers in this study also describe inquiry as important to promote student interest, not to engage students in genuine scientific activity. In another study Beyer and Davis (2009) explored the use of educative curriculum materials – materials intended to support both teachers and student learning - to help elementary teachers develop their pedagogical design capacity for critiquing and adapting lessons. When provided with educative supports, most students attended to the pedagogical principles targeted in the supports, engaged in an in-depth analysis with regard to the principles, and used the rationales from the supports to justify their analyses. When they no longer received support, only few continued to do so in subsequent analyses.

B3.2.2. Interventions focusing on field experiences, mastery and/or vicarious experiences

In several studies, field experiences are highlighted and argued as vital to gain confidence in mathematics (Bintas, 2008) and science teaching. Moreover, school placement is seen as the most positive factor to

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influence pre-service teacher's confidence towards science and the teaching of science (Howitt, 2007). Kenny (2009, 2010) reports on the effectiveness of a professional partnership approach to preparing pre-service primary teachers to teach science, focusing on the reflective process of the student teacher and on-going support by the teacher educator and the colleague teacher. The central role of the reflective process is due to the fact that it is seen as important for pre-service teachers to make connections between theory and practice.

However, Leonard, Boakes, and Moore (2009) noticed that prospective teachers' inquiry-based practices, learned in teacher preparation programs, were only sustained in supportive school environments. Shane (2002) found that student teachers who taught in 'progressive' classrooms (relational / conceptual focus) used more open questions, included more problem solving and games, encouraged children to challenge themselves and explain their methods. They showed a greater awareness of the children's thinking. These children made greater progress on written tests than those with student teachers in 'traditional' classrooms (instrumental / procedural focus). The student teachers in the traditional classrooms had narrow objectives for lessons and dismissed children's responses that did not conform to these. They looked for right answers to closed questions and did not examine the children's thinking. Goulding, Rowland and Barber (2002) also report on the problem of conflicting approaches between student teachers (relational) and teacher-mentors (instrumental).

During the field-based method course, described by Siry and Lang (2010), pre-service elementary teachers developed and co-taught science lessons to the children with the support of the classroom teacher and the course instructor. After each lesson, the three adult participants worked in small groups with the children to enact co-generative dialogue. These dialogues are conversations between different stakeholders in an educational setting and have as purpose to listen to, and learn from, the members of the group. Through these dialogues, young children are seen as scientific investigators and classrooms become places where they are able to theorize about their observations of scientific phenomena. The teacher participants, including the pre-service teachers, in this study felt increased confidence in themselves as teachers of science, being with others in the classroom, and experienced new understandings about the ways in which young children learn and interpret science.

Plonczak (2010) examined benefits and challenges of teaching through videoconferencing in the context of students' field placement experiences. Pre-service teachers, with the supervision of professors, field placement supervisors and cooperating teachers, taught a series of math and science lessons via videoconferencing to the 5th grade classes. This approach highlights strengths and weaknesses in questioning skill techniques (heart of an inquiry-based approach) and the challenge of teaching. It also allows pre-service teachers to look face to face into their

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limited understanding of content matter in mathematics and science. Moyer and Milewicz (2002) found similar results when they analyzed the questions used by pre-service teachers during diagnostic mathematics interviews. They found 3 categories of questions: 1) checklisting; 2) instructing; 3) probing and follow-up. Checklisting was when the pre-service teacher went to the next question with no follow-up questions and without regard for the child's response. This was a common behaviour and resulted in fast paced interviews. This category also included saying 'good' or 'okay' in a way that signalled no further information was needed. Instructing included leading questions and abandoning questioning in order to direct teach the concept. Probing / follow-up questions included a) only probing if the answer was incorrect; b) non-specific questioning (i.e. using a generic open ended questions e.g. What were you thinking?) and c) competent questioning (i.e. probing questions that relate to the child's responses). In their reflections many of the pre-service teachers said they had not been expected to explain / discuss their answers as children. They also said they found it hard to react to unexpected answers.

Rowland, Huckstep, and Thwaites (2005) evaluated the use of a 'knowledge quartet', with four broad units – foundation, transformation, connection and contingency - through which mathematics-related knowledge of pre-service teachers could be observed in practice. They claim that the quartet can be used as a framework for observation of mathematics lessons prepared and conducted by pre-service elementary teachers and for mathematics teaching development.

Gunning and Mensah (2010) noticed that short mastery experiences, microteaching lessons and one science night demonstration, also offer valuable learning experiences. Bautista (2011) reports on an instructional design study in which various mastery experiences, field assignments including teaching a science lesson, and vicarious experiences, actual modelling, symbolic modelling and simulated modelling, are combined. The data show that personal science teaching efficacy and science teaching expectancy beliefs increased significantly over the semester, however it provides no information about how long pre-service teachers maintain the high levels of self-efficacy.

Varma and Hanuscin (2008) discuss the usefulness of pre-service elementary teachers' field experiences (vicarious modelling) in classrooms led by science specialists. Interviews and observations revealed pre-service teachers experienced a wide range of instructional and assessment strategies. However, it was not clear how well this experience enabled them to envision how to create a stimulating and inquiry-rich environment for science in a general classroom nor how to integrate science with other disciplines such as mathematics.

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B3.2.3. Interventions focusing on reflective skills

Dietz and Davis (2009) evaluated the use of narrative vignettes as interesting reflection tools in an inquiry-oriented science course. Narrative vignettes are called 'images of inquiry' and describe a teacher's decision making with regard to lesson plans.

Philosophy statements are utilized by Gilbert (2009) as reflection tools to facilitate pre-service teachers' development of inquiry-based science practices. The research of Kukkonen et al. (2011), highlight the meaningful integration of blogging to support inquiry-based learning and reflection in pre-service science education. Video cases were used by Abell, Bryan and Anderson (1998) to stimulate pre service elementary science teachers' reflective thinking. The researchers learned that many students focused on purely technical aspects of teaching or they used buzz words for the description of their observations. They wondered if the ability to think deeply can develop over time through reflective coaching. Abell et al. designed reflection tasks to use with the video cases. Moyer and Milewicz (2002) report on one to one diagnostic interviews of pre-service teachers with children. The recordings of these interviews are then used to reflect on their questioning techniques

In several studies, the use of reflective journals is mentioned as an interesting tool to support the reflective process (Gunning, 2010; Kenny, 2009; 2010; Plevyak, 2007, Plonckzak, 2010).

In her study, Palmer (2009) highlights the possibilities of working with collective memory writing, memory/narrative writing and process writing in an early childhood education mathematics course.

B3.3. Key findings related to the teacher educator

Although in past and recent research the teacher educator is highlighted as important in effective initial teacher education, only few of the included studies describe the role of the teacher educator. In European literature these teacher educators are a very heterogeneous group (ETUCE, 2008).

