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

D2.2 Conceptual Framework

www.creative-little-scientists.eu

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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1	16.12.12	IoE (T2.2 Science/ Maths Ed.) OU (T2.3 Creativity) AUC (T2.4 Teacher Ed.) UEF (T2.5 Comparative Ed.)	Draft 1 of all four Lit Reviews circulated – all partners feed back
2	13.01.12	IoE (T2.2 Science/ Maths Ed.) OU/BG (T2.3 Creativity) AUC (T2.4 Teacher Ed.) UEF (T2.5 Comparative Ed.)	Draft 2 of all four Lit reviews circulated, drawn on for Conceptual Framework
3	05.01.12	OU / BG	Draft outline agreed for writing plan for Conceptual Framework

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6	20.02.12	OU / BG / AUC / IoE / UEF / UPJV / NILPRP / GUF / UofM / EA / UMinho/	Comments / corrections received from all partners enabling development of third draft of Conceptual Framework
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EXECUTIVE SUMMARY

The purpose of the Conceptual Framework for *Creative Little Scientists*

The Conceptual Framework to the EU research study *Creative Little Scientists* sets out the conceptual ground for this research project which spans nine European countries (Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania and the UK) representing a wide spectrum of educational, economic, social and cultural contexts. It articulates implications for *Creative Little Scientists* in terms of conceptual foci, the contextual ground to this work, and methodological issues. Comprising the conclusion to Work Package 2 (Conceptual Framework), it offers a synthesis of four literature reviews (on science and mathematics in the early years, creativity in education in the early years, teacher education and comparative education respectively). The Conceptual Framework then, draws together key areas for focus in *Creative Little Scientists*, suggests an appropriate methodological approach and offers research questions.

Contributing elements defining the focus of the study

Creative Little Scientists seeks to document current reality in the nine partner countries of the study, in relation to creativity in early years science and mathematics, through survey and classroom focused research. It seeks to mainstream exceptional and excellent practices by proposing changes in teacher education and classroom practice (encompassing curriculum, pedagogy and assessment).

The project is informed by a number of drivers which set the context for a range of conceptual challenges. These are summarised in the following pages of the Executive Summary, together with the teacher education aspirations of the project and its positioning as a comparative study.

Drivers for *Creative Little Scientists*

The *Creative Little Scientists* project focuses on the relationships and synergies between science and mathematics education and creativity. There appear to be four key common drivers for an increased research focus on science and mathematics education and creativity in the early years classroom:

- An economic imperative demanding capable scientists and creative thinkers in an increasingly knowledge-based globalised economy, which requires certain capabilities in the classroom, including reasoning skills, innovative thinking and positive attitudes;
- The role played by mathematics, science and creativity in the development of children and of citizens so that scientific literacy plays an increasingly important role not just for individuals but also for 21st century society as a whole;

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- Rapid changes in digital technologies that are shaping learning processes and affording new opportunities for expression, communication and assessment of learning;
- Growing recognition of young children's capabilities and the importance of early years education in building on children's early experiences and promoting positive skills and dispositions.

Conceptual challenges for *Creative Little Scientists*

There are a number of conceptual challenges relevant to *Creative Little Scientists* as a study of science, mathematics and creativity in the early years. These include the nature of the concepts, teachers' own conceptualisations, beliefs and stances in relation to science, mathematics and creativity in education and policy constructions. Effective scientific development is recognised as involving understanding of the nature of science. Effective development in science and mathematics is a complex interrelationship between procedural skills, often grouped into phases linked to the inquiry process, and conceptual understanding leading to scientific or mathematical 'literacy' and also affective aspects, such as motivation and attitudes. In this way, science and mathematics in the early years offer opportunities to foster and draw together processes, concepts and attitudes in building on children's curiosity and concern to investigate and explain the world around them from their earliest years. Creativity has a similar tension to science and mathematics between process and outcome and has moved away from the traditional link with the arts to problem finding and problem solving. Motivation has an important role to play in creativity too and whilst the three areas have different foci; creativity nurturing novelty and science/mathematics nurturing children's engagement with the content and process of bodies of knowledge, they share a recognition of the importance of hands-on and minds on exploratory engagement, and a focus on inquiry and investigation, often driven by young learners' curiosity and questions.

The literature reviews indicate that teachers' conceptualisations and their values and stances towards science and mathematics education and creativity frame and shape classroom practice. Teachers' perceptions of themselves, their values, their understanding and adoption of views of learning and understandings of inquiry based approaches are influential in guiding pedagogical views and practice.

Educational policy can shape practice by emphasising values and by indicating both content and pedagogy through frameworks, outcomes and assessment. However, the degree of regulation and the official status of documents varies across countries and phases of education. Common policy themes for science and mathematics education in the early years include the need to: foster positive attitudes, enhance knowledge about the world, develop skills and understandings associated with inquiry and promote a questioning and investigative approach to learning (European Commission 2011). In addition to skills, processes and conceptual

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understanding, the relevance of science and mathematics to everyday life is seen as important, although there are differences in emphasis in different countries. There are also differences in the way that countries define the areas of learning, particularly in science, with science existing within a broader grouping such as environmental or world studies or making links with technology. In preschool, science knowledge and understanding is often suggested in rather general terms and there is an emphasis on processes and attitudes. There is widespread emphasis on active learning and building on children's existing knowledge and experience and interests, although few explicit references were found in policy documents of inquiry based approaches and mention of creativity in the science and mathematics' curricula is limited in the documentation of many countries. In contrast to the emphasis on mathematics and science in the early years across Europe, creativity is less evenly highlighted, perhaps reflecting the perceived lack of a relationship between creativity and economic or technological imperatives or the development of the individual as a successful citizen.

The conceptual framework for *Creative Little Scientists* explores how Inquiry Based Science Education (IBSE) teaching and learning and approaches which foreground Creativity (Creative Approaches, CA) can enhance learning. Although definitions of IBSE vary, there is considerable agreement internationally, reflected in both policy and research, about the value of inquiry-based approaches to science education. CA, on the other hand, does not refer to a recognised set of approaches to education and learning, but nonetheless such approaches have gained considerable attention in research and policy contexts in recent years. IBSE and CA appear to have synergies and differences, with both sets of approaches being pedagogically associated with a range of child-centred philosophies from European and North American thinkers, which situate the child as an active and curious thinker and meaning maker and highlight the role of experiential learning. Common synergies are:

- Play and exploration, recognising that playful experimentation / exploration is inherent in all young children's activity - such exploration is at the core of IBSE and CA in the early years.
- Motivation and affect, highlighting the role of aesthetic experience in promoting children's affective and emotional responses to science and mathematics activities.
- Dialogue and collaboration, accepting that dialogic engagement is inherent in everyday creativity in the classroom, plays a crucial role in learning in science and mathematics and is a critical feature of IBSE and CA, enabling children to externalise, share and develop their thinking.
- Problem solving and agency, recognising that through scaffolding the learning environment children can be provided with shared, meaningful, physical experiences and opportunities to develop

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their own questions as well as ideas about scientifically relevant concepts.

- Questioning and curiosity, which is central to IBSE and CA, recognising across the three domains that creative teachers often employ open ended questions, and promote speculation by modelling their own curiosity.
- Reflection and reasoning, emphasising the importance of metacognitive processes, reflective awareness and deliberate control of cognitive activities, which may be still developing in young children but which is incorporated into early years practice, scientific and mathematical learning and IBSE.
- Teacher scaffolding and involvement, which emphasises the importance of teachers mediating the learning to meet the child's needs, rather than feel pressured to meet a given curriculum.

The challenge for teachers is to achieve a balance between structure and freedom in early years educational settings, adopting a more dialogical pedagogical model in which the teacher orchestrates standing back with collaborative intervention in science and mathematics classrooms.

Internationally the tension between formative and summative assessment in relation to assessment for learning *versus* assessment for comparative purposes, is evident. There is pressure on teachers to address specific assessment criteria rather than assess the holistic development of the individual, which the increase in formative assessment strategies has helped to ameliorate. This is not to deny the role of summative assessment for wider comparative purposes and its use for evaluation of performance and in focusing on assessment of creativity using psychometric and componential assessments. The project may wish to examine:

- The formative and summative ways in which assessment is used in science and mathematics in the early years;
- The involvement of children in assessment processes;
- The development of multimodal approaches to assessment sensitive to young children's capabilities and learning processes;
- The role of context and authenticity of assessment tasks;
- Broadening the assessment and evaluation of science and mathematics through employing a creativity lens in the context of inquiry;
- The person/people considered to be responsible for making judgements in assessing creativity in science and mathematics.

Initial teacher education and continuing professional development

Creative Little Scientists seeks to make a contribution to initial teacher education (ITE) and continuing professional development (CPD). The

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Conceptual Framework highlights a variety of models in relation to ITE, with varying balances of HE and school-based learning although with a general trend toward the latter. All ITE includes school practice but the balance between theory and practice varies considerably, along with the order in which these are developed; both concurrent and consecutive models. In the concurrent model, 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.

Overall there is a shift towards a more school based approach to ITE in many countries, with teacher education arranged in partnership between schools and higher education institutions. The development of reflective practice is a key feature of teacher development, together with the integration of theory and practice.

In participating European countries teacher education programmes have largely adopted the bachelor-master framework as recommended by the European commission and many countries emphasize the importance of educating pre-school teachers in providing high quality pre-school education. However, it would be dangerous to assume that a higher qualification results in a better quality of teaching. All of the countries participating in *Creative Little Scientists* (CLS) require students applying for teacher education to demonstrate a sufficient level of academic ability as pertinent to that country's examination processes and 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. Competences differ in number between countries, although there are common threads regarding professional issues.

Across and within countries the curricula for teacher education vary considerably. However, there are common themes:

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

Inquiry based science education (IBSE) is not referred to directly through legislation in the participating European countries, although there is a suggestion of this in the documentation. A key factor in teacher education is the professionalism of teacher educators, including professionals in school based settings who are acting as mentors to students on placement. Teacher educators influence 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 co-operating teachers is often overlooked. Another key factor is the importance of supportive schools involved in teacher education.

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With regard to continuing professional development (CPD), the literature review on teacher education highlights a range of approaches to and levels of CPD, and types of organisations offering it. Whilst there appears to be a common expectation for teachers to participate in CPD, it is not clear how far this professional duty is fulfilled. Research acknowledges strengths and weaknesses in different models. Field and mastery approaches are strongly endorsed by the literature for ITE and CPD provision although research also shows the importance of responding to teachers' needs rather than being imposed on them.

The Conceptual Framework highlights the need to use the knowledge of the curriculum and assessment of the CPD teacher as a starting point and for teachers to engage in collaborative learning communities, with professional development firmly set within a setting, as well as a more traditional approach of CPD where external experts introduce new and innovative ideas and act as a critical friend. The reviews also indicate the emergence of ICT based support has resulted in computer-supported collaborative learning (CSCL) in which resources and experience can be shared between settings. Other important factors for *Creative Little Scientists* are:

- the beliefs and attitudes of ITE teachers towards mathematics and science;
- the problem of inadequate science content knowledge amongst elementary ITE teachers and beliefs about science with CPD teachers;
- the wide view of creativity in science and mathematics among teachers and ITE teachers.

The literature review for teacher education identified a number of interventions that have been deployed to overcome some of the issues identified above, with the most successful involving a combination of content and methods courses. Inquiry or problem based learning appears to be an effective way in which ITE teachers develop a better understanding of the nature of science.

Comparative dimension of *Creative Little Scientists*

Creative Little Scientists is a comparative study working across nine participating countries. European integration and global competition have increased the need for comparative research and the European Union finances and encourages such research between its member countries. International organisations such as UNESCO, OECD and the EU are interested particularly in science, mathematics and technology education because of the key roles these have in a knowledge-based, competitive, technologically oriented global economy.

The review of Comparative Education highlights a typology of comparative education suggesting that *Creative Little Scientists* adopts the approach of studying various countries or regions using the same methods of data collection and analysis, informed by international

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research. In relation to focus, it is suggested that *Creative Little Scientists* is concerned with comparative pedagogy which focuses mainly on one theme in making cross-national comparisons in relation to a variety of educational issues and/or practice. In doing so, the project will need to encompass varied conceptualisations of early years education including recognising in the participating countries, differing balances between education and care and a wide span of purpose including at one end of a continuum a 'readiness for school' approach (and so a focus on cognitive development) and at the other, a 'foundation for lifelong learning' approach (with a social pedagogy approach).

The study is developing during a period when the dominant approach to comparative education is focused on 'measuring the other'; i.e. creating international tools and comparative indicators to measure efficiency and quality of education. Indeed some of the motivation for this study has come from studies such as the International Association for the Evaluation of Achievement's Trends in International Mathematics and Science Study (TIMSS) and the Organization for Economic Cooperation and Development's Programme for International Student Assessment (PISA) both concerned with older learners but very focused on 'measuring the other'. It is suggested however that since creativity does not fit easily into this quantitative measurement paradigm, the project may have more in common with the 'constructing the other' trend or even re-start a trend in 'understanding the other'. Clearly there will be issues to address with respect to representativeness, reliability and validity in relation to the comparative dimension.

One aspect of the comparative dimension of *Creative Little Scientists* will recognise is the differently-positioned curriculum framing for science, mathematics and also creativity, as well as acknowledging a range of definitions of creativity.

Proposed focus areas for *Creative Little Scientists*

The diverse drivers of this project, its comparative design and its concern to offer advice regarding teacher education, will run 'vertically' through each of the three focus areas with the aim of increasing creativity in the early years in science and mathematics education and having a positive impact on encouraging children to pursue careers in science and promote research and innovation.

Focus Area 1: Capturing Curriculum Focus and Design

A key task for this study will be to articulate conceptualisations of early science and mathematics education including IBSE and also creativity in relation to the early years. This will need to be undertaken at a conceptual level (already well under way through this Conceptual Framework drawing on the four literature reviews), also at an empirical level through the survey of teachers' perspectives in Work Package 3 (WP3) and classroom studies in Work Package 4 (WP4). Three aspects of curriculum focus and design will be explored:

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Domain conceptualisations: The study will need to investigate the different conceptualisations of:

- how young children's ideas, experiences and curiosity evolve in science and mathematics, as well as their meaning-making and generativity;
- how discourses of study in science and mathematics education map on to one another;
- scientific literacy;
- how creative teaching in science is distinct from scientific creativity and children's creativity in science and mathematics education;
- the links between cognitive and affective aspects of learning, revealed in different ways in the review on science and mathematics education, teacher education and comparative education;
- the relationships with regard to play and exploration, dialogue and collaboration, questioning and curiosity and, to a lesser extent, reflection and reasoning.

It is suggested that three particular approaches to studying these intersecting areas may be particularly relevant; it is suggested that the study seeks to *build models* (a cognitive approach), to *understand children's agentive curiosity and meaning-making* (a humanistic approach) and to *develop complex understandings of their learning* (a confluence approach). Exploration of such domain conceptualisations will emerge from WP3 and WP4.

The project might also probe into:

- teachers' identities; how they see themselves as teachers, scientists and mathematicians and their degrees of assurance towards science and mathematics teaching and similarly toward creativity;
- how teachers conceive of and nurture creativity in early mathematics and science education;

and be extended to include how ITE teachers could widen student teachers' conceptions of engagement and increase their repertoire of teaching behaviours.

Focus Area 2: Evidencing Practice

The second major area, then, which the project will need to address, is the evidencing of practice. Given the span of age being researched (3-8 years old), the research might use as lenses Banaji and Burn's (2010) creative classroom discourse with its focus on teaching and learning, and also the discourse they identify as widespread in education of play and creativity with its emphasis on exploratory playful engagement.

The evidencing of practice will need to be undertaken at the level of policy and also the classroom, as follows.

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Policy perspective: Work undertaken during the literature reviews for WP2 has highlighted tensions between levels of policy, practice and research in relation to foci and interpretation. The translation of the role of IBSE and CA from policy (as appropriate) into practice will need to be explored through the desk study and survey in WP3 and through the empirical work in WP4, as well as being drawn upon in the approaches and guidelines devised in WP5.

Classroom level: The empirical work undertaken in WP3 and in WP4, will need to explore the three areas of learning, pedagogy and assessment in science and mathematics education in the early years and their intersections with creativity. Researching teaching and learning would foreground children as active agents, recognise multimodal expression and experience, include for example exploration of the kinds of activity undertaken, roles undertaken by adults and children In relation to learning, the study will need to the study will need to:

- document how motivation and affect are entwined in the classrooms involved in *Creative Little Scientists*;
- explore the balance between teacher-supported dialogue;
- document the role of context, and the balance between children's and teachers' questions and how teachers model and foster positive attitudes toward curiosity and questioning.

In relation to pedagogy, the project will need encompass:

- how teachers engage in scaffolding young children's learning in science and mathematics in the early years;
- the role of teachers in assessment for learning, in other words how teachers collect assessment data and use it for learning;
- the role of documentation of children's learning;
- teasing out the inter-relationships between the fostering of creativity within science and mathematics and innovative and creative pedagogic practices

In relation to assessment, whilst there are pressures on the education of older children toward summative and comparative assessment, the emphasis on young children's learning journeys and therefore the value of formative use of assessment, exploring the sensitive and formative assessment of creativity in science and mathematics education would form a valuable focus in *Creative Little Scientists*.

Focus Area 3: Developing practice

The third area of focus suggested for *Creative Little Scientists* is the development of practice by offering guidelines, recommendations and curricula informed by the analysis of the two areas above which will include of course material already gathered during WP2 from the literature reviews. These identify research gaps and thus already indicate the following ways in which *Creative Little Scientists* can contribute to

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developing practice. It is suggested that the main approach of the project will be to reveal practices. The contribution to professional and practice development made by the project will thus emerge from its findings. It is proposed that the study will adopt a design which documents and analyses rather than having an intervention design.

Research approach and methodological issues

In terms of the overall research approach, we propose *Creative Little Scientists* develops more qualitative methods, such as a 'multi-modal approaches' that focus on the wide range of ways that children express their embodied thinking. There are opportunities, then, in *Creative Little Scientists* to develop more qualitatively focused approaches to researching, encompassing the processes of learning and not only the outcomes. One challenge will be how far creativity is a focus or a lens; it is suggested that creativity is seen as a lens for analysing practice and learning in science and mathematics. In addition the Creative Little Scientists project team face six methodological issues:

Language and meaning

Developing a common set of linguistic understandings across the project may prove challenging and there will be a need to consider 'value laden' terms across cultures with varying value systems.

Sample

For both the survey and the classroom-based research, decisions will need to be made about the size and scope of each sample; how to capture the breadth of the early years spectrum of 3 to 8 when the pre-school period and school starting age varies so widely as does pre-school provision. It is proposed that the project focuses in depth at the upper end: 7- to 8-year-olds, and also at the lower end: 4- to 5-year-olds.

Research approaches and methods

Reconciling paradigms such that the interpretive is the lead, encompassing quantitative methods needed in the survey, will be one tension the project faces. *Creative Little Scientists* should seek to reveal lived perspectives but by using the survey tool, comparisons will be able to be made on the personal (focus on children and what they are doing), interpersonal (focus on interactions with peers and adults) and contextual (institutional factors, teacher beliefs, resources, physical arrangements).

This is not without challenge as the researcher must take the responsibility to learn from the child through close attention to a wide range of facets. Given the gap in knowledge about how very young children learn science and mathematics across the nine partner countries and how (if) creativity is involved in this, it seems the documenting and analysis of practice must be the priority of the project.

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Balance between science, mathematics and creativity

There are tensions to resolve regarding the over-arching focus of the study. It is proposed that *Creative Little Scientists* seeks to identify and characterise what if any creativity is evidenced in early science and mathematics (in relation both to children's learning, and teachers' pedagogy). In so doing the study will produce a map of lived experience in providing early years science and mathematics education and will also articulate what creativity in early science and mathematics might look like.

Type of comparative study

In its attempt to investigate the concepts of science, mathematics and creativity across a number of European countries, the *Creative Little Scientists* study can be described as a thematic study in comparative education.

Addressing reliability, validity and trustworthiness

Each of these key issues will need to be addressed carefully within the study. Official data needs to be related to actual practice. The national data should be analysed through multiple viewpoints, including both participants from that nation and participants from other nations. In terms of sample the *Creative Little Scientists* project will need to determine which variables have to be considered in order to decide what would constitute a representative sample.

Provisional areas of research questions

To reflect the conceptual and research foci and methodological framing developed in the Conceptual Framework, it is suggested that the research questions in *Creative Little Scientists* are framed around the following:

- *capturing curriculum focus and design;*
- *evidencing practice;*
- *developing practice*.

Provisional questions are offered prior to the desk study and questionnaire being undertaken in WP3 of *Creative Little Scientists* which will no doubt help to focus these still further in anticipation of the classroom focused fieldwork in WP4. These were confirmed and refined during discussion at the Consortium's 2nd Project meeting in Paris in March 2012.

1 *(Mapping conceptualisations):* How are the teaching, learning and assessment of science and mathematics in early years in the partner countries conceptualised by teachers and what role if any does creativity play in these?

2 *(Probing practice):* What approaches are used in the teaching, learning and assessment of science and mathematics in early years in the partner countries and what role if any does creativity play in these?

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3 *(Probing practice):* In what ways do these approaches seek to foster young children's learning, interest and motivation in science and mathematics, and how do teachers perceive their role in doing so?

4 *(Drawing on mapping and probing questions):* How can findings emerging from analysis in relation to questions 1-3 inform the development of practice in the classroom and in teacher education (ITE and CPD)?

Sub-questions running across all research questions might probe:

- Aims/purpose/priorities
- Contextual factors
- Teaching and learning

It is suggested that, in WP4, the focus is on sites of exceptional practice, enabling the project to document, analyse and disseminate excellence at the cutting edge of creativity in early science and mathematics.

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A. INTRODUCTION

The EU research study *Creative Little Scientists,* seeks to document current reality in the nine partner countries of the study (Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania and the UK), representing a wide spectrum of educational, economic, social and cultural contexts, in relation to creativity in early years science and mathematics, through survey and classroom focused research. It seeks to mainstream exception and excellent practices by proposing changes in teacher education and classroom practice (encompassing curriculum, pedagogy and assessment).

The purpose of this Conceptual Framework to *Creative Little Scientists* is to set out the conceptual and contextual ground for the study. The project seeks overall to make a timely contribution to a better understanding, at European level, of the potential common ground that science and mathematics education in pre-school and early primary school can share with creativity. It seeks to offer a clear picture of existing and possible practices, with their implications and challenges.

Six months into the thirty-month study, the Conceptual Framework for the project thus sets out key issues surrounding the role of creativity in early years science and mathematics. These will guide the study and its outcomes which include guidelines, curricula and exemplary materials for relevant teacher training in the various European contexts. This document seeks to offer a synthesis of the four contributing literature reviews, each available as a separate Addendum (focusing respectively on science and mathematics education, creativity in education, teacher education, comparative education).

A glossary of key terms is appended as Appendix 1. Together, the Conceptual Framework and Addenda comprise Deliverable D2.2 for *Creative Little Scientists* and are available via the project website: http://www.creative-little-scientists.eu.

In sum, the Conceptual Framework, then, articulates implications for *Creative Little Scientists* in terms of conceptual foci, the contextual ground to this work, and methodological issues. Comprising the conclusion to Work Package 2 (Conceptual Framework), it offers a synthesis of four literature reviews (on science and mathematics in the early years, creativity in education in the early years, teacher education and comparative education respectively). The Conceptual Framework, then, draws together key areas for focus in *Creative Little Scientists*, suggests an appropriate methodological approach and offers research questions.

It thus provides a structure that can be used to examine policy and practice across the nine European countries involved in the project. Overall its function is to provide a foundation for the following work packages, which include a mapping and comparative assessment of existing practice (desk study and survey, Work Package 3), analysis of

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practices and implications of these (empirical phase, Work Package 4), directions for teacher training (Work Package 5), guidelines to policy makers (Work Package 6), and will also help inform exploration and dissemination (Work Package 6).

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B. ISSUES ARISING FROM SYNERGIES BETWEEN THE SCIENCE MATHEMATICS AND CREATIVITY REVIEWS

Structure of section

In order to situate the project *Creative Little Scientists* this section of the Conceptual Framework examines the relationships and synergies between science and mathematics education and creativity. It commences with the rationale for focusing on these three domains in early years education and then proceeds to consider the conceptual underpinnings of this work, including the nature of the concepts themselves, teachers' own conceptualisations, beliefs and stances, and the ways in which science, mathematics and creativity are conceptualised and constructed in the context of the policies of the nine partner countries and across Europe more generally. The focus of the section then turns to teaching and learning drawing upon research literatures. There is particular reference to Inquiry Based Science Education (IBSE) and Creative Approaches (CA), identifying commonalities and differences between them. Finally, the section concludes with an examination of assessment and evaluation issues relevant to the project and its focus in the early years.

B1. Rationale for Focus on Science, Mathematics and Creativity

At the turn of this century, multiple factors have influenced views of education in Europe. These factors are examined in order to understand the many drivers behind this project and the wider educational context in which it is being undertaken.

B1.1 The economic imperative

Both the research and curricular literature reveal that **there are economic factors driving the focus on both science and mathematics education as well as the inclusion of creativity in the classroom**. The research highlights how views about the aims and purposes of education are fundamentally being affected by a range of key external factors: social, political, historical and significantly, economical, beyond the classroom.

Today's knowledge economy dictates an imperative for countries to have scientists capable of competing globally (European Commission, 2006). Thus a central objective of science and mathematics education is to produce outstanding scientists but also to produce a scientifically and mathematically literate population who can utilise these skills in everyday life.

Within educational spheres, creativity as an economic imperative is a key driver across Europe and beyond. Gibson (2005) has suggested that, epistemologically, creativity in education is often framed in one of two ways. Firstly, it can be seen through an instrumentalist perspective as a skill that should be developed as a route towards innovation and building a 'knowledge economy'. Secondly, it is often interpreted in education through the notion of romantic 'self-actualisation' tied in with a democratic ideal of creativity – that creativity is something that we are all capable of and that creativity is an important part of childhood development.

It is clear that in relation to education policy in and beyond Europe, the instrumental perspective is a driver for the inclusion of creativity in education, positioning it as necessary for innovation in the 'knowledge economy'. Banaji and Burn (2010), in describing a number of 'rhetorics' of creativity, include 'creativity as economic imperative' and define it as "advancing the economic prospects of the nation by creating a more flexible workforce"(:41). This is similar to the idea that individuals must compete in the global knowledge economy, as suggested above (European Commission, 2006).

All three areas, science, mathematics and creativity are powerfully framed within a 21st century neo-liberal narrative around economic imperatives for flexible innovative thinkers who are also knowledgeable, competent and enthusiastic about science and mathematics, and who are also literate citizens in these areas. Economic factors therefore are significant, as are comparisons between countries' achievements (discussed further in B4.1) although it is important to question assumptions about how learning in the early years will ultimately translate to later economic gains and how comparative evaluations can be framed (discussed further in section D). Indeed, in the early years it is important to consider other reasons for greater attention to the relationships between science, mathematics and creativity.

B1.2 Development of the child and citizen

As well as succeeding as scientists in the 21st century knowledge based society, it is also important to develop socially aware and responsible citizens. Education must therefore strive to achieve this aim in the development of the child.

B1.2.1 Development of child and citizen through science/mathematics

There is a growing recognition that **scientific literacy plays an increasingly important role not just for individuals but also for 21st century society as a whole** (Harlen, 2008). Developing scientific and mathematical literacy in individuals then becomes an important part of the development of the child and the citizen. Looking at the world from a scientific perspective enriches the understanding and interaction with phenomena in nature and technology, empowers students (and therefore future adults) to take part in societal discussions and decision-making processes, and gives them an additional element from which to form interests and attitudes (Gago et al., 2004). High quality scientific thinking, Zohar (2006) argues, is one of the key goals in contemporary schooling, especially when facing a vast quantity of information and in

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using new technologies. As the need for more innovative thinkers increases, so the need to improve attitudes and the importance of scientific reasoning skills become more important. Indeed, in order to compete globally as future scientists, it is further important that individuals develop the skills and confidence to apply their knowledge in innovative ways. In Europe then, scientific literacy is viewed as a dimension of 'democratic citizenship', as an informed citizen can better contribute to the decisions of the community to which she/he belongs (European Commission, 2004).

The aim of science and mathematics education is not therefore simply to create future experts in the field. Indeed, a key point emerging from the report *Beyond 2000: Science Education for the Future* (Millar and Osborne, 1998) is that we can no longer continue to offer a science education whose primary function is a pre-professional preparation for future scientists. Rather, it is important also to teach young people something about science – commonly termed 'ideas-about-Science' – as well as developing an understanding of the major concepts of science. This is reflected in the European Commission (2007) who identifies 'mathematical competence and basic competences in science and technology' as key attributes needed by individuals for personal fulfilment and development, active citizenship, social inclusion and employment.

B1.2.2 Development of the child and citizen through creativity

Creativity is also framed as a valuable dimension in the lives of all. In Gibson's (2005) terms, as discussed above, this is his second epistemological framing: romantic 'self-actualisation'. This sees **creativity as an inherent capability in all people and thus an important part of childhood**.

The latter part of the 20th century saw increased focus on the role of dialogue and collaboration in creativity. The field was influenced by Gruber's (1989) work on networks of enterprise that support and enable scientific creativity inspired by his work on Darwin. It has also been given direction by John-Steiner (2000) who explored the creative work of paradigm-shifting individuals in a variety of contexts from the arts to the sciences, and revealed the extent to which artistic and scientific forms are shaped creatively through shared intellectual, emotional and passionate connection in the meaningful relationships between people. This work has been developed by many in education and recently by Chappell (2008) who highlights the interplay between individual, collaborative and communal creativity.

With the increasing recognition of creativity as a social phenomenon a focus on the ethics of creativity in relation to its ends has also developed. Sternberg (1985, 2003) introduced the exploration of creativity and wisdom, a challenge taken up by Claxton et al. (2008), who argue for the need to attend to the outcomes of creative effort in relation to their impact, particularly in education. Chappell and Craft (2011) more

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recently focused on wise, humanising creativity, emphasising collaborative and communal engagement with the ethics of creativity.

B1.3 The technological imperative

Science, mathematics and creativity have evolved through rapid advances in digital technologies, which are shaping new literacies. The introduction of the calculator for example, exemplifies how new devices can alter fundamental practices in areas such as science and mathematics. Shaffer and Kaput (1998) argue that as mathematics is inseparable from the tools we use, it is evolving with 'virtual' culture. Other digital technologies are not only altering the demands involved in recording and calculating, but are also gradually removing the demands of collecting, organising and presenting data. Various authors (Capobianco and Lehman, 2006; Wang et al., 2010) have claimed that technology is able to support inquiry in a variety of ways, including data collection, stimulating questioning and supporting thinking. For example, several recent projects have explored the use of mobile devices to support personal inquiry by allowing individuals to record and analyse information in the world around them (Anastopoulou et al., 2008). There have also been examples of technology promoting creative behaviours in mathematics, such as generating more ideas and incorporating more elements in their patterns (Moyer-Packenham et al., 2008).

In addition, digital technologies can foster children's creativity, for example, in gaming, in connecting with others and in content generation in particular (Craft, 2011). Children may use hand held as well as fixed console digital technology to collaborate with others in generating understandings and take digital images as a record of significant learning through their eyes. Thus **capabilities in science, mathematics and creativity are enabled through the rapid evolution of digital technologies but also to a degree demanded by these**. However, it is important to adopt a critical eye, as there are also arguments that technology might constrain children's interaction. Manches, for example, demonstrated how interaction through devices such as the mouse could limit the range of children's problem solving strategies in comparison to interaction with physical materials (Manches et al., 2010).

B1.4 Changing perspectives on young children and the importance of early years education

Alongside these wider societal concerns, the project is informed by changing perspectives on children and increased awareness of the child as an active and competent meaning-maker. **There is increasing recognition of children's capacities to take ownership of their own learning and take part in decision making in matters that affect their lives in the present.** Indeed this is recognised in the UN Convention of the Rights of the Child that identifies rights not just to provision and protection, but to participation (Mayall, 2006). In the last couple of decades, new research methods have highlighted young

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children's early capabilities and their concern to explore and explain the world around them from a very young age (Goswami and Bryant, 2007; Duschl et al., 2007). There is also increasing recognition that **young children's early educational experiences impact on later outcomes, not only in terms of educational attainment but also their attitudes towards learning** (Sylva, 2009). In relation to science, this is reflected in six assertions by Eschach and Fried (2005) about why children benefit from early exposure to science:

"(1) Children naturally enjoy observing and thinking about nature;

(2) Exposing students to science develops positive attitudes to science;

(3) Early exposure to scientific phenomena leads to better understanding later in a more formal way;

(4) The use of scientifically informed language at an early age influences the eventual development of scientific concepts;

(5) Children can understand scientific concepts and reason scientifically;

(6) Science is an efficient means for developing scientific thinking."

(Eshach and Fried, 2005: 315)

There are equivalent arguments made about young children's creative capacities and the benefits of fostering their creative potential (e.g. Craft, 2001; Laevers, 2005). These tend to highlight that children are naturally curious and actively seek to problem find and problem solve, making connections and imagining what might be as they explore ideas and ask questions of themselves and others. In the process it is posited they develop their capacity to take risks and to engage creatively.

B1.5 Summary of rationale for focus on creativity in science and mathematics in the early years

There appear to be four key common drivers for an increased research focus on science and mathematics education and creativity in the early years classroom:

- An economic imperative demanding capable scientists and creative thinkers in an increasingly knowledge-based globalised economy, which demands certain capabilities in the classroom, including reasoning skills, innovative thinking and positive attitudes;
- The role played by mathematics, science and creativity in the development of children and as citizens;
- Rapid changes in digital technologies that are shaping learning processes and affording new opportunities for expression, communication and assessment of learning;
- Growing recognition of young children's capabilities and the importance of early years education in building on children's early experiences and promoting positive skills and dispositions.

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B2. Conceptual Challenges in Researching Science, Mathematics and Creativity in the Early Years

There are a number of conceptual challenges relevant to *Creative Little Scientists* as a study of science, mathematics and creativity in the early years. These include the nature of the concepts, teachers' own conceptualisations, beliefs and stances in relation to science, mathematics and creativity in education and policy constructions.