Howitt (2007) sees the role of the teacher-educator as a 'powerful influence' for increasing pre-service teacher's confidence towards science and the teaching of science. Bleicher (2006) confirms these findings and describes the effect of intensive guidance on student teachers' confidence in learning science.

B3.3.1. Teacher educator = Instructor or teacher educator

In the study of Frisch (2010) pre-service elementary teachers writing stories are used to demonstrate physical science concepts. She clearly showed in her study that many pre-service teachers need scaffolding as much as their future pupils will – without guidance many students struggled to integrate science in stories. Beyers and Davis (2006) concludes in her study that critique activities used in science method courses to develop beginning proficiency of student teachers for adapting

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curriculum materials, should be authentic and scaffolded to be optimally effective. It needs systematic, explicit and consistent support. The latter was also noticed by Beyers and Davis. Their study provides insights into how science teacher's educators can support pre-service teachers in developing their pedagogical design capacity for critiquing and adapting lessons. Teacher educators have to provide student teachers with teacher education experiences that highlight general principles of practice.

Similar findings were also done by Bers and Portsmore (2005). They examined partnerships between pre-service early childhood students and engineering students. They found that many of the groups could benefit from guidance from instructors, particularly about working with others, keeping their project on schedule.

Weld and Funk (2005) noticed that student teachers were able to make a shift from believing that answering questions and clearly relating content were the primary responsibilities as science teachers to understanding their roles as facilitators who ask good questions, make more informal assessments and convey an excitement for science, when they had inquiry teaching strategies modelled for them. As pre-service teachers develop beliefs of science and maths teaching on their in-class experiences, teacher educators must model new (innovative) pedagogy if the pre-service teacher is to develop confidence in inquiry based teaching and creative approaches.

The teacher educator is also a supportive partner in field experiences of student teachers (Kenny, 2009) and they should help students to unpeel their thinking (Abell et al., 1998)

B3.3.2. Teacher educator = mentor

Pre-service teachers perceptions of their mentoring (Hudson, 2005), using a literature-based instrument (Hudson, Skamp and Brooks, 2005), indicate that mentors do not provide specific mentoring in primary science, particularly in science teaching practices associated with system requirements, pedagogical knowledge and modelling.

Jarvis, McKeon, Coates, and Vause (2001) developed support material to assist primary teacher mentors to help improve lesson plans, as well as science lessons. The support material, including a sample of lesson plans accompanied by completed checklists, is found useful for mentors and trainees. Groups of trainees use these sample plans and checklists to discuss and criticize without feeling personally threatened, so they are better prepared to write and evaluate their own plans.

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C. Professional development

C.1. Some general issues concerning policy and research

C.1.1. Policy

The Lisbon European Council 2000 decided on a new strategic goal for the next decade: 'to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion' (Lisbon European Council: Presidency Conclusions, Paragraph 5).

The Conclusions recommend what to do in order to reach the strategic goal. The conclusions talk about completing the internal market and the application of an appropriate macroeconomic policy mix. In addition to traditional economic measures, the need to invest in people is mentioned (Lisbon European Council: Presidency Conclusions, paragraph 5). Under the headline 'Education and training for living and working in the knowledge society' a series of measures related to Europe's education and training systems are mentioned. For the First time in the history of EU summits, education and training is described as a major tool for implementing a strategic goal (Fredriksson, 2006).

The Council of the European Union (2009) stated that continuing professional development of all teachers and trainers and school leaders needs to focus on equipping them with pedagogical and other competences necessary to take on the new roles implicit in this competence approach. It is also vital to make the teaching profession more attractive and better supported. Beforehand, they wanted to strengthen Europe's innovative capacity. According to them, this calls for much closer interaction between education, research and innovation. A Europe of knowledge, creativity and innovation needs education and training systems which promote the following things: creative, innovative and entrepreneurial mindsets among pupils, trainees, students, teachers and researchers; the highest possible quality of initial and continuing professional development for teaching staff at all levels; and reinforced commitment to the development of, as well as complementary between, a European Higher Education Area and a European Research Area (Council of the European Union, 2009).

As to Dawson and Suurtamm (2003), professional development should be long-term, with several short-term, realistic, manageable goals in mind. Long-term, sustained professional development facilitates evidence-informed change and improvement. Sound professional learning not only connects with beginning teachers and needs to be continually supported by all stakeholders. These stakeholders include administrators at board and school levels, consultants or coordinators, teacher mentors or facilitators, classroom teachers, and parents and students. Furthermore, professional development programs need to be continually evaluated and revised according to well-considered indicators.

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As for Timperley (2006), both time and voluntary participation are however not sufficient conditions for substantive changes to teacher practice and student outcomes. All learning activities require the twin elements of trust and challenge in relation to identified student needs. Another interesting understanding arising from the author's vision-building work is that professional learning is strongly shaped by the context in which the teacher practices. Therefore, professional learning is situated and professional development programs should assist teachers to translate an integration of knowledge and skills in locally adapted applications. Teachers' daily experiences in their practice shape their understandings, and their understandings shape their experiences. Unfortunately, in most of the EU27 countries, so far experts asserted that the continual professional development offer is not yet sustained enough and strategically targeted to give teachers the confidence to transform their teaching environment. This is usually the classroom, which is strongly influenced by the wider school culture and the community and society in which the school is situated. Hence, not just the agendas of those looking for changes in practice shape teachers' moment-by-moment decisions. In professional learning, it is important to set up conditions that are responsive to the ways in which in-service teachers learn and elaborate on their own experiences. Within the scope of this narrative review, it is supposed that outlining recent research could identify some actual enablers as well as barriers for the professional development of young children's science and mathematics teachers.

According to Eurydice (European Commission, 2009) continuing professional development is among the professional duties of teachers in over half of all European countries, including non-Member States. For example, while CPD is a professional duty in France, the Netherlands, Sweden, Iceland and Norway, participation in it is in practice optional. In Spain, Luxembourg, Poland, Portugal, Slovenia and Slovakia, CPD is optional, but clearly linked to career advancement and salary increases. Continuing professional development (CPD) in most European countries is planned and organized in a very heterogeneous way.

In Greece, there is currently a widespread initiative on teachers' professional development called the 'Major Professional Development Program', which will run from June 2011 until the end of 2013. The Program aims to promote the values and guidance of the emerging curriculum so that the vision of the 'New School' as presented by the Ministry of Education is implemented into practice. An estimated 150.000 teachers (early years-primary-secondary) will take part in the program.

In Finland there is an in service teacher education available sponsored by national board of education. All teachers have to participate in in service education for 4 days per year, but teachers can choose the contents and ways of doing it.

In England professional development is seen as a professional duty without clear checks on whether it has been undertaken. Besides private

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consultant initiatives, there is MaST [mathematics specialist teachers] – a 2 year Masters level programme led collaboratively by university and local authority which includes school based research; aims to support participating teachers in extending their knowledge, skills and understanding of mathematics and related pedagogy, including a deep knowledge of the progression in mathematics within the Early Years Foundation Stage and Primary curriculum, and into Key Stage 3. It will draw upon a wide repertoire of teaching approaches and will recognise how these support and direct children's learning of mathematics. Participants will develop their own practice through study, analysis and research, and will also be supported in acquiring the collaborative, practice-transfer skills to support other colleagues. In science, 'Science Learning Centres' run high quality, continuous professional development for teachers and technicians; a joint initiative between the government education department and the Welcome Trust.

In Wales there exists the Early Professional Development – a 2 year programme following the induction year. Numeracy might be a focus although science was not an option.

In Germany the lower-level school supervisory authorities are usually responsible for in-service teacher education. However, there are also central institutions for in-service training, like the state academy (staatliche Akademie), the Institute for Educational Progress (Institut zur Qualitätsentwicklung im Bildungswesen – IQB) or the academic institute for in-service teacher education (wissenschaftliches Institut für Lehrerfortbildung).

In Romania continuous professional development refers to the updating and development of educational personnel, including acquiring new competences, as function of the requirements of the educational plan and the educational curriculum, tuned to the educational structures and processes changes. For science teaching at primary and middle school level the Centre for Science Education and Training is running two accredited courses on inquiry-based science education. These are the first courses for science teaching in Romania accredited by the Department of CPD for Pre-university Staff Training, department belonging to the Romanian Ministry of Education, Research, Youth and Sport. The Institute for Educational Sciences is offering short CPD courses for preschool and primary school teachers.

C.1.2. Research

Action research has emerged in recent years as a significant methodology for development, intervention, and change. Action research is an interactive inquiry process that balances problem solving actions implemented in a collaborative context with data-driven collaborative analysis or research to understand underlying causes enabling future predictions about personal and organizational change (Reason and Bradbury, 2001). Action research often is a major part of assessment on

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programs of initial teacher education, especially at Masters Level. Currently, action research is also promoted and implemented by several in-service training programs building on the integration of science and mathematics in kindergarten and primary education. Within the field of science professional development, a number of authors mentioned educational programs in which schools undertake a range of activities designed to improve and change teaching practice and/or attitudes towards science and science teaching. Hence, many design studies are intertwined with an effect study. In most reports on research, qualitative analysis data collected from participants commonly indicated that in-service teachers expressed greater self-confidence about teaching science than before the program, they spent more class time on the subject, and finally, deficit-model negative assumptions about the children's science learning abilities were modified into more mature, positive views. Though, more research in line of the work of Bitan-Friedlander, Dreyfus, and Milgram (2004) is needed exploring the patterns of teachers' concerns about their personal and actual involvement when confronted with the task of implementing an innovation into the curriculum. School needs versus individual needs seems to be addressed as one of the dilemmas when covering emerging perspectives for professional development.

Next to action research, the area of teacher beliefs is emerging as a fruitful space in literature to remain considered in detail and this from different points of view. Data gathering here frequently occurred by means of teacher interviews, focus groups, and/or surveys, and, afterwards, grounded theory was used for data analysis. It has been shown that teachers' conceptualizations of the subject matter they teach both influence what they choose to teach and how they choose to teach. Teacher thinking in terms of teacher attitudes, perceptions, beliefs, etc. is often highlighted and incorporated in professional development programs, in order to help teachers to update teacher skills and learn from peers.

An overview of the characteristics of the selected studies is presented in Table 2 (see appendix).

C.2. Key findings related to professional development for science teachers

In recent years, inquiry-oriented science teaching has accumulated. Existing curricula usually emphasize factual content knowledge while new curricula typically emphasize reasoning and problem-solving skills (Timperley, 2006). A number of examples of (good) practice appearing from recent research articles illustrating the paradigm shift from cognitivism towards constructivism are documented below.

C.2.1. Examples of practice

Evanschitzky, Lohr, and Hille (2008) focused on young children's experimental and curious behaviour to be fostered through an Inquiry-

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Based Science Education (IBSE) program for in-service kindergarten teachers. In evaluating the impact of this project, the authors focused on the children rather than on the teachers. However, it seems that many researchers are interested in changes in observable teacher practices as several research projects have informed professional development materials used in schools and on courses. For example, Duran, Ballone-Duran, Haney, and Beltyukova (2009) reported on an inquiry-based teacher education project for early childhood education: Active Science Teaching Encourages Reform (ASTER). Zhang et al. (2010) developed a Problem-Based Learning (PBL) collaborative action research model focusing on science talks in kindergarten classrooms. Jui-Chen and Hung-Jen (2010) incorporated museum visit experience into an in-service program for science and technology teachers. In their recent research article, it is assumed that a professional development program that can make change for science teacher practice needs to include four features related to the teacher-as-learner experience: student involvement, heterogeneity of the participants, role models, and reflective thinking. Many authors and policy-makers noted likewise suggestions and elaborated on the insights and understandings of each other.

C.2.2. Student involvement

The study of Jui-Chen and Hung-Jen (2010) aimed to introduce in-service teacher education addressing many kinds of support and resources facilitating student activity: museum visit journals, reflective journals, lesson plans including peers' comments, class discussions, on-site practice, and a web-based platform. Referring to the Active Learning in Primary Science project in Bristol (ALPs), there is some evidence that undertaking continuous professional development helped teachers to be more confident in teaching science. Davies (2010) evaluated on the ALPs initiative by gathering pupil and teacher data. A major finding was that there needs to be full commitment and trust to professional development for it to be successful. Learning activities designed to raise engagement rather than volunteering when properly developing teachers' skills, knowledge, and enthusiasm were: classroom workshops, consultancy, and educational visits.

C.2.3. Heterogeneity of the participants

When designing professional learning opportunities, it is important to consider teachers' prior knowledge of curriculum and assessment and how they view existing practices (Timperley, 2006). This takes teacher diversity into account as we expect teachers to take student diversity into account. Teachers have very diverse professional learning needs arising from context-specific demands on what and how they teach. Moreover, they are diverse in their understandings and assumptions about students and how they learn, what counts as valued knowledge, and how best to teach it. Engaging teachers' existing ideas means discussing how those ideas differ from the ideas being promoted and assessing the impact the new approaches might have on their current practice and/or beliefs. In

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the OECD Talis survey (2009), it was suggested that more mobile training opportunities should be given to teachers across countries, which would allow expertise to be exchanged and applied in different national contexts. Training could be provided not only onsite but also online. However, in countries where provision of ICT is available, little effort seems to be devoted to creative pedagogy with ICT.