B2.1 Nature of early years science, mathematics, and creativity

This subsection explores both commonalities and differences between science, mathematics and creativity in the context of early years education.

B2.1.1 Conceptualisations of science and mathematics education

In science and mathematics it is possible to consider both the knowledge and the processes involved in gaining that knowledge. In this regard we can identify a number of ongoing debates concerning the relationships between these aspects and their relative importance for learning in different phases of education. Therefore, this section does not focus exclusively on the early years, though we do acknowledge that the emphasis in the early years tends to be seen by practitioners as less content/knowledge driven and more focused on children exploring, observing, and asking questions, although in fact many activities involve building knowledge foundations for developing future concepts. Duschl et al. (2007) identify four strands of scientific proficiency that are interwoven in learning and teaching:

1) Know, use and interpret scientific explanations of the natural world
2) Generate and evaluate scientific evidence and explanations
3) Understand the nature and development of scientific knowledge
4) Participate productively in scientific practices and discourse.

This reflects an increasing recognition of the importance not just of pupils' engagement with scientific concepts but of the need to develop their understanding of the 'nature of science' and 'procedural understanding' (Duschl, Schweingruber and Shouse, 2007; Eady, 2008; Harlen and Qualter, 2004; Kallery, Psillos and Tselfes, 2009b). According to Gago et al. (2004):

"The 'nature of science' has become an important concern in the curriculum. This often means the rejection of the stereotypical and false image of science as a simple search for objective and final truths based on unproblematic observations. The recent emphasis on understanding the nature of science is related to the attempt to give more attention to its social, cultural and human aspects. Science is now to be presented as knowledge that is built on evidence as well as upon arguments deployed in a creative search for meaning and explanation"

(Gago et al., 2004: 138).

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In this context procedural understanding refers to an understanding of the processes in which science knowledge is acquired. The perceived importance of procedural knowledge is reflected in moves toward more inquiry based learning approaches, epitomised in IBSE, that emphasise children's understanding and skills in finding out and evaluating information around them (European Commission, 2011a). An inquiry-based approach involves a number of different classroom activities, including, *"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).

Young children's experiences, both informal experiences and those nurtured in the classroom, provide them with 'data' with which to generate and evaluate different ideas in collaboration with adults and peers. As argued by Drayton and Falk (2001) an inquiry-based approach to learning is not only a means of fostering understandings and skills associated with scientific procedures, but is a means of learning content. Greater procedural knowledge may be informed by, and in turn inform, conceptual understanding (Rittle-Johnson, Siegler and Alibali, 1999); knowledge of content can provide the context for developing process skills, which in turn can help learners develop further concepts (Harlen and Qualter, 2004). Rather than attempt to evaluate their relative importance, it is perhaps more productive to consider their interdependence and how the relationship plays out in learning at different phases in education.

Debates about content and process are also echoed in mathematics education; however, it is important to acknowledge differences in terms and focus. In mathematics, a major tension that is discussed is between 'conceptual and procedural' knowledge. Procedural knowledge in this context refers more to the skills in applying the right procedures to solve problems. This is contrasted with children's understanding of the concepts involved. However, it has been argued that this debate unfairly promotes conceptual understanding by taking a narrow, superficial view of procedural knowledge (Star, 2000). This tension is similar to that between 'instrumental' and 'relational' knowledge discussed by Skemp (2006), where instrumental knowledge refers to the ability to carry out specific procedures or repeat facts, whilst relational knowledge is more concerned with understanding the significance of this information; how it relates to other ideas. In contrast to science, the terminology 'nature of mathematics' has not gained the same currency, although it is possible to draw parallels with debates around children's understanding of formalism in mathematics and how this can seem disconnected from children's informal experiences.

There is an emerging understanding in both science and mathematics education that the dichotomisation of 'process' and 'content' may obscure

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the relationship between the two, with arguments being made for efforts toward considering their interdependence (Harlen and Qualter, 2004).

Another aspect increasingly emphasised in science education is the role of emotive factors such as motivation and attitudes that affect engagement and quality of thinking (Brown and Campione, 1994; Duschl et al., 2007). Furthermore embodiment theories argue that it is not possible to separate thinking from perceptual and emotional experiences (Clark, 1999; Dourish, 2004; Lakoff and Nunez, 2000).

Science and mathematics in the early years offer opportunities to foster and draw together processes and concepts (i.e. knowledge) and attitudes in building on children's curiosity and concern to investigate and explain the world around them from their earliest years. As outlined in a later section, through participation in play, exploration and dialogue with others, children are engaged in generating, testing out and evaluating ideas.

B2.1.2 Capabilities in science and mathematics education

In science there are opportunities for the use and development of a range of process skills involved in the linking, generation and testing and evaluation of ideas, many of which are noted within IBSE. Lists vary, but common elements suggested include:

- *Questioning, predicting and planning;*
- *Gathering evidence by observing and using information sources;*
- *Interpreting evidence and drawing conclusions;*
- *Communicating and reflecting.*

(Harlen and Qualter, 2004: 66)

These processes Duschl et al. (2007) suggest can be grouped according to different phases in an inquiry or investigation. The first phase involves generating evidence through asking questions, formulating hypotheses and designing experiments, the second observing and recording and the final phase evaluating evidence. In section B.3 more detail regarding IBSE and its connection to approaches more likely to be labelled 'creative' rather than inquiry-based is offered.

Similarly, it is possible to identify a number of mathematical processes. Artz and Armour-Thomas (1992) develop a cognitive-metacognitive framework identifying six categories in problem solving: reading, analysing; exploring; planning/implementing; and verifying. In a further framework, Mayer (1985) identifies four components of mathematics problem solving: translation, integration, solution planning, and execution.

The mathematical processes identified above can be linked to science; indeed, various authors (e.g. Harlen, 1993) describe the relationship between science and mathematics, presenting mathematics as a grammar for science, or that mathematics helps science to derive

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models, develop formalisms and to approach conceptualisations. Reflecting debates about content and process as above, there is widespread recognition that these processes are inextricably linked with the contexts and concepts associated with their application and that they involve both action and thinking in linking and developing ideas. However, there may also be significant differences in the processes behind problem solving in mathematics and the science processes involved in IBSE.

With mathematics, children tend to be presented with certain problems. This is done so as to draw children's attention to particular mathematical aspects of the problem, for example, the need to count or add amounts. In a way, the mathematics problem supports children's thinking by reducing the messiness and difficulty of mathematics in the world around us. Whilst children are aware that mathematics plays a role in their everyday lives (Abraham, 2009), such as paying for goods (with cash) or working out how much time remains, these involve quite difficult concepts or amounts. There is a tension therefore between presented problems that are manageable but may lack links to personal experience and meaning, and everyday experiences, which may be difficult for children to interpret mathematically (Hughes et al., 1999; Zachaos and Koustourakis, 2011). This tension is arguably different in science that allows more scope to question and reflect on more everyday experiences rather than specific problems.

Affective factors also play a significant role in the early years; science and mathematics provide a context for developing important attitudes and dispositions as a foundation for future learning. These include curiosity, motivation and confidence to engage in inquiry and debate, willingness to change ideas, flexibility and respect for evidence and more widely positive attitudes to learning and respect for the environment. There is a growing recognition that the "affective dimension is not just a simple catalyst, but a necessary condition for learning to occur" (Perrier and Nsengiyumva, 2003: 1124).

The importance of supporting young children's early motivation and enjoyment for science and mathematics has also gained significant attention in light of the growing concern about older children's choice not to continue studying these subjects in study. In other words, negative attitudes to science and mathematics may stem from earlier school experiences. Consequently, a key objective of science and mathematics education should be to increase motivation and foster positive attitudes (e.g. Fensham and Harlen, 1999; Kallery, Psillos and Tselfes, 2009a; Millar and Osborne, 1998).

B2.1.3 Conceptualisations of creativity in early years education

There is a number of ways in which creativity evidenced in education is discussed. These discussions focus on the characteristics of creativity and, like the epistemological foundations, the ultimate purpose of what is

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being evidenced. Banaji and Burn (2010) examined discourses of creativity, grouping them into what they describe as nine 'rhetorics':

- creative genius;
- democratic and political creativity;
- ubiquitous creativity;
- creativity as a social good;
- creativity as economic imperative;
- play and creativity;
- creativity and cognition;
- the creative affordances of technology and;
- the creative classroom.

'Creative genius' focuses mainly on acts that are widely accepted as creative or ground-breaking; these might be movement-defining works of art or scientific discoveries. In relation to creativity in education, this rhetoric is perhaps less appropriate, although some authors continue to link creativity with 'giftedness' (Sriraman, 2010). The second rhetoric 'democratic and political creativity', refers to the culture and politics in young people's construction of identity. However, Banaji and Burn suggest that limiting the notion of creativity to activity linking identity construction with cultural knowledge limits creativity to the arts; an idea from which recent educational research has sought to distance itself, recognising that creativity is relevant across all domain contexts. Whilst Banaji and Burn refer to the rhetoric of play and creativity as being particularly relevant in the early years, it could be argued that the remaining rhetorics may also help frame creativity in early years education. The notion of 'ubiquitous creativity', that is, creativity is something that we are capable of, ties in neatly with the self-actualisation framing discussed earlier (Gibson, 2005). Similarly 'creativity and cognition' suggests that creativity is tied to act(s) of individual(s) and related to the notion of the romantic perspective. The 'creative classroom' may contain elements of either romantic self-actualisation or instrumentalist perspectives or both. If the goal of the creative classroom is to produce 'creative individuals' then it is likely to be situated within an instrumentalist epistemology, whilst if the goal is self-expression then the creative classroom can be seen to be driven by romantic individualism.

By contrast, there remain a number of other rhetorics that can be seen as reflecting the idea of creativity as instrumental, and of developing the individual. These might include creativity as social good (well-rounded individuals contribute more to society), creativity as economic imperative, and creative affordances of technology (towards building a 'knowledge economy'), which can be directly related to the headings above. Whilst these seem more remote from early years education on

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one level, evidence of these rhetorics can be traced in policy documents across Europe.

Children's creativity in the early years has in particular been characterised as problem finding and problem solving, involving playful exploration that prompts individual, collaborative and communal engagement (Burnard et al., 2006; Craft et al., 2012). As in science and mathematics education there is a similar tension in creativity between process and outcome, although this is also framed by the paradigm which informs the conceptualisation of creativity with cognitive, social-personality, humanistic and evolutionary approaches in particular foregrounding the process alongside the product (see the creativity in education literature review – Addendum 2 out of 4 - for more detail).

B2.1.4 Capabilities in creativity

Broadly speaking, there are two main approaches when examining the processes of creativity. The first considers creativity as de-contextualised, applied in a variety of situations and thus more general. The second interprets creativity as contextually and culturally situated; the processes are specific to context. In a way, the de-contextualised-approach echoes the nature of science and mathematics processes listed above as these are presented as being a list of potential actions independent of context. In the creativity field, decontextualized perspectives have led to tests that focus for example on divergent thinking (e.g. Torrance, 1969, 1976). In these, children elicit ideas from a stimulus, which are then rated against criteria for fluency, originality, elaboration, abstractness of title and resistance to premature closure.

However, **creativity is increasingly understood as contextualised, social, ethically situated, and concerned with both paradigm shifts and the everyday**. This too draws parallels with arguments in science and mathematics where the domain context matters when considering processes. Studies such as the work on 'possibility thinking' by Craft with her colleagues (Burnard et al., 2006; Chappell et al., 2008; Cremin et al., 2006) have investigated creativity as a culturally situated concept. These confirm and document possibility thinking as driven by children's questions and responses in a playful and frequently narrative context, in which a leading question shapes both service and follow-through questions (Chappell et al., 2008). Immersed in the creative process, children behave with intentionality, are self-determined, use imagination, and innovate and take risks. Jeffrey and Woods (e.g. 2003) also in England have also explored everyday creativity in the primary classroom. They highlight four key features in relation to children and teachers: a sense of relevance in the experience they are engaged in, control over its articulation, a feeling of ownership over their learning, and opportunities to innovate.

As with science and mathematics education, it is arguable that motivation plays an important role in creativity. Studies (Amabile, 1983, 1996, 1998; Brolin 1992; Chappell et al., 2008) suggest that intrinsic

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motivation, curiosity for example, contributes positively to creativity, whereas extrinsic motivation is negatively related to creativity and indeed learning generally. More recently, studies have focused on the impact of emotional states on creative performance, however the findings are not consensual (e.g. Cropley, 1997).

B2.1.5 Common themes across science, mathematics and creativity in early years education

There is an emphasis on learning processes and the development of positive dispositions in the early years. Both science and mathematics education and creativity in the early years can be framed in terms of the capabilities developed through the processes involved. As indicated in the previous section, in early science and mathematics, process skills and attitudes associated with inquiry are emphasised but with increasing recognition of their inter-relationship with conceptual development, while in the creativity literature this is framed towards looking at the processes of creative activity and what this enables.

Clearly, creativity and science/mathematics education have different foci; creativity emerging novelty and science/mathematics emerging children's engagement with the content and process of bodies of knowledge. **What is shared is recognition of children's hands-on and minds on exploratory engagement, and a focus on inquiry and investigation, often driven by young learners' curiosity and questions**. They also share important questions to consider in terms of the purpose of classroom experiences including the balance and interrelationship between process and content, or the extent to which processes can be considered independently of the context. A further challenge may be the emergence of understanding about the role of collaborative and collective engagement, where it is important to recognise a possible tension between personal and shared experiences and meaning, and how this tension might be resolved through collaborative activity.

Creative Little Scientists offers opportunities to explore more fully this common ground that science and mathematics education in pre-school and early primary education share with creativity.

B2.2 Teachers' conceptualisations of science, mathematics and creativity

Teachers' conceptualisations and their values and stances towards science and mathematics education and creativity frame and shape their classroom practice. Teachers' values are made manifest in learning contexts and tasks, and need to be translated meaningfully for each learner. Teachers' perceptions of themselves as 'creative practitioners' or as 'scientists' and their understanding of and commitment to child development also shape their pedagogy (Fleer, 2009). In investigating pre-school teachers' educational practice Einsdottir (2003) shows that their educational beliefs and knowledge of

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child development have a fundamental impact on their teaching. Marshall et al. (2009) examined links between beliefs about inquiry-based learning in science and mathematics and how frequently these approaches were used in the classroom. Thiel (2010) identified differences in teachers' beliefs about the importance of mathematical thinking and application of mathematics in the nursery curriculum, while Iannone and Cockburn (2008) documented the impact on classroom practice of belief in the importance of mathematical thinking and conceptualising mathematics as being about structure, pattern and connections.

In a study examining the stance of teachers teaching written and musical composition to 4-14 year olds, Craft et al. (2007) also reveal that teachers' own values are highly influential in guiding how pedagogy is conceived, how classrooms are resourced, how ethos is developed, and how tasks are formulated. This is also confirmed by Forrester and Hui (2007) in relation to nurturing creativity. Woods and Jeffrey (1996) highlight the humanist approach, openness to emotions and strong moral and political investment of creative teachers and Cremin, Barnes and Scoffham (2009) drawing on their research, suggest that creative educators are aware of, and value, the human attribute of creativity in themselves and seek to promote this in children. Such teachers, they posit, have a 'creative state of mind'. Additionally, in the early years possibility thinking work, it is noted that teachers, influenced by particularly constructivist views of learning, viewed the children as active constructors of meaning and positioned themselves as facilitators (Cremin et al., 2006). Durmus (2011) too noted connections between constructivist values and the use of models in mathematics as multi-representations and explanatory tools to construct understanding.

However, the beliefs that individual teachers possess do not always represent one particular theoretical approach, and external factors such as high stakes assessment can serve to compromise professional practice and create contradictions between teachers' reported beliefs and their practice (English et al., 2002). Marshall et al. (2009) identified tensions between beliefs in the value of inquiry-based learning and curriculum requirements to cover specific knowledge. Goldstein (1997) views such inconsistency in early childhood education as inevitable – "a fact of life in the open-ended, complicated teaching profession" (:21), yet it can create tension and may evoke mixed messages about what is valued or sought (Smith and Croom, 2000).

Teachers' views and understandings of inquiry-based approaches will also influence their practice in this regard. As the analysis of Initial Teacher Education (ITE) students' views and attitudes, (more fully documented in Section C of the Conceptual Framework and in Addendum 3 out of 4) indicates, there are challenges and concerns around less than positive attitudes and arguably limited conceptualisations of the nature of science and mathematics as well as creativity. In science specifically, a negative cycle appears to exist with student teachers drawing upon their own less

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than positive school experiences and demonstrating discomfort and a lack of assurance (Brady and Bowd, 2005). Primary ITE teachers also had a narrow conception of creativity in science lessons, perceiving it as more associated with the arts (Newton and Newton, 2009). In particular, there is an evident need to improve student teachers' conceptions of inquiry in order to influence their practice (Leonard, Boakes and Moore, 2009).

B2.3 Policy and policy makers' conceptualisations of mathematics and science education and creativity

Educational policy can shape practice by emphasising values and by indicating both content and pedagogy through frameworks, outcomes and assessment. However, the degree of regulation and the official status of documents varies across countries and phases of education.

Early years curricula for science and mathematics are the focus of directives from education authorities in many countries. These may set out (through explicit statements and/or in learning objectives and curricula) the aims of education, such as the broad areas of knowledge, or skills, and attitudes to be promoted, curriculum content, the learning outcomes to be achieved, assessment requirements and procedures for monitoring and evaluation, as well as directing approaches to learning and teaching. However, in a study of values and aims in curriculum frameworks across 16 nations, Le Metais (1999) found there are often mismatches between aims, curriculum requirements and indeed assessment regulations.

Common policy themes for science and mathematics education in the early years include the need to: foster positive attitudes, enhance knowledge about the world, develop skills and understandings associated with inquiry and promote a questioning and investigative approach to learning (European Commission, 2011a, 2011b).

B2.3.1 Policy conceptualisations in the nine partner countries in relation to science and mathematics education in the early years

As part of the literature reviews the *Creative Little Scientists'* partners reviewed policy documents relating to science, mathematics and creativity in the early years, including curricula, in the nine participating countries. This analysis showed that **curricula often refer to attitudes in general terms, although more specific terms such as 'curiosity', 'interest', 'motivation', and 'self-esteem' often appear to be synonymous with attitudes in science and mathematics education**. **Skills and processes are a key focus in all documents across phases and subjects and there is widespread reference to 'exploration', 'investigation' and 'problem solving',** as well as a common emphasis on observing and communicating. **Science knowledge and understanding is represented in very general terms in curricula aims**, including reference to the natural environment, the world around children, or technology, with more specific details occurring in subject-specific supplementary documents. In

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contrast, in mathematics, there is often greater indication of specific content to be taught, identifying for example key strands such as number, shape and space, measuring, data handling.

Reference to connections with everyday life – society and culture is widespread across phases as is issues in society, though this is more common in the primary phase, alongside sustainability (e.g. Greece), and links with technology (e.g. England, Malta). There is also a related focus on the physical environment: the use of materials, and resources both in the indoor and outdoor environment (Finland, England), organisation of different areas of activity (Belgium), the social environment, collaboration and group work (e.g. Germany). References are commonly made to linking everyday life and practical applications of science (e.g. Belgium Flemish, France, Malta).

Areas of learning are defined in different ways – in many systems mathematics appears as a separate area of knowledge and skill, however science, in pre-school in particular, is often included within a broader grouping such as environmental or world studies or making links with technology; for example, in the early years in Belgium (Flemish community, 2.5–6yrs) 'World Orientation'; UK (England, 0-5 years) 'Knowledge and Understanding of the World' or in Greece (4-10 years) 'Environmental Studies', Portugal (3-6 years) 'Knowledge of the World and (6-10 Years) 'Environmental Studies'. In the primary phase in the UK (England and Wales) science is presented as a separate subject.

In preschool, science knowledge and understanding is often suggested in rather general terms through indicating broad topics to be addressed. Although specific areas of study are not often identified or required in the early years – an emphasis on processes and attitudes predominates. More precise detail is frequently provided in relation to mathematics in the early years. In contrast, in primary education, there is a tendency for greater detail in curriculum content. In some countries, links between science and other subjects are not only indicated in the way that the curriculum is presented but encouraged in the approaches to science teaching advocated - for example in preschool in Greece, Belgium, Germany where guidance encourages programmes built around cross-curricular topics and children's interests.

There is widespread emphasis on active learning and building on children's existing knowledge and experience and interests (e.g. Portugal, Finland). The most common references are to observation, practical hands on experience, investigative, problem solving experiences, discussion and communication of ideas and to the promotion of positive attitudes, reflecting the aims. There is also encouragement of autonomy and children's decision-making, and reference to children's own project work (Germany). In Flanders there is a particular emphasis on the individual talents and competences of children (linked to Gardner's multiple intelligences) and the importance of play is often highlighted in preschool guidance (Greece, England, Wales, Belgium). However, there is

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more limited detailed reference to ICT (although its significance across the curriculum is often mentioned, e.g. Greece) – either as a tool to support specific aspects of learning or the need to consider possible limitations of technology

In reviewing the learning and teaching approaches advocated in the curricula, few explicit references were found linking to inquiry-based approaches and mention of creativity in the science and mathematics' curricula is limited in the documentation of many countries; although there appear to be more references in recent policy developments. In France for example, there is an explicit reference to the IBSE for the primary school with the development of the project "hands on" (la main à la pâte) and the online resource for teachers from this project as well as support for engaging scientists in primary classes. In Romania, over the last three years, the concept of IBSE has also been introduced and developed at elementary and middle school level through courses accredited by the Ministry of Education. From 2012 this project is being developed in cooperation with the French school in Bucharest with kindergarten educators. An e-learning platform (http://www.teachscience.activemoodle.com/) has been created for resources to support this with translations from European (La main à la pâte, Pollen, Fibonacci) and American (Hands-on Optics) projects. As IBSE encompasses a wide range of processes, it is possible to identify implicit references made within policy documentation to issues such as curiosity, questioning and inquiry.

A central feature of mathematics and science policy is assessment guidelines and requirements. There is variation in approach across partner countries. For example in most partner countries the emphasis in pre-school is on ongoing formative teacher assessment, whereas in England and Wales there are statutory requirements for summative assessment. In the primary years there is more widespread emphasis on summative assessment and increased use of standardised tests for accountability and evaluation purposes. This is examined in more detail in section B4, though it is worth noting here that researchers' highlight that summative testing arrangements can have a distorting impact on the nature and breadth of the curriculum (Laevers 2005; Alexander and Amstrong, 2010). Indeed, the EACEAP9 Eurydice Report (European Commission, 2011a) states that in many countries, "the focus [of learning] tends to be on the test content rather than curriculum standards or objectives"(:90).

B2.3.2 Policy conceptualisations in the nine partner countries in relation to creativity in education in the early years

In contrast to the emphasis on mathematics and science in the early years across Europe, creativity is less evenly highlighted. What it means in practice, as in science and mathematics education also varies. As indicated earlier, there is a version of the 'content vs process' conceptualisation evident in creativity discourses with some emphasising

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outcomes more than others according to the emphasis on instrumentalist vs self-actualisation narratives. Across Europe there are dramatic differences in the use and frequency of the word 'creativity', this is shown in Heilmann and Korte's (2010) content-analysis of curricula from countries around Europe, they found that the relative frequency (occurrences per 1000 words of curricular text) of the word 'creativity' (and its synonyms) varied considerably. In the Netherlands, 'creativity' was not to be found in the curriculum, while in Estonia, 'creativity' had a relative frequency of 1.92 0 almost once every 500 words. The emphasis in each participating country of *Creative Little Scientists* is slightly different.

Creativity is sometimes referred to as a more independent (reified) entity to be fostered alongside other aspects, e.g. "promote greater flexibility and creativity" (Scotland), "develop curiosity, creativity, critical thinking and interest in the scientific and technical progress" (France) or "mathematical thinking i) creative thinking ii) reflective thinking iii) critical thinking" (Greece). In Wales, the phrase, "activities should foster curiosity and creativity and be interesting, enjoyable, relevant and challenging for the learner" suggests that creativity is something distinct from these other aspects. In England, the previous national curriculum document listed thinking skills (including enquiry skills, creative thinking skills, reasoning skills and evaluation skills); key skills such as problem solving; and creativity, these were to be applied across the curriculum. Currently the curriculum is being re-written.

The positioning of science and mathematics education and creativity in curricula is closely allied to their perceived and respective purposes. While there may be underlying similarities in relation to purpose, such as economic or technological imperatives or the development of the individual as a successful citizen or of particular capabilities, these are not mutually dependent. Furthermore, the way in curricula are constructed by governments, regional, local and school policy makers is inextricably linked to political aims and motives. For many it may be politically attractive to portray aspects of the curriculum as economically "good for the nation" whilst at the same time appealing to a more child-centred approach. As such, presenting both epistemological positions in the same curriculum may be politically beneficial and thus few curricula are situated solely within the instrumental or romantic framework.

It is worth noting that discussing policy and policy makers' interpretations of science and mathematics education and creativity is not straightforward. How these curricula initiatives are enacted in the classroom affords another issue of significance for the project *Creative Little Scientists*.

B2.4 Summary of conceptualisations of science, mathematics, creativity in early years education

The project *Creative Little Scientists* faces multiple conceptual challenges. These relate in particular to:

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- the 'nature of science' in the early years and the importance of procedural understanding alongside the issue of developing subject knowledge;
- the duality of process and content and recognition of their relationship in science and mathematics in the early years;
- the role of inquiry and investigation, problem solving and problem finding, often driven by young learners' curiosity and questions;
- the role of emotive factors such as motivation and attitudes which affect young learners' engagement and quality of thinking;
- the role of collaborative engagement and learning;
- issues of process and outcome in conceptualisations of creativity;
- early years teachers' conceptualisations and beliefs and how these influence their practice;
- the diverse policy constructions and curricula framing across the project in the early years;
- the influence of curricula and assessment which can frame and influence practice.

B3. Exploring Teaching and Learning with a Focus on Inquiry Based Science Education (IBSE) and Approaches that Foreground Creativity (CA)

In addition to the previous examination of the drivers of the project *Creative Little Scientists* and the ways in which creativity, science and mathematics are conceptualised in research, by the profession and by policy makers, it is important to consider the research literature in relation to the pedagogical synergies between these domains. It is evident that considerable common ground is shared in relation to the inquiry-based and problem solving work developed in science and mathematics which is also recognised as a core part of creativity, not only in the early years. So attention is now given to teaching and learning with a particular focus on IBSE and approaches to education which foreground creativity, which for the purposes of this Conceptual Framework we are labelling Creative Approaches (CA). It is useful therefore to offer more detail on both these umbrella terms; the former is being used broadly and includes inquiry based approaches to science as well as problem solving approaches to mathematics; the latter is also being used to include a number of teaching and learning practices (for more detail see below).

Whilst **there is considerable agreement internationally, reflected in both policy and research, about the value of inquiry-based approaches to science education** (Asay and Orgill, 2010), the review of inquiry in science education undertaken by Khalik et al. (2004) indicates that definitions of IBSE vary. This is reflected in the categories that Minner et al. (2009) argue are associated with the term inquiry –

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"*what scientists do* (e.g. conducting investigations using scientific methods); *how students learn* (e.g. actively inquiring through thinking and doing into a phenomenon or problem, often mirroring the processes used by scientists), and a pedagogical approach that teachers employ (e.g. designing or using curricula that allow for extended investigations)" (:3). According to Drayton and Falk (2001), the purpose of IBSE is to "introduce students to the content of science, including the process of investigation, in the context of the reasoning that gives science its dynamic character and provides the logical framework that enables one to understand scientific innovation and evaluate scientific claims". They view inquiry not as process versus content, but rather perceive it as an approach to learning and enhancing content knowledgeThe US National Research Council (2000) identifies five attributes of learners in Inquiry Based Science Education, who they assert: 1) Engage in scientifically oriented questions; 2) Give priority to evidence in responding to questions; 3) Formulate explanations from evidence; 4) Connect explanations to scientific knowledge; and 5) Communicate and justify explanations. Whilst the focus of inquiry has been predominately science education, which for many may be synonymous with 'natural sciences' Rocard et al. (2007) suggest that IBSE can also encompass problem based learning in mathematics and arguably therefore teaching and learning in other areas of the curriculum.

In relation to CA, it should be noted that in contrast to IBSE this term does not refer to a recognised set of approaches to education and learning. Nonetheless, a number of studies of creativity focus on aspects of teaching and learning and in England two particular foci have gained considerable attention in research and policy contexts in recent years: teaching creatively and teaching for creativity (NACCCE, 1999). The former is arguably teacher centred and relates to the repertoire of teaching strategies upon which the creative practitioner may draw, whilst the latter is focused more on increasing creativity in general and in relation to fostering children' creativity. In exploring the relationships between these foci, Jeffrey and Craft (2003), note that they are closely related; teachers teach for creativity and also teach creatively as appropriate and sometimes do both simultaneously. Furthermore, **teaching for creativity often arises spontaneously and is more likely to arise from contexts where teachers are teaching creatively**. In connecting to the work on the key characteristics of creative educators, Prentice (2000), in reviewing early years practice at the turn of the century, highlights the need for creative teachers to show 'cultural curiosity' and engage themselves in playful learning, remaining open to children's ideas and using a flexible and creative pedagogical style. Research studies which implicitly and explicitly explore exploring creative pedagogical approaches highlight a number of strategies which are employed in the primary and early years. These are examined later in this section alongside those strategies and practices which empirical studies indicate are core to IBSE.

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B3.1 Exploring synergies and differences in IBSE and CA

Arguably, whilst IBSE and CA differ in their origins and developmental histories, they are also connected by underpinning influences. IBSE reflect the recommendations of Dewey who considered that there was an over-emphasis on facts without sufficient emphasis on science for thinking, in his model, the learner is actively involved and the teacher's role is as facilitator and guide. CA, whilst also influenced by Dewey's ideas about balancing children's interests with the curriculum, have been further shaped by recent studies of creative teaching and teaching for creativity. In both there is an emphasis on the learner, but in IBSE there is a greater emphasis on the role of the teacher in supporting the development of specific skills and understandings in science and mathematics. In CA, the role of the teacher is less subject specific and may be more focused on developing learner creativity within and beyond the curriculum.

Both sets of approaches, which lie at the core of the project, are pedagogically associated with a range of child-centred philosophies from European and North American thinkers, including Rousseau, Pestalozzi, Fröbel, Owen and Isaacs, Steiner and Magaluzzi. These writers variously foreground the child as an active and curious thinker and meaning maker and highlight the role of experiential learning. Both are closely aligned to early years education and theories of child development, but differ to some degree with regard to their expressed purposes, with IBSE focusing on questioning and the generation, justification and evaluation of ideas within a community. The expressed intent in CA is to help young people "believe in their creative potential, to engage their sense of possibility and to give them the confidence to try" (NACCCE, 1999:90).

While there are a range of definitions of IBSE, as indicated earlier, a number of common emphases are evident including for example: the notion of authenticity in focusing on students' interests and issues relevant to their everyday lives (Hofstein and Lunetta 2002); the central role of children's own questions as a context for inquiries (Drayton and Falk, 2001) and the importance of inquiry within a community, fostering a climate of discussion and debate with peers (Hmelo-Silver et al., 2006).

Researchers of creative approaches highlight the role of innovation, originality, ownership and control (Woods and Jeffrey, 1996, Jeffrey, 2003, Jeffrey and Woods, 2003) and recognise the need to encourage attributes such as risk taking, independent judgement, commitment, resilience, intrinsic motivation and curiosity. Additionally, curiosity, connection making, autonomy and originality have been documented as key features of the pedagogy and ethos found in the classrooms of highly creative professionals (Grainger, Barnes and Scoffham, 2006). Creative approaches are arguably open and applicable to a range of contexts and subject domains. In seeking to capture both creative teaching and teaching for creativity, Dezuanni and Jetnikoff (2011) view creative

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pedagogies "as both the imaginative and innovative arrangement of curricula and teaching strategies in school classrooms and the development of students' creative capacities"(:264). Based on the possibility thinking studies, it is claimed that creative approaches include such pedagogic strategies as 'standing back', affording time and space for exploration and profiling learner agency (Cremin et al., 2006).

CA appear to include less emphasis on rational explanation and reasoned argument than IBSE, which tends to highlight reasoning and metacognition in relation to a focus on scientifically or mathematically oriented questions. Notwithstanding their different emphases, IBSE and CA are both interpreted and employed as tools for knowledge construction, they can be seen not only as ways of learning content, but also as motivational supports for the development of positive attitudes with regard to science, mathematics and creativity. Additionally, to different degrees both approaches appear to profile a number of pedagogical practices which seek to foster particular aspects of children's learning. These are now examined.

Pedagogical commonalities are found in relation to: play and exploration, motivation and affect, questioning and curiosity and dialogue and collaboration as well as problem finding, problem solving and developing agency as learners. The focus on reflection and reasoning whilst strongly part of IBSE has been afforded less research attention in CA particularly in the early years. With regard to the critical scaffolding role of the teacher, research reveals some commonalities and some differences and these are also examined. This subsection concludes with a consideration of implications for assessment to inform teaching and learning and discussion of some of the professional challenges involved in developing IBSE and CA approaches in the classroom.

B3.1.1 Play and exploration

Whilst pre-school children differ with regard to their experience of play, exploration and interaction, the significance of play in early learning is widely recognised and represents the focus of considerable research within both approaches. It is argued that **informal playful experiences nurture children's motivation to understand their world,** (Larsson and Halldén, 2010) and Gopnik, Sobel, Schulz and Glymour (2001) claim that from as young as two or three, children are able to make causal inferences about information they gain from the environment, demonstrating an ability to reason and reach conclusions, although not necessarily verbally. The environment affords significant opportunities for scientific learning through play, indeed in Reggio Emilia pre-schools, which often involve young children playfully investigating the environment, the power of play is evident (Edwards, Gandini, and Forman, 1993), and research by Garaigordobil and Buerrueco (2011) suggests that sustained play in early years settings increases children's creativity.