C.2.4. Role models

According to Timperley (2006), designated educational leaders (e.g. teacher educators, supervisors) have a key role in developing expectations for improved student outcomes and organizing and promoting teacher engagement in professional learning opportunities. Their management capacities include: ensuring that teachers understand new information, engaging dissonance constructively when existing assumptions are challenged, ensuring that teachers have productive opportunities to learn, and providing incentives for teachers to continue to enact the new learning in practice. Building on the research of Zhang et al. (2010) investigating on how to use science talks to promote student learning, as to the results, in-service kindergarten teachers emphasized three areas through which modelling occurs: collaborative learning community, guidance of facilitators, and video analysis. Kenny (2009) formed triadic partnerships, consisting of a final year pre-service primary teacher and an in-service colleague, to teach science in the colleague teachers' classroom with the support of a teacher educator. In this article, it is well documented that pedagogical knowledge is enhanced with sustained guided and mentored practice in real teaching settings. Also the work of Goebel, Umoja, and DeHaan (2009) serves as confirmation of the emerging view that next to field experiences, partnerships between members of the scientific and elementary school communities promote reform as science partners bring explicit science content knowledge, enthusiasm, and a sense of the importance of the subject. Schollaert (2011) argues that constructivist approaches to teaching and learning dramatically alter the way in which teachers install subject knowledge in their learners, but their role is also to turn them into better learners, learners for life. Apart from subject experts, teachers also need to be experts in learning. They can only achieve the latter if they are expert learners themselves. Not only should they be able to convey content knowledge and explain to their students how to learn, they should also be able to demonstrate how learning works, in rather generic terms. In other words, teachers should be role models with regard to both subject-specific and pedagogical knowledge; likewise, they make an attempt to teach what they preach.

C.2.5. Reflective practice

Answering the question what is the best way to assist elementary science teachers through in-service programs, the studies of Klein (2001) and Cheng (2001) revealed that elementary science teachers need guidelines for (1) strategy addressing hands-on activities, and (2) questioning skills

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to develop high level thinking. With regard to the latter, results of research of Eshach, Dor-Ziderman and Arbel (2011) showed that when provided with efficient affective and cognitive scaffolding; kindergarten children can be involved in scientific inquiry. In addition, Nentwig-Gesemann (2007) stated that teachers need to be able to reflect on their pedagogical praxis according to theoretical guidelines. When initial teacher trainees and those engaging in professional development are given extensive time to explore problems and difficulties as well as new approaches, they can become more reflective practitioners. According to Timperley (2006), recent conceptions of professional learning are related to self-regulated inquiry. Teachers need to develop self-regulatory skills that will enable them in the role of a lifelong learner who is able to monitor and reflect on the effectiveness of the improvements he makes in practice. As mentioned in the research article of Crockett (2002), the dominant approach to teacher development locates reflective actions within individuals rather than within communities of teachers in school settings. However, recently, even professional communities may help supervisors to take the stance of inquiry, critically identifying and rethinking taken-for-granted practices and principles (Levine, 2011).

C.2.6. Science teacher's beliefs

Exploring perceptions on the subject matter of nine beginning elementary school teachers teaching science, Appleton and Kind (2002) found that, compared to language areas frequently displaced by school events, there is little tendency to build up teacher image around science. Though, Posnanski (2010) and also Cullen, Akerson, and Hanson (2010) developed understanding of the nature of science within a professional development program for in-service elementary teachers. Learning science is clearly related to having an in-depth understanding of nature of science in order to effectively teach children. As teachers began to look for easy opportunities to infuse science into their classroom, their attitudes changed from negative to positive. The results of the study of Roehrig, Dubosarsky, Mason, Carlson, and Murphy (2011) indicated that sustained, culturally-based professional development can advance the quality of science teaching. Teachers started to listen more closely to their children's interests and ideas and used curiosity to drive instruction rather than the schedule. Teaching science is perceived to be more child-centred.

With respect to this finding, Van Houte, Devlieger, and Schaffer (2012) stated that teachers are expected to become inquirers themselves, at first under supervision but over time independently. Moreover, teacher education should foster teachers' familiarity with subject knowledge so that they are able to react immediately to unanticipated but scientific events in the child's environment.

In the article of Howes (2008), John Dewey's explication of 'educative experiences' was also applied to design settings in which children's interests are piqued and purposes for learning inspired. Teaching science

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inquiry processes may assist both teachers and children in developing a science-learning atmosphere that values observation and exploration in non-threatening teaching contexts. In the ASTER project (Duran et al., 2009), early childhood teachers' beliefs about inquiry-based teaching were measured using the Survey of Teacher Beliefs in Inquiry-Based Teaching, and Teachers' beliefs about science in general were measured using the Science Teaching Efficacy Belief Instrument. As to the results, inquiry-based teaching requires hands-on activities, helps students enjoy science, builds upon students' prior knowledge, promotes cooperative learning, helps retain content knowledge, and develops higher-order skills. Teachers' beliefs in teaching science revealed high self-efficacy beliefs with regard to teaching science and answering questions, high understanding of science concepts, and a positive relationship between effective professional training and improved academic performance of in-service teachers.

A very interesting study underlying teachers' perceptions on inquiry teaching comes from Ireland, Watters, Brownlee, and Lupton (2011). Phenomenographic data analysis revealed three different ways in which teachers perceived teaching for inquiry learning in science education. They are as student centred experiences, teacher generated problems, and student generated questions.

C.3. Key findings with regard to professional development for mathematics teachers

Summarizing the research of Dawson and Suurtamm (2003), effective professional development in mathematics values teachers' prior knowledge; builds mathematical understanding and confidence with mathematics; shares and promotes effective instructional and assessment strategies; connects with student learning, the curriculum, and classroom practice; allows time for practice, reflection, and meaningful dialogue and sharing among teachers; recognizes that growth takes time and requires ongoing sustained support; is supported and valued by the larger educational community: parents, principals, senior administrators, the school board, and the Ministry of Education.

Related to the aforementioned key issues, the primary assumption of the design study of Crockett (2002) is that professional development should engage teachers in what teachers do in everyday practice in order to reconsider practice. Consequently, the weekly inquiry groups of mathematics teachers in elementary schools included the teachers' engagement around an open-ended problem, a video teaching vignette, lesson planning sessions, and the examination of student work. Similar findings were emphasized by Harkness and Portwood (2007). For them, learning mathematics is clearly related to application to the real world, and they agree that it is better received if it can be seen in an authentic context.

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Connect-ME offered a method and means to meet the expressed needs of novice elementary mathematics teachers through mixed-method delivery mechanism (Dalgarno and Colgan, 2007). In this example of practice, it is assumed that technologies such as video clips and web-based resources may help to offer evolving opportunities to collect evidence and to develop creativity in teacher practice with regard to mathematical issues. Researchers within the SIPS (Support and Ideas for Planning and Sharing) mathematics professional development project associated meaningful collaboration with identity-based trust. They pointed to important aspects of trust and caring relations to be further investigated when building communities between school-based elementary teachers and university-based mathematics educators. For example, mathematics educators had to face the challenge of learning when to push and when to let go, when to express their ideas and when to listen quietly, when to be active as reform-agents and when to step back as status-quo observers (Sztajn, Hackenberg, White, and Allexsaht-Snider, 2007).

As reported by Dawson and Suurtamm (2003), a lead teacher in each school, dedicated to improving early mathematics teaching and learning, will be essential to sharing information, helping to create a collaborative culture of teachers as learners, and improving student learning in mathematics. Initially, the role of the lead teacher will be to attend initial training sessions; gain confidence by implementing new mathematical strategies in his or her own classroom; reflect on his or her own practices – through a journal, interview, questionnaire; meet with other lead teachers from within the board or region. In subsequent years, the lead teacher will be able to: attend professional development sessions; continue to implement new mathematical strategies in his or her own classroom; offer support to the primary team in the school; share resources and ideas with others on an ongoing basis; act as a mentor when appropriate; be a source of support for other teachers; be a team leader for the primary mathematics teachers in the school.

C.4. Key findings with regard to professional development for creativity

Action research cited in teacher education literature on the relationship between creativity and teaching children science and mathematics suggest that practitioners tend to see creativity concerned with supplying specific resources or activities, rather than processes (Kampylis, Berki, and Saariluoma, 2009; Worthington, 2011). Creativity is predominantly fostered in elementary science teachers who endeavour to establish a learning environment which promotes combinatorial thinking (Bore, 2006), divergent thinking (Cheng, 2001), risk-taking (Dalgarno and Colgan, 2007), or transversal skills (OECD, 2009). According to Bore (2006), creativity in science is fostered in teachers by means of curriculum development that encompasses four stages: uncertainty, visioning, realization, and readiness.

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However, a clear conceptual distinction between creativity and mimicry still needs to be made while some practicing primary teachers need to widen their view to see constructing a scientific explanation as a creative incident (Newton and Newton, 2010). Based on the interviewing of EU teachers attending professional development courses, the OECD Talis survey (2009) on creative learning and innovative teaching found that the majority of teachers argue that technology has improved their teaching and that ICT can be used to enhance creativity. This is important, because, data from this study showed that teachers who had received ICT training were more likely to select interactive and social computing applications as contemporary tools for more creative pedagogy. But this also suggests that changes in learning objectives cannot be implemented in practice if assessment and support for pupils and schools remain the same.

C.5. Professional development as multidimensional support

Analysis of the variety of support provided in professional development initiatives revealed striking consistencies to be further explored.

Constructivist teaching formats, where instructional methods are demonstrated by teacher educators followed by guided practice in the field or among peers, are widely claimed as providing supportive trajectories toward application in classrooms (Clift and Brady, 2005; Risko et al., 2008).

Constructivist learning formats, in which in-service teachers as lifelong learners had to collaboratively plan, develop and deliver diverse kinds of educational resources, could also be presented as a key theme. In this respect, it is assumed that professional development designers deliberately create experiences in which in-service teachers share and discuss their attitudes and abilities with one another and with other education institutions.

The evidence brought up in the research and policy statements above suggests that many professional development programs succeeded in making an impact due to multidimensional support delivery to teachers following intensive training for context-specific purposes. To give one example coming from recent research, success components of the elementary science education partners program as introduced by Goebel, Umoja, and DeHaan (2009) were threefold: participants benefited from the sessions that offered in-depth exploration of existing curricular materials, the collaboration with scientists, and especially from the opportunities teachers had to design and implement sessions for other teachers.

It was also found that the indicators for success in improving inquiry-based science instruction should have included more formal assessment of teacher knowledge and more pupils' achievement scores in science. Another more policy-related example of multidimensional support delivery to in-service teachers following intensive training is the European

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project PRIMAS (7), supported by the EU's Seventh Framework Programme. It aims to develop and work with networks of teachers and professional development providers across 12 countries in order to support them to promote students' inquiry skills in mathematics and science. The project provides professional development materials to explore effective teaching methods as well as classroom materials for direct use by students; and it ensures that teachers are also supported indirectly through work with a wide range of stakeholders such as parents and policy makers (European Commission, 2011).

C.5.1. Collaborative support

Sharing and collaborating emerged as a key theme in in-service education and continuous professional development initiatives. Following Schollaert (2011), collaborative activities are clearly learning activities of the professionals that constitute a professional learning community. School-based and self-directed learning community activities may include: observing colleagues' lessons; giving and receiving feedback from colleagues; coaching each other; planning lessons together with colleagues; doing action research; mentoring novice teachers; assessing students' work together with colleagues; reflecting together with colleagues; teaching together (team teaching); a weekly newsletter. Levine (2011) and Timperley (2006) noted that teachers should engage in 'deprivatized' practice in order to create a resource that promotes individual reflection and group learning.

In many articles 'communities of practice' were valued as highly supportive, and were seen as an essential for professional growth and for improving the practice of teachers. According to Wenger (2006), communities of practice are groups of people who share a concern or a passion for something they do, and learn how to do it better as they interact regularly. In exploring the evidence provided by formal professional development experiences for learning about inquiry-oriented science teaching, many studies embraced the notion of community which provides the chance to learn from others through social interaction. Wenger's three key characteristics of a community of practice to be cultivated in parallel are: a shared domain of interest, a shared repertoire of resources, and engagement in joint activities. As to Loughran (2008), an effective way to push further the professional development of elementary science teachers and to increase their confidence is to build a community of practice, where experience is accumulated collectively and not individually. In order to achieve sustainable improvements in mathematics teaching too, it appears crucial to support 'communities', i.e. small teams, communities of practice and loosely-coupled networks (Krainer, 2003), where teachers and other relevant players cooperate and collaborate with each other with a view to learning autonomously as well as supporting the learning of others.

Particular studies reporting on how designing and implementing communities of practice in teacher professional development indicate that

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many institutes have jumped on the bandwagon of computer-supported collaborative learning (CSCL). In general, there is a growing demand by educators and researchers to understand and take best advantage of environments where a web-based platform is an essential component of joint activity and co-construction of knowledge. To illustrate, results from Dalgarno and Colgan (2007) showed that elementary mathematics teachers viewed the technology-facilitated sharing and communicating Connect-ME community as unique and as valued support. Referring to the perspectives of the teachers participating in the Connect-Me educational program, virtual learning platforms and social media are conceptualized as enablers for the collegial sharing of self-directed, multi-purposed, convenient, and sustainable support. Consequently, ICT skills should be adequately covered in teacher education courses, particularly developments which could enhance creativity. So far, the potential of ICT to enable educational progress towards a creative school environment is far from fully exploited.

In a collaborative learning culture, teachers should be supported to work together within their schools and boards to acquire a richer knowledge base and develop leadership skills. Professional development takes place both through structured and informal interaction and through group discussions among teachers. Frequently, however, these discussions need to be stimulated by an external resource person or consultant who has the knowledge of mathematics teaching and learning and who has experience in the elementary context to help to guide the discussion. Discussion among teachers who teach the same grade and share many experiences and issues can help teachers make sense of their experiences and feel less isolated, and can be helpful in generating new ideas and practices. In the case where a teacher is the only teacher of the grade or feels isolated in a small school or in a remote area, online discussion groups can serve as a community of learners.