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In seeking to interrogate the similarities between play and learning in the early years, Samuelsson and Carlsson (2008) comment that "pedagogy should not separate play and learning but draw upon the similarities in order to promote creativity in future generations". They suggest the similarities include: children's experience as a point of departure, discernment, simultaneity and variation as well as meta-cognition, meta-cognitive dialogues and meta-communications. A Finnish case study of pre-school teachers, further underscores the idea that play and child-initiated activities characterise the pedagogical work of teachers of this age group (Einarsdottir, 2003). Most scholars appear to perceive that **playful experimentation/exploration is inherent in all young children's activity, such exploration is at the core of IBSE and CA in the early years.** Poddiakov (2011) asserts there are two main types of experimentation in the classroom which teachers need to foster – 'personal experimentation [mental]', aimed at discovering relations and the quest for new knowledge and 'utilitarian experimentation [physical]' aimed at solving practical tasks. Poddiakov also proposes a third 'special' type of experimentation 'social experimentation', which he suggests involves trying out forms of behaviour. These three forms connect to on-going empirical work in the UK examining young children's 'possibility thinking' (Burnard et al., 2006; Cremin et al., 2006; Craft et al., 2012).

Many empirical studies within the wide field of science, mathematics and creativity research examined in the appended literature reviews, suggest that (apparently[1]) **open-ended exploratory contexts are well suited to fostering learner creativity and learning in mathematics and science** (Jeffrey, 2004; Burnard et al., 2006; Bonawitz et al., 2011; Cremin et al., 2006; Einarsdottir, 2003; Fawcett and Hay, 2004; Poddiakov, 2011). Supported by the pedagogic space and scope offered for exploration, it appears that children in these studies often extended boundaries and explored with interest and commitment. The young learners' affective engagement in this 'third area', as Winnicott (1974) calls the deep play of childhood, appeared to prompt an openness which their teachers frequently sought to build upon. Such openness, alongside objectivity, is recognised as a critical feature of the development of a scientific stance or attitude (Feng, 1987).

According to Goswami and Bryant (2007) pretend play contexts which prompt children's imaginative engagement enhance their thinking, reasoning and understanding of concepts, although they argue that scaffolding by an adult is required if these are to be effective for learning in school. Edo et al. (2009) found that structured sessions and educational visits between free play sessions helped focus the children on the mathematical elements in their role play. In a not dissimilar manner van Oers (2010), notes that parents, in re-intepreting children's

[1] It could be argued that in a teaching and learning context, nothing is actually 'open-ended' as all is framed pedagogically.

[2] International Association for the Evaluation of Achievement

[3] TIMSS was linked with PIRLS (Progress in International Reading Literacy Study) in 2011

[4] Organization for Economic Cooperation and Development

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verbalisations in play, are able to 'mathematicise' play, capitalising on opportunities for learning mathematics in such contexts.

Several studies which can be seen to involve examination of IBSE and CA, albeit implicitly, demonstrate the importance of providing children with sufficient time and space to foster such exploration and creative thinking (e.g. Cremin et al., 2006; Jeffrey, 2005; Martin and Schwartz, 2005). The provision of 'stretchy' time in the possibility thinking studies encouraged children's immersion in extended playful activities and, alongside the enriched and mutually-owned space, appeared to motivate and involve the young thinkers (Cremin et al., 2006). In the European Creative Learning and Student's Perspectives (CLASP) project, Jeffrey (2005) also noted that considerable time was afforded to 'open adventures', and that these exploratory opportunities enabled the young to experiment, push boundaries and take risks. Additionally, though somewhat differently, Metz(1988) argues that in relation to developing scientific concepts through investigations, over time children improve strategies, and shift in emphasis from making things happen to developing their understanding. This need for time to support exploration is also emphasised by Glauert (2009a), who proposes that over time children "may begin to raise questions for investigation, look for patterns and relationships and offer explanations".

In promoting opportunities for exploration in the early years, research in science, mathematics and creativity also highlights the importance of a rich physical environment, use of the outdoor environment and the importance of making links with children's everyday lives to engage interest and foster curiosity (French 2004). Furthermore provision of a wide range of materials in the classroom can be motivating and offer different ways for young children to represent ideas and express their thinking.

B3.1.2 Motivation and affect

Research in science, mathematics and creativity indicates that **play based exploratory contexts afford rich opportunities for supporting the development of both positive attitudes and motivation;** which as noted earlier are key constructs of the affective domain in science education (Koballa and Glynn, 2008) and arguably mathematics. Based on the Experiential Education project, Laevers (2000, 2005) argues that the creation of playful learning contexts which foster deep learning is at the core of quality early education which he posits is affectively engaging and 'affects the deeper structures on which competencies and dispositions are based' (2000: 20). Early years science and mathematics teachers are seen to make learning relevant and engaging by incorporating children's prior-knowledge and embedding activities into the children's everyday experiences, this, it is argued, makes it easier for children to state their own opinions and work imaginatively with the tasks given. Moreover, it is suggested that stressing the relevance of science through issues based hands-on

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experience can help children start to see connections between science and their close surroundings which it is argued acts as a motivating factor (Kobolla and Glynn, 2007; Kramer and Rabe-Kleberg, 2011).

Other work has also highlighted the role of aesthetic experience in promoting children's affective and emotional responses to science and mathematics activities. Milne (2010), for example, argues that fascination, engagement, awe, wonder and interest can prompt aesthetic engagement, spark children's curiosity and lead to the use of scientific inquiry to develop explanations of phenomena. Devlin (2000) also argues that experimentation, guessing and connecting to personally relevant real life issues can encourage young mathematicians. The affective dimensions of science learning which have received less attention by researchers than the cognitive dimensions, is not Perrier and Nsengiyumva, (2003: 1124) argue, just a simple catalyst, but "a necessary condition for learning to occur". Certainly creativity research highlights the importance of engaging children affectively and emotionally (Woods, 2001; Woods and Jeffrey, 2006) and others also highlight that utilising the widely recognised power of narrative and dramatic story making, can make learning relevant by engaging children imaginatively and thus fostering their creativity in different domains (Bruner, 1986; Craft et al., 2012; Cremin et al., 2006; Paley, 2001; Sawyer, 2004a, 2004b). The role of narrative as a playful imaginative context in which young children's creativity can be nurtured is an area for potential exploration in mathematics and science; it connects to children's emotional engagement and is evidenced as a context in which possibility thinking may be fostered (Craft, McConnon and Mathews, 2012).

B3.1.3 Dialogue and collaboration

Another area of synergy between the research literatures focused on creativity and on IBSE in mathematics and science is the significance of dialogue and collaborative learning. It is widely accepted that language plays a crucial role in learning in and through science (Carlsen, 2008; Roth, 2007), and communication is seen to be one of the critical features of IBSE, although other modes of communication also enable children to externalise, share and develop their thinking (Glauert, 2009b). Listening to children's initial ideas is important not only to afford respect, but to emphasise the validity of alternative points of view (Coltman et al., 2002), their perspectives are not simply misconceptions. In school, IBSE involve problem solving activities with peers, which are often highly collaborative, and afford children access to a wider range of problem-solving strategies.

The process of explaining their thinking verbally can help children consolidate their ideas (Chi, De Leeuw, Chiu, and Lavancher, 1994) and enable them to develop their verbal reasoning skills (Mercer, Wegerif and Dawes, 1999). Such skills are seen to be essential for learning in mathematics and science. The communication of ideas and ways of thinking allows children to listen to others' strategies and ideas and

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develop increased awareness which may prompt a desire to restructure their own ideas, in the face of other more plausible or consensual ones (Varela, 2010). This links to research on the value of developing children's metacognitive awareness. Although little of this work is focused in the early years, it does suggest that if children are afforded opportunities to explore and work in small groups, this may make them more attentive to their own thoughts and the thoughts of others, encouraging monitoring and self-regulation (Larkin, 2006; Littleton et al., 2005). (See also the subsection 3.6 on Reflection and Reasoning.)

Much current creativity research recognises that creative processes are essentially social and necessarily collective and collaborative (see John Steiner, 2002; Sawyer, 2006) and there is considerable work exploring the nature of creative dialogue which indicates that **dialogic engagement is inherent in everyday creativity in the classroom** (Littleton et al., 2005; Mercer and Littleton, 2007; Rojas-Drummond et al., 2006; Wegerif, 2005, 2010; Vass, 2007). This body of work, much but not all of which orients around the 'Thinking Together' programme, demonstrates that children may benefit from support in developing their collaborative reasoning, and when supported are able to engage creatively. Mainly undertaken in upper primary classrooms, this work reveals inter-subjective co-construction and collaboration in the context of shared social ground rules in the most successful creative dialogues. Howe et al., (2007) also show how extensive training in generic group skills can lead to increased collaborative learning and new knowledge. Additionally, in order to support the development of children's reasoning in primary science lessons, Naylor et al (2007), show that the use of puppets can help to engage and motivate children, promote talk that involves reasoning, and encourage the involvement of reluctant speakers. Perhaps the 'as-if' world and imaginative play prompted by the use of the puppets offered additional support in this context. Collectively, these studies suggest that children of all ages may need support in developing their capacity for dialogue and collaboration that enhances their reasoning skills.

However, even in the absence of teacher guidance and the use of ground rules, puppets or training, on the basis of other studies it is claimed that children are able to construct an argument and appreciate alternative viewpoints (e.g. Naylor, Keogh, and Downing, 2007). Also that without the presence of a teacher, there are benefits to unstructured group discussion (Kramer and Rabe-Kleberg, 2011). In analysing the findings from a Flemish project entitled 'Haus der Kleinen Forscher' (the House of Little Scientists), which sought to enhance the technological, mathematical and scientific education of preschool children, Kramer and Rabe-Kleberg (2011) note that **open discussion in problem solving contexts without a teacher appeared to nurture creativit**y. They document two main forms of group interaction: constructive, creative interaction and competitive interaction. Reminiscent of Mercer et al.'s (1999) category of 'disputational talk', the latter was less productive,

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however the former, which occurred when the children were able to experiment collaboratively with one another relatively free from constraints, appeared to nurture creativity. In their interactions without their teacher, the young children's collaborations often displayed creativity and also fostered their effective task-management and scientific understanding. Kramer and Rabe-Kleberg (2011) argue that as the young learners actively applied their knowledge to creatively solve problems, they enhanced their understanding of scientific processes. On the basis of this study, they identify two criteria that they claim are necessary for efficient and creative work: open dialogue between children and the teachers, (so that children learn to express and discuss their own ideas) and enough space/opportunities for the children to experiment and work on their own or in peer groups. This work also reveals some interesting insights with regard to teachers' positioning and interaction over time discussed later in subsection 3.8.

B3.1.4 Problem solving and agency

Related to the common focus on dialogue and collaboration are the data around the identification of problems and group problem solving which is a central part of IBSE (National Research Council, 2000) as well as widely recognised within CA to education. As discussed by various authors defining inquiry-based teaching approaches can be problematic, in particular there is considerable debate about the role played by the teacher in constraining or affording learner agency(Asay and Orgill 2010; Keys and Bryan, 2001). In an attempt to identify approaches to inquiry that can foster creativity, Barrow (2010) maps the five learner attributes of inquiry identified by the US National Research Council (see section B3), to a dimension of more or less student directedness or agency (see Figure 1 below). Barrow discusses how this scale reflects teacher approaches that range from student-directed open inquiry approaches, to guided inquiry approaches, and ultimately teacher directed 'cookbook' approaches.

Barrow's work highlights that the extent of children's agency in inquiry approaches is often unclear. Indeed, in a critique of inquiry and problem based approaches, Kirschner, Sweller and Clark (2006) argue that such approaches disregard evidence of the limitations of guidance during instruction. This criticism is contested by Cindy, Duncan and Clark, (2007) who argue that inquiry approaches actually involve a high level of scaffolding. There are debates therefore in the literature concerning the role of the teacher in IBSE, and the extent to which teachers are able to scaffold young children's problem finding and solving without hindering their agency. In this regard, it is helpful to consider the role the teacher can play in providing children with materials and activities, to foster shared and meaningful experiences. This reflects greater recognition of a more holistic approach in early learning that considers the physical, social, and affective context in meaning-making (Duit and Tregust, 2003;

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Glauert, 2009b; Goldin-Meadow, 2009; Beghetto and Kaufman, 2007; Chappell, 2008).

Essential Feature	**Variations**			
Learner engages in scientifically orientated questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials or source	Learner engages in question provided by teacher, materials and source
Lecturer gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyse	Learner given data and told how to analyse
Learner formulates explanations from evidence	Learner formulates explanations after summarising evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	
Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to sharpen communication	Learner gives steps and procedures to communication
More........Amount of Learner Self-Direction.......Less				
Less........Amount of Direction from Teacher Material......More				

Figure 1: Essential features of classroom inquiry and their variations (Barrow, 2010: 3)

Structuring the learning environment appropriately can give children space and agency to explore problems. Indeed, research has shown that, given the opportunity, children will independently vary their problem solving approaches over time (Siegler, 1987). Moreover, children are often competent in identifying efficient strategies for solving problems. This is important considering the role that cognitive flexibility has been attributed in learning and creative problem solving (DeHaan, 2009). The flexible use of different strategies by more competent learners has been

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shown in various mathematical problems (Gray and Tall, 1994; Torbeyns, Verschaffel, and Ghesquiere, 2002). This process of exploration tending towards more efficient strategies has also been articulated by Martin and Schwartz (2005) in their theory of Physically Distributed Learning. They demonstrate how children with nascent ideas in a domain are able to manipulate the environment (e.g. number blocks in a fraction problem) to explore different possibilities, interpreting alternatives to identify more effective strategies. Whilst several studies highlight the benefits of encouraging children to generate and evaluate possible strategies, it is possible that this may detract from time spent practising / becoming familiar with domain specific strategies. Schwartz, Bransford and Sears (2005) refer to this as the trade-off between 'innovation and efficiency'. In discussing the cognitive benefits of innovation, they propose that 'optimal learning' is a balance between the two. Their work refers to learners of all ages, so it is possible that the benefits of generative thinking are more pronounced for young children. Baran et al. (2011) recommend that there should be less emphasis on finding the correct answer in the fastest way possible and more emphasis on exploring different solutions and approaches when problem solving in mathematics.

Providing children with shared, meaningful, physical experiences can therefore provide them with opportunities to develop their own questions as well as ideas about scientifically relevant concepts. In other words, by scaffolding the learning environment, it is possible to foster children's agency in problem finding and solving. As highlighted by Fleer (2009), teachers play a fundamental role in mediating children's thinking between everyday concepts gained through playful interaction and more formal scientific concepts. This issue of the degree and purpose of adult intervention in IBSE and CA is discussed later in the Conceptual Framework.

In the creativity research literature it is also evident that problem finding and problem solving are core elements and that engagement with problems can foster child agency, ownership of learning and the development of self-determination and control (Craft et al., 2012; Cremin et al., 2006; Cremin, Barnes and Scoffham, 2009; Jeffrey, 2005; Raggl, 2006; Sugrue, 2006; Woods and Jeffrey, 1996). These studies collectively suggest that children's creative engagement in finding their own problems, problems which they wish to explore or solve is central to creativity, and links closely to their curiosity and questioning stance examined earlier. Additionally, teachers' trust, interest and respect for children's questions facilitates young people's sense of autonomy and the degree to which they are in control of their own learning. Rather than leading, the teachers in these various creativity studies often set open ended tasks which the children undertook in groups or pairs and which they organised themselves, following their own ideas and interests as collaboratively engaged problems solvers. McWilliam (2008) however in acknowledging that for decades teachers have been expected to position themselves as 'custodial risk minimisers', suggests that they have

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potentially limited the autonomy and agentic space offered to children. Although this was not the case in the possibility thinking studies, where the teachers prioritised learner agency and expected high degrees of independence of even the youngest learners. These teachers encouraged problem solving and problem finding activities and actual and mental play (Joubert, 2001), furthermore, they often employed reverse questioning, passing the problem back to the learners to foster their decision making and agentic actions (Cremin et al., 2006; Craft et al., 2012).

B3.1.5 Questioning and curiosity

The role of questions, both children's and teachers' is another common area of research across these interrelated fields and is recognised as central within both IBSE and CA. Whilst it is widely accepted that young children are innately curious and seek to explore the world around them, Nickerson (1999) suggests that the educational process can both inhibit and stifle their curiosity, their impulse to question and their engagement in mental play. Some studies indicate that teachers who use a lot of questions achieve high levels of pupil involvement and promote learning (Rojas-Drummond and Zapata, 2004),and others, that **creative teachers often employ open ended questions, and promote speculation by modelling their own curiosity** (Craft, 2002; Cremin et al., 2009; Robertson, 2002). Arguably, they make use of open questions to promote deeper, transferable thinking and to invite learners to engage with problems of relevance. With upper primary learners in science and mathematics, this can, it is claimed, improve standards of understanding and knowledge through increasing metacognition (Shayer and Adey, 2002).

However, working with young children (Harris and Williams, 2007) show that if they have little experience of open questions at home, they may find such questions difficult. These researchers suggest that rather than focusing on open and closed questioning, it may be preferable to consider the relationship between children's understanding of questions and the referential codes in the questions (e.g. whether they refer to objects that are present) and **how teachers might use resources or gestures to help ground questions to support children's thinking**.