One of the main advantages of including site-based components in professional development models is that they can be tailored to suit the needs and objectives of the students, teachers, and administrators. However, the site-based model should also connect with a larger vision or initiative. Involving a lead teacher from every school in this initiative would provide that important link with the board and provincial focus. Such site-based models encourage school administrators, teacher leaders, and teachers to have some responsibility for professional development while connecting with a larger initiative that has a broader support base. This model increases accountability and empowerment, and provides a basis for sustaining growth beyond the short term. A system focused on mathematics promotes increased networking and sharing opportunities among families of schools or teachers of the same grade across a board, region, or province (Dawson and Suurtamm, 2003).

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The aforementioned co-operation implies teachers working together in groups or teams to improve educational processes and outcomes. To achieve complex objectives such as quality of education and school development requires common goals and cooperation among staff, which facilitate the co-ordination of resources and strategies of individual teachers, since no teacher can achieve such goals without at least some input from others. Furthermore, co-operation among staff creates opportunities for social and emotional support, exchange of ideas and practical advice. It can thus enhance professionalism and feelings of self-efficacy and prevent stress and 'burnout' (OECD, 2009).

C.5.2. Peer support

The peer system brings beginning teachers (from one school or from different schools) together, thus creating opportunities to network within and across schools. In the peer system different kinds of support are in effect: social (especially in groups of teachers from the same school), personal/emotional and professional (peer) support to the new teacher. The peer system is essential in creating a safe environment in which participants have the same status and in which beginning teachers can discover that they face many of the same problems. The peer group needs to be based on face-to-face meetings, but can partly be a virtual community. The peer support system and the mentoring system can overlap when group mentoring is used and the mentor and novices gather in groups to exchange their experience, doubts, and good and bad practices (Directorate-General for Education and Culture, 2010).

C.5.3. Support in the production of resources

According to the effect study of George and Lubben (2002), science teachers agreed that a context-based materials development experience during face-to-face workshop sessions empowered them to be more critical practitioners who can let go of the straight-jacket of their - sometimes old-fashioned - syllabus objectives. In addition to narratives and drama, contexts were presented in the form of newspaper clippings, diagrams, concept cartoons, photographs, and calypsos. Other studies (Appleton and Kind, 2002; Jui-Chen and Hung-Jen, 2010; Kenny, 2010) suggest that more attention should be placed on the role of in-service teachers in planning and transforming curriculum materials for classroom instruction. They appeal to the kinds of collegial collaboration and support that may occur through resource availability within a common area of competence, such as lesson plans and peers' comments, hands-on-activities, stories, experiences, video-tapes, textbooks, etc. A particular form of collaborative support in the production of resources which is frequently described as being effective at improving teaching is 'lesson study', in which groups of teachers meet regularly over long periods of time to work on the design, implementation, testing, and improvement of a specific lesson (European Commission, 2011b).

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C.5.4. Expert support

External experts can act as 'eye-openers' by introducing ideas that no one would have thought about. They can break through existing patterns of navel gazing by their unbiased approach. Most of all, they can be of assistance by taking on the role of critical friend, coaching people on one occasion, confronting them on the next. The expert as facilitator makes a link with current practice, makes use of experiential learning, promotes reflection, supports practitioner research, uses a diversity of learning approaches, is part of a longitudinal process, takes into account the participants' emotions, takes into account group dynamics, models desirable behaviour, focuses on content and process alike (Schollaert, 2011).

An 'expert system' should be initiated to ensure professional support to new teachers. In the expert system the focus is on creating access to external expertise and advice in order to expand content and teaching. The expert system can focus on seminars, participation in courses by experts in teaching, but also on creating access to support materials, resources and guidelines. In those cases where the license of beginning teachers is probationary and the probation period ends with a formal exam, the expert system is essential and mostly dominated by national agencies, institutions or universities. In other cases, the expert system can be organized at school level, where the experts are mainly experienced teachers, or can be a service offered by universities to their graduates, or by other professional development providers (Directorate-General for Education and Culture, 2010).

Within the research field of science, the engagement of professional scientists and science students along with teachers of primary schools and their children is at times mentioned. As an example, within the triadic partnership model of Kenny (2009) expert scientists and teacher educators play the role of guide-support and help pre- and in-service teachers in the planning and implementation of scientific programs with the educational goals of primary school. Through investigating school-based programs of professional development in elementary mathematics education, Sztajn et al. (2007) wisely stressed the meaning of the maintenance of caring relations and trust between university-based mathematics educators and school-based teachers. As the first worked towards fulfilling the teachers' needs and understanding teachers' interests, they were flexible, respectful, knowledgeable, and resourceful.

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D. General conclusions

D.1. Emerging conceptual/contextual ground in area of this literature review and any notable issues

Several issues are emerging from this literature review. Some important issues are the development of professional identity of the teacher; the impact of attitudes and beliefs; integration of different courses, disciplines and knowledge; the interaction between theory and practice and the importance of field experiences (role of the mentor); school based versus university based teacher education and the role of the teacher educator.

Teacher education programmes have to build upon student teachers' belief making use of systematic support and guidance of teacher educators and of cooperating teachers during teaching practice periods

The development of professional identity has a link with self regulation, ownership, lifelong learning, systematic reflection (teacher as reflective practitioner), the teacher as a researcher and innovator (role and importance of classroom-based research – action research), attitudes, beliefs, perceptions, prior knowledge, … of pre- and in-service teachers. Beliefs, conceptions and attitudes towards science and mathematics of pre-service teachers play an important role in the development of teachers teaching practices, as well as (student) teachers understanding of science- and mathematics-related knowledge. It is important to build upon these beliefs, conceptions, attitudes and understandings.

Integration of different courses, disciplines and knowledge

- Competence-based education that focuses on the holistic person comes forward in policy
- Integration of (science and mathematics) method and subject courses - interactions between subject knowledge and pedagogical knowledge
- Integration of mathematic courses and science courses in early childhood education
- Integration of affective and cognitive aspects: importance of caring, trust, respect, ... in professional relationship

Dynamic interaction between theory and practice

- Field experiences – important role of the mentor
- Learning by doing – problem solving approaches – inquiry
- Context-based approaches (real world approaches) and subject-matter integrated approaches
- Screening of curriculum materials with the learners, including feedback loops
- Critical approach of lesson plans, materials (not following the manuals in a linear manner) and the learning processes
- As a teacher educator using the same materials as those that will be used in the field

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School based vs. university based teacher education

- Importance of collaboration, community, partnerships – how to foster these
- Peer-learning in different ways
- Collaborative approach between institute and the field (notions of hybrid spaces)
- Evolution toward a 'broad' approach in education

Importance of variety of approaches, resources, contexts, development of repertoire – for both teachers and pupils – neglect of opportunities afforded by ICT

- The role of astonishment (inherent to childhood) when initiating learning processes
- Field experiences – important role of the mentor
- Learning by doing – problem solving approaches – inquiry
- Blended learning seems powerful in combination with group work
- Constructivist approaches are dominant (Vygotsky, Piaget, Bruner, ...)