The role of the context in questioning is also important in considering children's own questions. As discussed in the previous section, younger children in particular may need time, and space to explore materials in order to formulate ideas and questions (Glauert, 1996). Moreover, it is important to consider that children's curiosity may not be expressed verbally, but through other modes. Children's drawing, gestures, or even actions with materials may illustrate the focus of their investigation; attending to these other modes can provide teachers with means to build upon the different ideas children are exploring, indeed studies that foreground children's visual representations have been seen as an entry point to their creativity since the 1940s and are still in use today (Uzsynka, 1998) including 'gestalt holistic assessment' introduced by

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Brewer (1989) and subsequently developed by others (Nelson et al., 1998) who used the technique to examine the relationship between chronological age, children's rated-drawing ability and their scientific knowledge. Children's 'intellectual play' is explored through their visual representations by Wood and Hall (2011) and Stevenson and Duncum (1998).

In terms of possibility thinking, it is important to consider differences between different domains and the potential tensions that may arise when considering how broadly we wish to encourage children's thinking. In mathematics, for example, how beneficial is it to encourage children to question and consider alternative symbols or vocabulary? In science, are there any risks in children's sharing personal explanations that may detract other children's attention from particular science concepts? It is important therefore when discussing 'open questioning' to consider how questions are interpreted by children and how this may help them reflect on particular concepts. As an example, a question such as 'what would be the best way to build this tower?' can focus children's attention whilst allowing a range of concept relevant ideas such as flat v curved surfaces and balancing; broad v narrow bases; structural v aesthetic considerations. In science Harlen and Qualter (2004) draw attention to the different kinds and purposes of questioning for example whether they are person or subject centred, open or closed or designed to foster inquiry or to explore ideas. They indicate that questions can be framed for different purposes and emphasise the importance of giving time for thinking and response.

The notion that questioning of different kinds and for different purposes can act as a support to children's inquiries and learning is also reflected in the work of Chappell et al. (2008). In arguing that question-posing and responding is the driving feature of possibility thinking this work highlights the significance of teachers offering leading questions, which the research suggests, are often possibility broad in nature. Such questions appear to provide the over-arching framework for the learners and to some degree lead/shape their possibility thinking. Though it should be noted that in the study these overarching leading questions often followed an extended discussion with the children and were therefore responsive to some degree to children's interests and motivations. Their questions may have acted as scaffolds to support creative learning (Bruner, 1986).

Finally, it is important to consider how the teacher can model and foster positive attitudes to curiosity and questioning. Teachers who show their own creativity by constantly questioning themselves and thus profiling self-reflection are well placed to foster such attitudes in others, thus potentially generating new questions on the part of the learners and 'developing intrigue' (Poddiakov, 2011), a core capacity of young scientists.

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B3.1.6 Reflection and reasoning

In terms of reflection and reasoning, there is rather more in the research literature evidencing the importance of these skills within IBSE than in CA. IBSE seek to help children make use of 'data' from home, school and community experiences. However, this requires understanding of the relationship between evidence and theory linked to the nature of science, with which children, Metz (2004) argues, have difficulties as they are biased towards interpreting evidence in terms of their existing theories and will not develop scientific reasoning automatically from experience. In coordinating theory and evidence, Kuhn (1989) emphasises the importance of metacognitive processes: reflective awareness and deliberate control of cognitive activities. This may explain younger children's difficulties as their metacognitive abilities are still developing. Goswami and Bryant (2007) identify four forms of infant learning mechanisms: statistical learning (neural structures from patterns of observed events); learning by imitation; learning by analogy; and causal learning. They argue causal or 'explanation-based' learning is present in infancy but that the ability to deal effectively with multiple causal variables – scientific reasoning – develops more slowly.

Scientific reasoning is usually understood as the kind of thinking that requires the co-ordination and differentiation of theories and evidence, and the evaluation of hypotheses (Kuhn, 1989). Arguably this relates to conceptions of creativity which focus upon the generation and evaluation of ideas, but there is little explicit discussion in the creativity research literature on the role of reflection in the early or later years. Although the Reggio Emilia schools, profile children's reflection and documentation of their learning, this is not always seen through a creativity lens (Malaguzzi, 1993; Rinaldi, 2006), though more recently colleagues in the UK working within more overtly creative approaches have begun to analyse the process of evaluation and thus reflection (Bancroft et al., 2008).

In the context of IBSE it is argued that participating in the processes of sharing, testing and then evaluating ideas can foster an appreciation of scientific argumentation and explanation. The teacher has a key role to play here in promoting a supportive climate for debate, questioning, feedback and critical reflection. Research suggests that children as young as six can understand the goal of testing a hypothesis, and can distinguish between conclusive and inconclusive tests of that hypothesis in simplified circumstances (Sodian, Zaitchik and Carey, 1991). It has also been shown that children have an early capacity to reason scientifically (Duschl et al., 2007; Eshach and Fried, 2005), but find this difficult in situations when they have to ignore their pre-existing knowledge and reason purely on the basis of the data, and when they have to keep multiple variables in mind at once (Kuhn, 1989).

There are important roles for expression and recording in different modes in encouraging reflection and evaluation of ideas, strategies and learning

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and providing a basis for discussion and dialogue with others. This may take many forms: children's drawing (Barnes, 2001; Heath and Wolf, 2005; Stevenson and Duncum, 1998; Wood and Hall, 2011), their writing and text-making (Armstrong, 2006; Chapman, 1995; Pahl, 2007) questioning assumptions, redefining problems and considering what else might be possible (Richhart, 2002), and may involve the use of digital technologies. Children's creativity is revealed through these means as well as their understandings. In exploring creativity in science in the early years, Wollman-Bonilla (2000) for example showed how even very young children would change their writing styles to suit instructional, recount of events and fictional narratives, an act which may be considered creative when considering Pahl's work (2007), who has suggested that children's abilities to bring a number of different experiences into one coherent piece of text is an indicator of creativity in young children. In whatever form children have expressed their ideas, the teacher in focusing the young learners' attention on how they think about something, fosters the child's meta-cognitive awareness and helps to make the implicit more explicit. In a study exploring the science of forces, a teacher, who profiled reflection and questioning, noted that the metacognitive capacity of the 6-7 year olds in her class far exceeded her expectations; their ability to engage in metacognitive dialogues about their learning and to make creative metaphorical comparisons was marked (Williams and Cremin, 2008).

In mathematics, two studies profile the value of children becoming aware of their own cognitive practices, with Schoenfeld (1987) arguing metacognition involves: knowledge; self–awareness (self–regulation); and beliefs and intuitions. Wellman and Lagattuta (2004), focusing on the relationships between theory of mind, learning, and teaching, suggest that children's psychological explanations are central to formal school-based teaching and learning. They posit that psychological explanations are frequently required in schooling, providing 'an important platform for logical-explanatory reasoning'. Thus, encouraging children to provide explanations and to evaluate and comment on other's mathematical explanations is important, in order for them "to understand the explanations and reasons for various phenomena and procedures" (Wellman and Lagattuta, 2004: 492). In contrast, children's metacognitive awareness of their own creative thinking in the early years has not been widely researched.

B3.1.7 Teacher scaffolding and involvement

Notwithstanding the recognition that IBSE and CA both include attention to problem solving in exploratory contexts, in which questions, collaboration, motivation and reflection play a significant role, the efficacy of these approaches depend in large part on the teacher's role, scaffolding children's learning. **Scaffolding has been considered beneficial for young children fostering their independence as inquirers and problem-solvers** (Rittle-Johnson and Koedinger, 2005;

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Metz, 2004), their creativity as possibility thinkers (Cremin et al., 2006; Craft et al., 2012), their conceptual knowledge (Coltman, Petyaeva and Anghileri, 2002), and their strategies (Secada, Fuson and Hall, 1983), and meta-cognitive strategies (Aleven and Koedinger, 2002).

However, studies of scaffolding in varied contexts indicate the complexity of the issues involved in relation to the context and purposes of activities. For example, in a quasi-experimental study undertaken with pre-schoolers in a science museum, Bonawitz et al. (2011) investigated the implications of explicit instruction on exploratory play. It could be argued such instruction should scaffold learning and enrich their creativity, yet this research suggests that teaching children in this way constrains their exploration and discovery, since even the children not being explicitly taught in this context, extended their assumptions from overhearing adults' comments and demonstrations to other children, and adapted their behaviour accordingly. As a consequence, the researchers suggest that such "pedagogy promotes efficient learning but at a cost: children are less likely to perform potentially irrelevant actions, but also less likely to discover novel information." (2011: 322). Their work on the 'two-edged sword of pedagogy' has considerable implications for the project *Creative Little Scientists*, and suggests for example that **delaying instruction until the learner has had a chance to investigate and inquire on their own or with others could promote innovation and discovery**.

In the study the 'House of Little Scientists', already discussed, Kramer and Rabe-Kleberg (2011), in observing teachers and children during their work on a scientific problem, identified two types of teachers' behaviour which emerged naturally: 'ignoring' and 'integrating' interaction with children. The former behaviour involved teachers more or less ignoring the children's ideas and approaches; they tended to tell the children how to do the experiment 'in the correct way'. In contrast, the occasions on which teachers showed more 'integrating behaviours', they tried to incorporate the children's views and foster self-directed inquiry. However two distinct forms of children's reactions to their teachers' behaviour were noted: in the former when their ideas were 'ignored' the children worked together to try to find answers and 'crossed new frontiers' being open to new ideas/approaches, in the latter they sought to conform to the teachers guidance and exercised less agency and problem solving.

This issue of teacher positioning relates to a strategy noted earlier, that of standing back, which has been identified as a core pedagogic strategy nurturing possibility thinking (Cremin et al., 2006). What distinguishes this strategy is the position of the teachers, who prioritise stopping and observing, and listening and noticing the nature of the learner's engagement. By being 'one remove' yet highly attentive, the teachers, it is claimed, were able to notice any unusual or unexpected actions, behaviours or ideas suggested or enacted by the children. Whilst the teachers in the House of Little Scientists study, 'stood back' for other

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reasons, (often due to lack of assurance and scientific knowledge) the effect appears to have been the same- the young were able to take up positions both as decision-makers and agentic learners, utilising the time and space made available for them to explore and experiment. The work of other scholars also highlights the pedagogic practice of respecting children sufficiently to stand back from their endeavours in order to observe their interests, needs and direction of learning and then build upon this (Fawcett and Hay, 2004; Rinaldi, 2006; Tobin, Hayashi and Zhang, 2011). This suggests that **IBSE and CA to fostering creativity and problem solving requires professional restraint and well developed skills of close observation.** Hyvönen (2008) too highlights the role of teacher as 'allower', implying some degree of standing back and avoiding too much intervention, though she also mentions other roles: leader, afforder, coordinator, supporter, tutor, motivator and facilitator.

In articulating their theory of early developmental pedagogy, Samuelsson and Carlson (2008) argue that one of the main features is the teacher focusing the child's attention towards problems that arise. They suggest that at times the teacher is more fully and playfully involved as a fellow collaborator and provocateur. Drawing on the philosophy of Reggio Emilia, others such as Bancroft et al. (2008), and Craft et al. (2012) also highlight the significant role of provocations triggered by adults as supportive scaffolds. In the latter study, the teachers not only stood back from the learners but also at times played alongside them as partners. As such they were often present 'in the moment', and effectively combined observing with intervention (see Figure 2 which highlights both the features of possibility thinking and the attendant pedagogical strategies which nurture it. This connects to McWilliam's (2008) conception of the 'meddler in the middle' and involves the teachers in working alongside children with intense sensitivity as to appropriate interventions. This positioning of the teacher as a fellow artist or at least fellow collaborator engaged in co-authoring is in contrast to more traditional notions of power relationships in the classroom. Although in early years education the hierarchical model, more common in later primary and secondary education, is less prominent (Smidt, 2006), there is still scope for a closer examination of teachers positioning in IBSE and CA.

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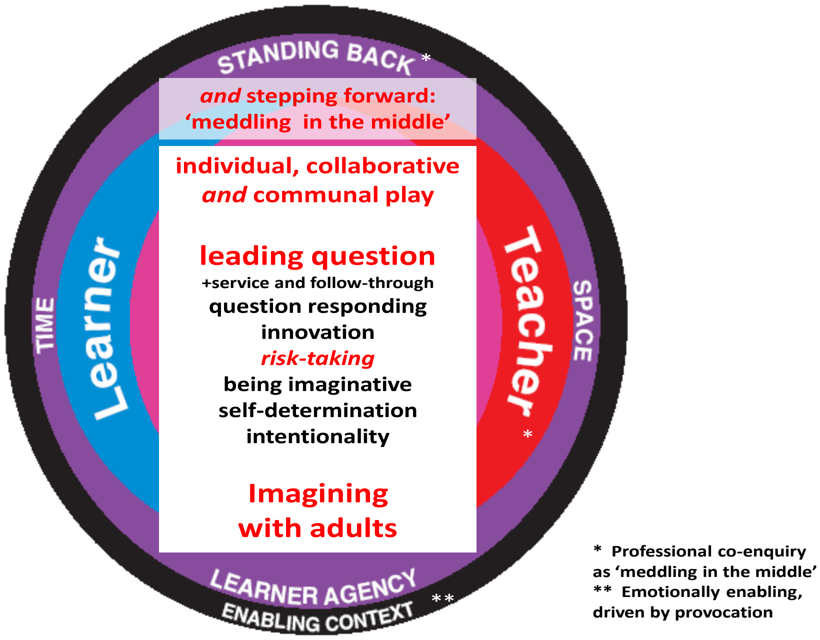

Figure 2: Pedagogy nurturing possibility thinking (Craft, MConnon and Matthews, 2012)

B3.1.8 Assessment for learning

The perspectives on teaching and learning discussed in this section of the conceptual framework have considerable implications for assessment. There is a central role for formative assessment in a responsive approach to teaching involving identifying and building on the skills attitudes, knowledge and understandings children bring to school; in supporting and encouraging children's active engagement in learning and fostering their awareness of their own thinking and progress. Harrison and Howard (2011) highlight the key roles of feedback, sharing criteria with learners, questioning and self assessment in promoting effective learning. The role of children in assessment is particularly significant when considering that evaluating ideas is an important learning process. This may include peer assessment as well as self assessment, thereby contributing to community aspects of the class.

In the early years there are also arguments that a more holistic approach to assessment is important, that takes account of children's attitudes and interaction with others and with the environment in thinking (e.g. Glauert, 2009b). Insights from recent research highlight the need to develop assessment approaches sensitive to the capabilities of young children (Robbins 2005) and to afford opportunities for children to express their ideas in different ways through for example speech, gestures or visualisations (Glauert 2009b). There is an important role for the project in exploring and developing assessment approaches and criteria to support science, mathematics and creativity in the early years. These are further discussed in section B4.1.

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B3.2 The challenge of developing IBSE and CA approaches

The challenge of achieving a balance between structure and freedom in early years educational settings should not be underestimated. The 'disciplined improvisation' (Sawyer, 2004) of creative teaching, which may also be a feature of IBSE, makes high demands on teachers who seek both to utilise routines in the context of wider curriculum structures/ requirements and to work flexibly and responsively in order to offer opportunities to build new knowledge and understanding. **Adopting a more dialogical pedagogical model in which the teacher orchestrates standing back with collaborative intervention in mathematics and science classrooms represents a significant challenge.**

In relation to constraining factors, the significance of teachers' dispositions and attitudes on task construction has been noted (Craft, Cremin, Burnard and Chappell, 2007). In this study, as the children grew older, the tasks offered were more tightly framed and overseen, influenced by the curriculum and external assessment; they afforded diminishing opportunities for agency, collaboration and exploration. Forrester and Hui (2007) also found that whilst pedagogy can enable creativity it can also form a barrier to it. Likewise in relation to inquiry approaches Kind and Kind (2007) suggest that teachers may frame students' investigations by providing apparently supportive formulae/recipes for success, restricting apparatus or offering strong guidance which leads children towards specific solutions. Some of the teachers who participated in the 'House of Little Scientist' programme, for example, whilst able to explain the idea of open inquiry, were not able to transfer this theoretical knowledge into praxis. Insecure in teaching science and afraid of losing control over the children's working process, they avoided any deviations in the problem solving contexts they set and provides limited space for children to solve their own problems or think their own ways forwards (Kramer and Rabe-Kleberg, 2011).

Additionally, depending on their views of inquiry and of children's capabilities, it has been shown that some teachers predominantly focus on gathering and analysing data and offer little space for child-led or child-initiated inquiries (Asay and Orgill, 2010). This may be due to multiple institutional policy contexts as well as other constraining factors. Thus evidence of teaching practices related to both IBSE and CA highlight the tension between structure and agency and in so doing link to the instrumentalist and romantic underpinnings examined earlier. Another potential challenge relates to teachers' knowledge of children's creativity and experiences of science and mathematics that they bring to school; this is not always credited or used in the classroom, indeed Dawson (2003) argues that teachers tend to underestimate young children's mathematical capabilities and make few connections between their everyday mathematics practices in the classroom.