Collaborative approaches between peers (communities of teachers, group work with student teachers, …), between institutes and schools

Lack of attention to role/professional development of teacher educator

- Role of the teacher educator (and professionalism of the teacher educator) -Mentoring/coaching, train the trainer (not much found and how to become a professional, criteria -based?)
- Modelling versus coaching: the Cognitive Apprenticeship paradigm emphasises the social base of knowledge construction and relates student's learning to a dynamic enculturation process wherein facilitators gradually fade out their prominent presence, assistance switches from model to coach when students become more experienced and skilful in structuring the discourse

D.2. Issues and implications for *Creative Little Scientists* in area of literature review stating explicitly what research gaps exist

Assessment in teacher education would be worth exploring

- Need for a clear concept/definition on 'expert' roles and tasks
- More formative assessment is necessary in order to get positive experiences from learning
- There is a need to increase 'learning by doing' and progressive evaluation towards both preset goals and prior knowledge

The integration of informal learning and formal learning is relevant given the increasing number of peer learning through easily accessible online communities and resources

- Computer supported collaborative learning (CSCL): potentials of ICT in science teaching are not yet used in their full strengths (o.a.

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blogging, (a)synchronous discussion groups, tablets, cloud computing)
- ICT skills training is missing, media literacy should be promoted and developed
- Need for focus on education of the teacher as a person in the society, education should be about the labour market, citizenship and well-being

Teacher education research

- There isn't much research that focuses the outcomes of integrated working, most of the research focuses on only one intervention or course, the key competences should be better taught in a cross-curricular way
- Integrated practices in teacher education institutions concerning science, mathematics, inquiry, and creativity are underemphasised
- Competence-based education that focuses on the holistic person of the learner isn't a clear focus point in research
- The link with all stakeholders (also the student teachers as researchers) should be strengthened, schools should be embedded in the community to become so-called 'extended schools'
- There is a focus on elementary education in research, less articles were found on early childhood
- Not much research was found as through the eyes of a young child himself, for example, creativity in relation to inner fantasy
- In-service training not only for teachers but also for headteachers and staff should be encouraged
- More research is needed with regard to flexible pathways in teacher education

Attention should be kept on transfer issue

- Sharing good practice seems a very attractive idea in teacher education, however apprenticeship students express concerns with regard to when, why, how, ... implementing new knowledge, skills, attitudes, more research is needed on barriers and success factors
- Testimonies and supervision are important to be installed
- It is hypothesized that creative learning and teaching is leading to greater personalised learning and instruction

D.3. Issues and implications for *Creative Little Scientists* in respect of methodology including patterns of methodological approaches

Most research centres around qualitative interpretive approaches

- Action research is a central research method (in CPD)
- Teacher thinking studies (beliefs, attitudes, concerns, ...) are often mentioned in relation to Grounded Theory
- Educational design research illuminates appealing interventions, methods and resources in current teacher education

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- A lot of effect studies were included, mostly instructional design combined with effect measurement, they focus a lot on the impact on the student and less on the messages/interventions themselves
- Other types of literacy in content gathering and data analysis become apparent
- Data-triangulation is predominant

Limitations and suggestions for further research:

- Dual vision approach can be further explored
- Limited use of focus groups in research, unfortunately
- Phenomenographic research seems interesting to be further explored
- Self-efficacy is not always researched in a profound manner, mostly because of the fact that references to Bandura are missing in the construction of self-assessment scales or self-report questionnaires related to context-specific teacher self-efficacy beliefs
- Drawing on Bandura's Social Learning Theory, self-efficacy positively contributes to self-regulatory cognitive functioning
- It's not easy to richly contextualize the findings mentioned in research, clear method description is necessary (participants, setting, procedure, research instruments, data analysis)
- Research should occur interactively (multidisciplinary teamwork) and/or mixed method
- A less prescriptive, more open curriculum is needed in order to foster creativity within learning and instruction

D.4. Emergent, relevant working definitions of key terms in the area of this literature review

Several terms were used in this literature review. In order to clarify you will find here some working definitions.

- Initial teacher education: Initial teacher education for preschool and primary school teachers is the professional preparation organized by a college, university or specialized school in order to obtain the certificate to teach in preschool and primary school contexts.
- Pre-service education: this can be seen as a synonym for initial teacher education. So pre-service education is education which takes place before a person (the student teacher) begins a teaching job.
- In-service education: In-service education is professional development that happens while the teacher is a full-time employee.
- Teacher educator : 'The various profiles of teacher educators include: academic staff in higher education institutes who are teachers of education or teaching subjects; education researchers; other teachers of didactics or general courses; supervisors of

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practice in schools closely linked to initial teacher education institutes; trained and experienced teachers supervising practice in other schools; tutors (counsellors, coordinators, mentors, guides etc.) supervising prospective teachers at the 'on-the-job qualifying phase'; networks of supporters in the 'on-the job' qualifying phase' (ETUCE, 2008).

- Professional development: Continuous professional development for preschool and primary school teachers encompasses all professional inputs that are given to teachers, either to provide them with new insights or to improve their competences. This concerns both pre-service teachers still in training, which can be viewed as not yet qualified and in-service teachers can be considered to be qualified.
- Collaborative learning: Following Schollaert (2011), collaborative activities are clearly learning activities of the professionals that constitute a professional learning community. Collaborative learning is a situation in which people learn or attempt to learn something together.
- Reflective practitioner: the teacher is a reflective practitioner who continually evaluates the effects of his/her choices and actions on others - students, parents, and other professionals - in the learning community, in order to grow professionally. The teacher is an inquirer of his/her own practice.
- Action research: Action research is an interactive inquiry process that balances problem solving actions implemented in a collaborative context with data-driven collaborative analysis or research to understand underlying causes enabling future predictions about personal and organizational change (Reason and Bradbury, 2001).
- Educational Design research (developing the design principles): 'Educational design research is perceived as the systematic study of designing, developing and evaluating educational interventions, -such as programmes, curricula, teaching-learning strategies and materials, products and systems – as solutions to complex educational problems, which also aims at advancing our knowledge about the characteristics of these interventions and the processes to design and develop them.' (Plomp and Nieveen, 2010).

D.5. Suggestions for research foci and possible research questions and research approach

D.5.1. Suggestions for research foci

- Practices in teacher education institutions concerning open inquiry and problem based learning using real life contexts
- Guidance and the role of mentors in field experiences especially concerning science and mathematics activities in the classrooms
- Partnership approaches school versus university

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- Teacher educator: interesting research focus for a research however no research focus for *Creative Little Scientists*
- Approaches in elementary schools (active learning, learning by doing, constructivist approaches, inquiry, integration of disciplines (for example science and mathematics...), problem based learning, inquiry based learning ...)

D.5.2. Research approach

Educational design research (curriculum design research) to design the principles (in collaboration with teachers and other stakeholders)

Important issues for the design principles:

- See 4.1
- See suggestions for research foci

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Table1: Initial teacher education

Study	type		focus					methodological approach		level of pre-service teacher			topic				Region
	book	article	review	instructional design with effect study	instructional design without effect study	conceptual framework	beliefs, perceptions, views, knowledge, conceptions...	qualitative	quantitative	preschool	elementary	primary	science	maths	inquiry	creativity	
Abd-El-Khalicka, 2004		x		x				x			x		x				USA
Abd-El-Khalicka, 2009		x		x				x	x		x		x				USA
Abell, 1998		x		x				x			x		x				USA
Akerson,2006		x		x				x			x		x				USA
Aktamis, 2010		x		x					x		x		x				Turkey
Amirshokoohi,2010		x					x		x		x		x		x		?
Anderson, 2011		x		x				x	x		x		x				USA
Appleton, 2006	x										x		x				Australia
Bautista, 2011		x		x				x	x	x			x				USA
Bers, 2005		x			x			x		x			x	x			USA
Beyer, 2009		x		x				x			x		x				USA
Bintas, 2008		x		x				x	x	x				x			Turkey
Bleicher, 2006		x					x		x		x		x		x		USA
Bleicher, 2009		x					x		x		x		x				USA
Bolden, 2010		x					x		x			x		x		x	UK
Brady, 2005		x					x	x	x		x			x			Canada
Brigido, 2010		x					x		x			x	x				Spain
Broderick, 2005		x		x				x		x			x	x	x	x	USA
Davis, 2006		x			x			x			x		x		x		USA
Dietz, 2009		x			x			x			x		x		x		USA
Downing, 1999		x					x		x		x		x				USA
Eick, 2010		x					x	x			x		x		x		USA
Ergul Remziye, 2009		x					x	x			x		x				Turkey
Etherington, 2011		x		x				x				x	x		x		Canada
Forbes, 2011		x			x			x	x		x		x		x		USA
Frisch, 2010		x		x				x			x		x				USA

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Garbett, 2003	x					x		x	x			x				New Zealand
Gilbert, 2009	x		x				x		x			x		x		USA
Goulding, 2002	x					x	x	x			x		x	x		UK
Gunning, 2010	x		x				x			x		x				USA
Haefner, 2004	x		x				x			x		x		x		USA
Harkness, 2007	x		x				x		x				x			USA
Hechter, 2011	x		x					x		x		x				Canada
Howes, 2002	x					x	x			x		x				USA
Howitt, 2007	x				x		x	x		x		x				Australia
Howitt, 2009	x		x				x		x			x		x		Australia
Hudson, 2005a	x					x		x			x	x				Australia
Hudson, 2005b	x			x			x	x			x	x				Australia
Isabelle, 2008	x		x					x		x		x		x		USA
Isiksal, 2009	x					x		x	x	x			x			Turkey
Jarvis, 2001	x		x				x	x			x	x				UK
Jones, 2003	x				x				x			x	x			USA
Kampylis, 2009	x					x		x			x	x	x		x	Greece
Kenny, 2009	x		x				x	x			x	x				Australia
Kenny, 2010	x		x				x				x	x				Australia
Koray, 2009	x		x					x		x		x			x	Turkey
Kukkonen, 2011	x		x				x	x			x	x		x		Finland
Leonard, 2009	x		x				x	x			x	x		x		USA
Loughran, 2008	x	x								x		x				international
Lu, 2008	x		x				x				x	x				Taiwan
Luera, 2005	x		x					x		x		x		x		USA
Moyer, 2002	x					x	x			x			x			USA
Newton,2009	x					x					x	x			x	UK
Newton, 2009	x					x	x			x		x			x	UK
Newton, 2011	x					x		x			x	x				UK
Palmer, 2008	x				x		x				x	x				Australia
Palmer, 2009	x		x				x		x				x		x	Sweden
Plevyak, 2007	x		x				x		x			x		x		USA
Plonzack, 2010	x		x				x			x		x	x	x		USA
Rowland, 2005	x		x				x				x		x			UK

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Schwarz, 2009	x	x		x			x		x		x		USA
Shane, 2002	x	x		x		x				x			Israel
Siry, 2010	x	x		x		x			x		x		USA
Skamp, 2001	x		x	x				x	x				Canada/Australia
Sundberg, 2008	x		x	x	x	x			x			x	Sweden
Tselfes, 2009	x	x		x		x			x			x	Greece
Ucar, 2011a	x		x		x		x		x				Turkey
Ucar, 2011b	x	x		x	x	x			x		x		Turkey
Vacc, 1999	x	x			x		x			x			USA
Varma, 2008	x	x		x			x		x				USA
Varma, 2009	x	x		x			x		x		x		USA
Wagler, 2010	x	x			x		x		x		x		USA
Weld, 2005	x	x		x	x		x		x		x		USA
Yilmaz, 2011	x		x		x	x			x				Turkey
Yilmaz-Tuzin, 2007	x		x		x		x		x				Turkey
Zacharos, 2007	x		x		x	x				x			Greece

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Table 2: Professional development

Research study	type		focus				methodological approach		level of in-service teacher			topic			
	book	article	review	instructional design with effect study	conceptual framework	beliefs, perceptions, views, attitudes, conceptions,…	qualitative	quantitative	preschool	elementary	primary	science	maths	inquiry	creativity
Appleton, 2002		x				x	x			x		x			
Bamtwini, 2009		x				x		x			x	x			
Bitan-Friedlander, 2004		x				x	x			x		x			
Bore, 2006		x				x	x				x	x			x
Cheng, 2001		x		x			x			x		x			x
Crockett, 2002		x		x			x			x			x	x	
Cullen, 2010		x		x			x			x		x		x	
Dalgarno, 2007		x		x			x			x			x		
Davies, 2010		x		x			x	x			x	x			
Davis, 2010		x				x	x			x		x			
Duran, 2009		x		x			x	x	x			x		x	
Eshach, 2011		x		x			x		x			x			
Evanschitzky, 2008		x		x			x	x	x			x	x	x	
Goebel, 2009		x		x			x	x		x		x		x	
Harkness, 2007		x		x			x		x				x		x
Howes, 2008		x			x		x		x			x			
Ireland, 2011		x				x	x			x		x		x	
Jui-Chen, 2010		x		x			x			x		x			
Klein, 2001		x	x				x			x		x			
Newton, 2010		x				x	x				x	x			x
Posnanski, 2010		x		x			x			x		x			
Roehrig, 2011		x				x	x		x			x			
Sztajn, 2007		x				x	x			x			x		
Timperley, 2006			x		x		x							x	
Worthington, 2011		x				x	x		x				x		x
Zhang, 2010	x			x			x		x			x		x	

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