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The pressure on teachers to deliver the given curriculum and in many countries to respond to the accountability agenda, undoubtedly reduces the space and time, autonomy and trust afforded young people as inquirers and creative thinkers, particularly after they move beyond the early years (Troman, Jeffrey and Raggl, 2007; Troman, 2008). This may mean that some teachers resort to what they perceive to be less demanding teaching approaches, both for themselves and their students (Minner, Levy and Century, 2010). Moreover, a lack of recognition of creativity and inquiry within policy documentation and the currently available tools for assessment of children's related learning may restrict pedagogic practice. Arguably IBSE and CA develop attitudes and understanding that are underrepresented in standard assessments.

Additionally, as a consequence of the relentless quest for higher standards and the pressure to ensure curriculum coverage, professionals may create pedagogic routines, boundaries and timetables which obscure the personal and affective dimensions of IBSE and CA**,** fostering 'a mind-set characterised more by compliance and conformity than curiosity and creativity' (Cremin, 2010:19). Such a mind-set may not only be adopted by teachers but also by younger learners, markedly reducing their sense of agency and possibility. Furthermore, as Hennessy (2003) observes some research suggests that evaluation, rewards, deadlines, surveillance and competition can destroy intrinsic motivation and reduce learners' creativity, and perhaps also their curiosity and orientation towards inquiry. Although where choice is given, she shows that intrinsic and extrinsic approaches to motivating creativity appear to have an 'additive' effect nurturing creativity even in contexts which are challenging to its development (Hennessy, 2003). In England also, as Jeffrey and Woods (2003) have shown, a constraining national agenda has prompted some professionals to respond with creativity and flexibility in order to retain their values and creative practice.

B3.3 Summary of teaching and learning approaches in science, mathematics and creativity in early years education

It is clear that IBSE and CA to education in the early years should not be seen in juxtaposition, but rather in dynamic relation. In relation to the benefits of these approaches, Kind and Kind (2007) argue, there has been relatively limited empirical work demonstrating the benefits of IBSE in terms of children's learning, this is arguably also the case in CA, where the impact of such approaches have not always been closely scrutinised. Arguably, more attention has been paid to the nature of the pedagogical strategies than the impact of these strategies on children's learning.

In relation to the synergies between IBSE and CA, it is suggested that the following features, to different degrees are common to both approaches:

- play and exploration
- motivation and affect

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- dialogue and collaboration
- questioning and curiosity
- problem solving and agency
- reflection and reasoning
- teacher scaffolding and involvement
- assessment for learning.

Though as noted, developing contexts for inquiry and exploration which foster creative learning and achieve a balance between intervention and collaboration, as well as standing back and learner agency, represents a considerable professional challenge.

B4. Assessment and Evaluation

While there has been increasing emphasis in recent years on assessment for children's learning as indicated in the previous section of this framework, there is also an impetus at national level to make comparisons between cohorts over time and space, as well as internationally. All children's learning has been affected by this. Within science and mathematics education, the evaluation of children's progress is high stakes, both for children themselves and as a reflection of the success of schools. Over time the focus and means of assessment is affected by the changing aims of science and mathematics education. Thus for example **the testing of children's scientific literacy has become a focus** (Carstensen, Lankes and Steffensky, 2011) **alongside mathematics and language literacy, and there are calls for greater investment in exploring how to achieve this** (Osborne and Dillon, 2008).

Whilst there is less of an effort toward seeking to assess creativity, this is an area of growing interest, as creativity and innovation are perceived as increasingly important globally. The EU has paid attention to the assessment of creativity since the 2009 European Year of Creativity and Innovation which included a conference on the measurement of creativity held in Brussels, later published by the Joint Research Centre, European Commission (Villalba, 2008, 2009). Hingel (2009) argued as part of this EU exploration of the potential for measuring creativity, that measures should be developed to provide evidence of progress over time. Clearly, assessment of any aspect of learning reflects the value placed on it in the education system. Assessing learning helps teachers to develop appropriate and differentiated learning activities for students as well as allowing for comparison. In addition, when passing tests is the focus, test scores rise (Harlen, 2005).

B4.1 Formative and summative approaches

The last decade, particularly in England, has seen an increased focus on assessment (Gipps, 1994; Black, 2001; Black and Wiliam, 2006) this frames the over-arching ways in which assessment is approached in early mathematics and science. Two purposes need to be distinguished:

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- *formative assessment* which directly informs learning and teaching (Black and Wiliam, 2003, 2009) and emphasises the trajectory of each learner; this is generally shared in the learning and teaching process thus may involve children themselves in self-assessment, peer-assessment and reflection and evaluation within a learning community, but not necessarily reported more widely,
- *summative assessment*, sometimes also framed as high stakes in itself (Taylor, Jones, Broadwell and Oppwal, 2008) which summarises performance at a particular point in time in order to compare children over time or to compare cohorts. This may be reported to parents or used for monitoring or accountability.

Attempting to meet both purposes in the classroom is complex, particularly when summative assessments or tests may need to be undertaken using context-free approaches, which can be a result of seeking to develop standardised approaches that allow comparison as acknowledged in B3.9. Calls have been made for the development of multimodal approaches to assessment in early mathematics and science activity (e.g. Glauert, 2009b) that attend to, for example, children's gestures, speech or visualisations, and digital technology offers increasingly holistic ways of capturing children's engagement. Similarly within creativity, efforts have been made in the last two decades toward understanding and assessing creativity as complex (Feldusen and Ban, 1995), involving multiple components (Amabile, 1983). In the context of the early years this has meant an emphasis on children's learning in context, close observation and documentation, sometimes from multiple perspectives (Rinaldi, 2006, Project Zero and Reggio Children, 2001).

Whilst formative assessment for learning is vital in helping diagnose appropriate next learning, there remains an emphasis in policy on the role of summative assessment for wider comparative purposes and its use for evaluation of performance at school, national and international levels. International comparisons in particular are driving national and European concerns to document and nurture economic competitiveness. This can be seen within schemes that seek to document the learning of older learners, for example in the IEA[2]'s Trends in International Mathematics and Science Study (TIMSS[3]) for grades 4 and 8 introduced in 1995 and the OECD[4]'s Programme for International Student Assessment (PISA) for fifteen year olds, introduced in 1997. Each of these large scale assessments systems provide comparative summative assessment information of older learners for educational policy making purposes and have rapidly gained international governmental support. TIMSS encompassed more than sixty countries in 2011. In the case of PISA, 74 countries were involved in the 2009 wave. Both produce summative data through specially administered tests.

[2] International Association for the Evaluation of Achievement
[3] TIMSS was linked with PIRLS (Progress in International Reading Literacy Study) in 2011
[4] Organization for Economic Cooperation and Development

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Whilst TIMSS focuses on mathematics and science, PISA offers an interesting blend. Since PISA sets out to measure knowledge and skills seen as vital to living as an effective 21st century citizen, its focus is not only on the domains of knowledge seen as vital in participating countries, but also on appropriate skills (Schleicher and Tamassia, 2003). Thus since 2003, problem-solving has been assessed within the context of using mathematics and science knowledge to solve everyday problems as part of the PISA assessment framework.

The inclusion of problem solving highlights increasing concern within Europe to find ways of measuring complex skills in relation to traditional domains of knowledge, and work undertaken by OECD has also recently focused on the development of a composite indicator for creativity (reported by Saltelli and Villalba, 2008). There is a clear recognition of the need to move beyond the pure acquisition of knowledge in the ways that education systems evolve (Stewart, 2011). What is not yet in place is a way of assessing creativity in the context of other subjects such as mathematics and science, and it is not clear how this might develop; the European Commission's Joint Research Centre probe was sceptical about the cost and effectiveness of using PISA or another international test (Villalba, 2008:33). It may also be undesirable to do so, with the danger of straight-jacketing creative activity nevertheless it is clear that there is international interest in finding ways to assess creativity.

As the previous discussion has highlighted, **internationally the tension between formative and summative assessment in relation to assessment for learning vs assessment for comparative purposes, is evident**. Summative assessment is being used as a powerful tool for policy makers to know not only how individual children are doing but also how cohorts of children are doing, and to compare countries' performance. Arguably, these large scale surveys are used to aid policy development, ensure preparation for adult life and influence national growth rather than formatively guide individual progress or development. It is possible, as Saltelli and Villalba (2008) argue, that measurement of creativity is vital in that the comparison between countries' performances may provide insight into how key variables interact at a wider societal and economic level – for example, how the rise of the 'creative class' might relate to economic growth. They argue that a European creativity indicator should be developed – a challenge taken up by Kern and Runge (2008) who grouped thirty-two indicators for creativity which focus on social and economic factors, although the establishment of an intercultural notion of creativity is not yet under way (Hingel, 2009).

It should be noted that **the summative use of assessment for comparative purposes is highly economically-focused**, seeing creativity as a means to the ends of economic prosperity; an assumption that can be challenged as discussed earlier (Gibson, 2005). Not only that, but as Looney (2009) notes, writing for OECD, there is a tension between high-stakes summative assessment and innovation. Looney argues that it

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has been possible to reconcile such testing through a range of strategies encompassing performance measurements for students and schools, re-aligning standards and assessment and integrating assessment and learning and perhaps most importantly through staff taking appropriate risks to foster creativity and innovation in their institutions.

Alongside such summative use of assessment, is an emphasis in schools on using assessment to enable learning, particularly in the early years as discussed above. The close observation and documenting of children's early learning facilitates appropriate interventions, provocations and teaching that promote meaning-making. In assessing creativity, to the extent that this occurs, it too is likely to be contextualised in children's play and imaginative engagement. The importance of context highlights a further distinction beyond formative and summative purposes of assessment. In the assessment of creativity there are two main approaches: psychometric and componential.

B4.2 Psychometric and componential assessment of creativity

Psychometric assessment tends to offer summative assessment and sees creativity as generalized, objectifiable and measurable, adopts a focus on product rather than process, sites the locus of judgement outside of the creator, is focused on the individual's performance and embraces the use of decontextualized standardised tests enabling judgements and comparisons to be made across time and across populations. It stems from early cognitive approaches to creativity (e.g. Guildford, 1950), viewing creativity as innate and testable. Seminal work in the USA by Torrance led to development of standardised tests; the Torrance Tests of Creative Thinking (TTCT) (Torrance, 1966, 1968, 1974, 2008). As noted earlier these encompass five sub-scales for fluency, originality, elaboration, abstractness of title and resistance to premature closure. Although not the only creativity tests, TTCT are widely used (Kim, 2006a), translated into 35 different languages. Another widely used test is EPOC, developed by Lubart et al. (2011). This measures 'Creative Abilities of Children' in two areas (verbal and graphical, divergent and convergent thinking). EPOC is translated into Arabic, Turkish, German, and English. Other translations are being investigated following the demands of researchers (Dutch, Greek, Russian, Portuguese, Italian).

However, psychometric tests of creativity lack sensitivity to factors such as affect and context, culture, language and gender, and overly focus on individual behaviours and product (Craft and Clack, 2008; Kim, 2006a, 2006b; Strom and Strom, 2011). A growing concern with separating the act of assessment from context, has led to a second approach to the assessment of creativity, i.e. 'componential assessment'.

Componential assessment, generally used formatively, sees creativity as contextualised, as a result it may offer insight into change over time for individuals or groups. Whilst it adopts a focus on the product it can also be used to evaluate the process and can be adapted for use with

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individuals and pairs or groups. It sites the locus of judgement with the field of judges which may include the creator/s. Componential assessment recognises the complexity of creativity (Feldusen and Ban, 1995), involving interlinked processes of decision making, metacognition and critical thinking in a wider personal and social context, as well as involving both the product and processes of creativity. The term denotes the recognition of multiple 'components' in creativity and attempts to assess creativity more holistically, and in-context. US researcher Amabile (1983a, 1983b, 1996, 1997, 1998) has been influential in developing the componential approach. In assessing creativity using multiple components, she developed the Consensual Assessment Technique (CAT), which involves shared expertise around criteria derived by consensus, by judges of creativity. Judges may include the producer (in the case of schools, the children themselves). There are many versions of Amabile's CAT, some formally identified as such and others reflecting aspects of it, although some, for example the Reggio Emilia pre-schools in Northern Italy (Rinaldi, 2006) or the 5x5x5=creativity initiative in England (Bancroft et al., 2008) use their own version of a componential approach in the interpretation of documentation which evidences each child's creative engagement and development and involves artists, teachers, children and to a degree parents. Similarly an emergent approach (APIC: Assessment of Progression in Creativity) being developed by Creativity, Culture and Education in England focuses on how teachers, children and others can evaluate the dispositions associated with creativity.

Learning in the early years leans, at least in Western contexts, toward attending to the process of learning as well as its outcome; a componential approach. Whilst the term 'componential' may be more familiar in a creativity context than a mathematics or science context, it is suggested to be a useful one across the intersection of the three areas in *Creative Little Scientists*. Efforts to develop assessment approaches which encompass process and outcome, reflect growing concern to capture learning for formative purposes (Project Zero and Reggio Children, 2001), and in recognising multiple forms of creativity (Han and Marvin, 2002; Besançon, Guignard and Lubart, 2006) which offer the opportunity for negotiating values and judgements. The discursive and negotiative style of the componential approach means that culture and the emotional climate which play an important part in creativity (Davis, 2009) can be considered.

In practice, the componential approach has tended to be developed in European contexts whereas North American and far Eastern contexts are more likely to use a psychometric approach with older learners, although in the North American early years classroom there remains a concern for the learner and their trajectory (e.g. Cox Suarez, 2006; Donovan and Sutter, 2004; Paley, 2001). In relation to the early years, it is the context-sensitive, child-centred, componential approaches that are most commonly in use, particularly in Europe and in parts of North America,

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influenced by the approach to close observation and documentation of children's learning developed by Reggio Emilia and others in dialogue with these approaches (Bancroft et al., 2008; Krechevsky and Stork, 2000; Krechevsky et al., 2002).

B4.3 Summary of approaches to assessment of mathematics, science and creativity in early years education

Given the European emphasis on developing ways of monitoring creativity in children and young people, empirical work in *Creative Little Scientists* may wish to consider what this may look like in early science and mathematics within the age ranges researched and in the respective national contexts. In addition, in assessing and evaluating mathematics and science, the project may wish to examine:

- The formative and summative ways in which assessment is used in science and mathematics in the early years;
- The involvement of children in assessment processes;
- The development of multimodal approaches to assessment sensitive to young children's capabilities and learning processes;
- The role of context and authenticity of assessment tasks;
- Broadening the assessment and evaluation of science and mathematics through employing a creativity lens in the context of inquiry;
- The person/people considered to be responsible for making judgements in assessing creativity in science and mathematics.

B5. Conclusion: Synergies and Differences Between Science Mathematics and Creativity in the Early Years

There are multiple synergies and differences between science, mathematics and creativity in early years education: some relate to common drivers, others to the nature of professional, research and policy conceptualisations, as well as pedagogy, practice and assessment. These represent both opportunities and challenges for the project. In commenting on links between creativity and inventive problem solving, DeHaan observes that

> *"evidence suggests that instruction to support the development of creativity requires inquiry-based teaching that includes explicit strategies to promote cognitive flexibility. Students need to be repeatedly reminded and shown how to be creative, to integrate material across subject areas, to question their own assumptions, and to imagine other viewpoints and possibilities"*
>
> (DeHaan, 2009: 172).

He goes on to call for research in this area. The project *Creative Little Scientists* responds to this call. It seeks to move beyond the documentation of differences and similarities across the related research literatures of mathematics, science and creativity, to document teachers'

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perceptions and observe their pedagogic practices and use of assessment in the early years.

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C. ISSUES ARISING FROM REVIEW OF TEACHER EDUCATION

The review of teacher education focused on both initial teacher education (ITE) and continuing professional development (CPD) for teachers. ETUCE (2008) identified the improvement of the education of teachers and trainers as one of the key objectives to improve the overall quality of the education and training systems in the EU. Some key policy steps were suggested by the Commission:

- 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 multi cultural settings;
- to help young children to acquire the key competences.

In addition teachers should be encouraged to:

- engage in classroom-based research, and
- reflect on their own practice in a systematic way.

More recently, in 2011, the council of the European Union stated that education and training are key factors to achieve the ‘Europe 2020’ goals, including several which are particularly relevant to *Creative Little Scientists*:

- ensure a sufficient supply of science, mathematics and engineering graduates;
- equip people with basic skills and the motivation and capacity to learn;
- foster the development of transversal competences including those that enable the use of modern digital technologies; and
- encourage creativity innovation and entrepreneurship.

Within this remit the aim is to improve Europe’s innovative capacity, and here too strong links have been identified between education, research and innovation. In short a Europe of knowledge, creativity and innovation can be achieved through education and training systems that promote a creative, innovative and entrepreneurial mindset amongst pupils, trainees, students, teachers and researchers.

C1. Initial Teacher Education

Initial teacher education (ITE) refers to the professional preparation organised by teacher education institutions in order to obtain the certificate to teach in preschool and primary school contexts, the goal being the education of teachers. Despite this common goal, a review of the literature regarding initial teacher education revealed distinct differences in approaches to ITE among the sample countries; however, whilst approaches might differ, issues surrounding ITE were comparable between countries in the EU, such as supporting teachers’ identity,

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relating theory and practice, achieving the balance between subject and pedagogical studies, preparing the teachers to meet modern pupils' needs and raising the status of teachers (Snoek and Zogla, 2009).

C1.1 University based and school based ITE

Historically, ITE has been dominated by the academic tradition, also known as the 'application of theory' approach (Zeichner, 2010; Korthagen, 2010; Schepens et al., 2009). In this approach teacher education institutions provide the knowledge through various, often fragmented courses, whilst schools provide the settings for students to apply the theory to practice. However, research has identified that such programmes have often been ineffective in preparing student teachers adequately (Korthagen and Kessels, 1999). This has resulted in **a shift towards a more school based approach to ITE in many countries, with teacher education arranged in partnership between schools and higher education institutions**.

Zeichner (2010) achieved this by bringing together school and university-based teacher educators, combining practitioner and academic knowledge to enhance the learning of prospective teachers through 'hybrid spaces'. In this model partnerships involve bringing teachers into campus based teacher education, bringing a portion or all of a campus method course into schools and connecting it to the practices and expertise of the teachers in the school, creating hybrid teacher educators.

Bezzina, Lorist and Van Velzen (2006) identified a similar model of collaborative school-based education in which schools and higher education institutes work together through professional development schools (PDS). Here student teachers are educated whilst at the same time faculty and school staff can collaborate on research and development. Snoek, Uzerli and Schratz (2008) noted the benefits of this as providing an establishment which takes into account the specific needs of both its participants and on the local needs and conditions. As well as providing ITE, this model also contributed to the professional development of the school, curriculum innovation and shared research.

The review of literature, then, identified various challenges and significant differences in terms of ITE between the European countries in the study.

The issue of whether provision should take place in university or school based settings or some form of combination, impacts upon the characteristics of the course in terms of theory or practice. Whilst historically ITE has taken place predominantly in a University based setting with short periods of school based experience, there has in recent years been a definite shift towards a more school based form of ITE, with concentration around the practical rather than the theoretical.

C1.2 Theory and Practice

A tension identified between ITE providers is the emphasis on theory or practice and which should come first. Korthagen et al. (2001) developed

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the so-called 'realistic-approach' to teacher education which takes into account the causes of the theory and practice divide, the emphasis here being on the student teachers' experience, concerns and existing gestalts. This new pedagogy is focused on helping student teachers to become good teachers who understand themselves as teachers engaged in personal and professional change. This approach starts from concrete practical problems and concerns experienced by student teachers in real contexts. It also promotes 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. This is a view supported by Bell (2004) with a reflective practitioner model of teaching, where theories are continually developed through both practice and research. However, in a later study, Korthagen (2010) expressed concern that the change in focus from 'theory first, practice later' to 'practice first, theory later', in which the balance seemed to shift completely from an emphasis on theory to reliance on practical experience, did not always guarantee success.

In their review, Wideen et al. (1998) argue that successful teacher education programmes should not merely change but build upon student teachers' beliefs 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 programmes characterized by the integration of practical experiences and theoretical study.

In Europe two dominant models exist to link theory and practice: the concurrent model and the consecutive model. In the concurrent model, 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.

C1.2.1 Reflective Practitioners

In several studies, the use of reflective journals is mentioned as an interesting tool to support the reflective process (Kenny, 2009; Kenny, 2010; Gunning and Mensah, 2010; Plevyak, 2007; Plonckzak, 2010). Korthagen et al.'s (2001) realistic programme has a strongly integrated character. Two types of integration are involved: integration of theory and practice and integration of several disciplines. When initial teacher students 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

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monitor and reflect on the effectiveness of the improvements he makes in practice. According to 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 a stance of inquiry, critically identifying and rethinking taken-for-granted practices and principles (Levine, 2011).

Philosophy statements are utilized by Gilbert (2009) as reflection tools to facilitate ITE 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 ITE science education. Video cases and reflection tasks were used by Abell, Bryan and Anderson (1998) to stimulate ITE 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.

C1.3 Level of Qualifications for Teachers

The recommendation from the EU commission is that teacher education programmes should be available at Master and Doctorate levels, as well as Bachelor cycles of higher education. Whilst in participating European countries teacher education programmes have largely adopted the bachelor-master framework as recommended by the European commission there are only a few countries which have all teachers' qualification at masters level (e.g. Portugal, France, Finland), although a similar model is currently under discussion in Malta and Flanders.

In most EU countries preparation for early childhood education also takes place at tertiary level. In Belgium, France, Cyprus, Portugal and the UK teacher education for early childhood education is similar to study for teaching at primary level. Malta is an exception as kindergarten teachers are usually BTEC National Diploma Graduates in Care; however by 2015 policy is that all teachers, even in the age range of 3-5 years, will have a degree.

Many countries studied by ETUCE (2008) placed specific emphasis on early childhood education, and the importance of appropriately educated pre-school teachers in providing high quality pre-school education, with many policy makers requiring teachers to have at least a Bachelor's degree. However, Early et al. (2007) suggested that focussing solely on education is not sufficient to improve classroom quality or maximise children's academic gains, and recommended instead policy should also focus on a broad range of professional development activities specifically with regards to teachers' interactions with children.

It would be dangerous to assume that a higher qualification results in a better quality of teaching, since there are a range of other factors which must also be taken into consideration such as

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the entry qualifications of ITE teachers, the quality of education providers and the teacher educator, and curriculum coverage.

C1.4 Entry Qualifications for Prospective Teachers

Dr Sarah Farquhar of the Early Childhood Education Network (cited in Tarr, 2006) stated, "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 teachers' personal characteristic matters". In teaching young children practitioners have to bring together the educational and care functions in order to enhance learning.

All of the countries participating in *Creative Little Scientists* (CLS) require students applying for teacher education to demonstrate a sufficient level of academic ability as pertinent to that country's examination processes, and in some instances prospective students must also complete entrance exams or skills test analysis as part of the selection process. However, it was not always clear whether a specific level of study in science and mathematics was part of the entry requirements. Only four countries (England, Wales, Finland and Romania) made reference to a specific interview process, whilst only England and Wales stipulated that the candidate should have completed some voluntary or paid work in school prior to entry onto the course to gain an understanding of the teacher's role. The focus on the result driven processes would suggest that ITE teachers are chosen on academic merits rather than the propensity to the role of teacher, although it should also be borne in mind that individual institutions may well have their own recruitment processes that could indeed encapsulate other aspects of the role.

C1.5 ITE competences / standards

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, used in Germany and the UK, teachers' skills and competences in teacher education have been defined in a fairly centralised way at national level. 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

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acquire during teacher educators courses. In several of the participating countries the second model is applied: Belgium, France, Portugal, Romania.

- 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.

Competences differ in number between countries, although it is reassuring to see that many common threads can be seen, particularly regarding professional issues, such as planning for diversity, working as part of a team, collaborative practice and personal development. Competences directly related to teaching involve planning, delivery and assessment in addition to good behaviour management skills, and whilst the areas of science and mathematics are not referred to directly, good subject and curriculum knowledge are made direct reference to in the majority of countries.

C1.6 ITE Curriculum

Just as there are differences in the level of national intervention in determining teacher competences, a study into the design of ITE curriculum identified two basic models for curriculum design in ITT institutions (University of Jyväskylä, 2009). In 24 countries in the study national documents, laws and regulations provided general guidelines and frameworks on how teacher education has to be organised, although the institutions designed the teacher education curricula independently. In Greece, Luxembourg and Malta institutions are quite independent and define the structure and content of the curriculum autonomously. This means that both **across and within countries the curricula vary considerably**. However, there are common themes:

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

(European Commission, 2007)

A European Commission report (2011a) identified that 'knowing and being able to teach the official mathematics/science curriculum' is the most important competence emphasised during the initial education of teachers of science / mathematics. Specific reference to science education varies between countries, and the research identified that this

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was most prominent where countries had a strategic framework for the promotion of science (Germany, Spain France, Ireland, the Netherlands. Austria, UK and Norway). In Malta, a strategy for mathematics, science and technology is currently developed (European Commission, 2011a). In these cases the frameworks make some reference to the improvement of science teacher education.

Inquiry based science education (IBSE) is not referred to directly through legislation in the participating European countries, although there is a suggestion of this in the documentation, for example;

- Greece – IBSE can be seen through the didactics of the science module;
- Malta – IBSE is promoted in the new policy document 'vision for science education in Malta', and is present in training courses focussing on science as part of Bachelor of Education courses in primary and early years.

In Romania there are projects to promote IBSE at both the elementary and middle school levels, although this is not part of the official policy.

C1.7 Teacher educators

As identified by Coonen (1978) **the 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 co-operating teachers is often overlooked** (Koster and Korthagen, 2001). Snoek et al. (2010) found no specific information about the current status of the teacher educator profession, and where mention was made this was in respect of concerns regarding their quality. They recommended that more should be done by policy makers, researchers and teacher educators to develop the induction and further development of teacher educators. In the *Creative Little Scientists* countries teacher educators vary from being required to have Qualified Teacher Status as a minimum requirement in England and Wales, to having a relevant PhD but no specific school experience in Greece.

Here too, lies a tension between whether the higher qualification or school based experience is of most value. It would be interesting to see whether this bears any resemblance to a country's approach in terms of a theory or practice based model of initial teacher education (ITE). The varied requirements for teacher educators mean that some could have doctoral level science but little or no experience in school, while others may have teaching experience but no science at degree level. This would have implications on both the content and nature of any continuing professional development (CPD) resulting from the *Creative Little Scientists* project.

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C1.8 School mentors

It should not be overlooked that **teacher educators also include those professionals in school based settings who are acting as mentors to students on placement**. Indeed it could be argued that every teacher who comes into contact with a trainee or inexperienced teacher is a 'teacher educator', influencing through attitudes as well as expertise. This is particularly significant given the recent emphasis on field experience and the increased amount of teaching practice in teacher education curricula (OECD, 2005). The review revealed little, however, in terms of how professionals within schools are monitored to ensure that high standards are observed by ITE teachers in settings. Many countries referred to the importance of mentors in school based settings, but again there was little evidence of how mentors are chosen or themselves monitored. This could well prove to be an issue if systems for monitoring field experiences are not sufficiently rigorous.

Several studies have identified the importance of supportive schools and noted problems which result when the school mentor's approach conflicts with student's approach. Leonard et al. (2009) stressed the importance of a supportive environment, particularly when students are experimenting with inquiry based practice, as did Kenny (2009, 2010) who recognised that the ongoing support of the teacher educator and colleague teacher was a vital component of the learning journey. Leonard et al. (2009) identified that students in a progressive classroom (relational conceptual focus) were far more at ease in using a variety of approaches including open questions, problem solving, pupil challenges and explanation. These students made more progress than students in traditional classrooms with an instrumental or procedural focus. In these classroom students had narrow objectives and tended to dismiss pupil responses that did not conform to the learning objectives. Goulding et al. (2002) also saw the problem of conflicting approaches between student teachers (relational) and teacher-mentors (instrumental), which would suggest a tension between what the student teachers were learning in the ITE provider and what they were being encouraged or allowed to do on placements.

C1.9 Summary of initial teacher education

Teacher education takes place through a variety of models, with varying balances of HE and school-based learning. **All ITE includes school practice but the balance between theory and practice varies considerably, along with the order in which these are developed (both concurrent and consecutive models)**. ITE takes place at different levels, mostly bachelor's and master's, while the qualifications of teacher educators ranges from bachelor's to doctorate with varying requirements for school experience. Academic entry requirements are in place for prospective ITE students but the level of mathematics and science within these varies. In some countries personal characteristics are also considered. In some countries the structure of ITE is heavily

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influenced by national teaching standards or competences but there is greater freedom for individual institutions in determining the actual curriculum. This makes it harder to identify what science and mathematics are taught in ITE and the role of IBSE within this. Each of these factors has implications for the project.

Within the *Creative Little Scientists* countries there are different models of partnership between schools and higher educational (HE) institutions. For example, Finland uses university practice schools for several placements, while other countries have varied amounts and types of placements in state schools. When planning any ITE interventions it will be necessary to know what aspects take place in the HE institution and which in schools and the amount of collaboration between these. Another consideration is whether both partners view ITE as an opportunity for research, professional development and curriculum innovation for both the HE institution and the school. It would also be relevant to consider how the different forms of ITE provision impact on the quality of early career teachers and their capacity to teach mathematics and science creatively.

Within the different models of ITE there are different balances to theory and practice and different approaches to developing these. There are examples of both the concurrent model (e.g. England) and the consecutive model (e.g. Germany) in the *Creative Little Scientists* countries. In both models it would be important to know if theory and/or practice were seen to be the exclusive domain of HE or school or whether both partners are involved in both. What will the balance of theory and practice be in any *Creative Little Scientists* interventions? How would an intervention work in both concurrent and consecutive models? We may also need to consider different levels of theoretical engagement since the early years teachers' qualifications will range from BTEC in Malta to Master's level in France, Finland and Portugal.

Subject knowledge appears to be related to confidence in teaching these subjects so it would be relevant to check the science and mathematics qualifications needed for entry to teacher education. This could also be compared to the curriculum that the teacher students are taught during ITE. It would be interesting to compare the personal characteristics considered in interviews to the personal characteristics identified as being relevant to creativity.

A consideration is whether approaches used by *Creative Little Scientists* would be compatible with the teaching competences required in the various countries. There is evidence in the Comparative Education review that aspects which are not directly related to the required standards are not being included in English ITE programmes. Therefore if the programme did not match the existing standards it might be difficult to encourage ITE courses to use it. **IBSE is an important concept underlying *Creative Little Scientists* but there was little explicit mention of this in ITE**. The lack of IBSE in legislation and

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documentation may indicate that this is not perceived as an important approach in ITE. However, it may result simply from the fact that ITE institutions have autonomy in determining their curriculum. Therefore it would be necessary to study the documentation of individual institutions to determine the extent that IBSE is promoted in ITE.

The difficulties encountered with conflicts between school and ITE approaches, such as with IBSE, suggest that the processes by which school based placements are selected and the monitoring of practices within should receive more consideration. The literature review for science and mathematics highlighted the differences between relational and instrumental approaches and the impact these had on learning. Therefore it may be relevant to raise the issue of relational and instrumental approaches in the teacher questionnaires, in the selection of schools and in the observations.

C2. Continuing Professional Development

The continuing professional development (CPD) of teachers has become the subject of increasing focus in recent years, and the council of the European Union clearly stated its intentions regarding the investment of people, seeing education and training as a major tool for implementing their strategic goal, "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).

C.2.1 CPD requirements

European Commission (2009a) identified that CPD was among the professional duties in over half of all European countries, including non-member states, yet, as can be seen in the table below, the application of CPD is somewhat inconsistent.

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Country/ies	Approach to CPD
France, the Netherlands, Sweden, Iceland, Norway	CPD is a professional duty but participation in it is optional
Spain, Luxembourg, Poland, Portugal, Slovenia and Slovakia	CPD is optional but linked to career advancement and salary increase
Greece	Widespread initiative on CPD called the 'Major Professional Development Programme' running from June 2011 to the end of 2013 – aims to promote the values and guidance of the emerging curriculum so that the vision of the 'New School' presented by the Ministry of Education is implemented into practice – estimated over 150,000 teachers will participate
Finland	CPD training available sponsored by National Board of Education. Stipulates that teachers have to complete 4 days per year but can choose content and ways of doing it
England	Seen as professional duty but no clear check of completion. There is a range of providers for CPD, including private consultants, local authorities and national programmes. In the 2000s there were national CPD programmes related to the introduction of the National Numeracy Strategy. Currently there is a national programme for mathematics specialist teachers (MaST) which is at Master's level. In science there is a national programme of Science Learning Centres that offer CPD for teachers and technicians.
Wales	Early Professional Development – 2 year programme following induction year
Germany	Lower-level school supervisory authorities responsible for CPD training. Central institutions also exist e.g. State Academy, Institute for Educational Progress, Academic Institute for CPD teacher training
Romania	Updating and development of educational personnel, including acquiring new competences, as function of the requirement of the educational plan and the educational curriculum – tuned to the educational structures and processes changes. Centre for Science Education and Training – 2 accredited courses on inquiry-based science education. Institute for Educational Sciences offering short CPD courses for preschool and primary school teachers

Table 1: Approach to CPD in European countries summarising European Commission (2009a)

C2.2 CPD building on existing skills and knowledge

In order for planned programmes of CPD to be effective **it is important to use the knowledge of the curriculum and assessment of the CPD teacher as a starting point**, in order to establish how they view existing practices (Timperley, 2006). In the same way that teachers would plan for diversity in the classroom so CPD should account for the different starting points of participants, and professional learning needs should arise from the context specific demands on what and how they teach. It should be expected that CPD teachers will demonstrate diverse understandings and assumptions of how pupils learn, and tensions will exist between entrenched ideas and new ideas and approaches – good CPD should break down these barriers. Davison and Suurtamm (2003) saw effective professional development in mathematics as one which values teachers' prior knowledge; builds mathematical understanding and confidence with mathematics; shares and promotes effective instructional and assessment strategies; connects with student learning, the

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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.

C2.3 Models of CPD

There are several models of CPD. **Much CPD comes from forming effective collaborative learning communities**. Zhang et al. (2010) investigated how to use science talks to promote student learning. The CPD 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 ITE primary teacher and a CPD colleague, to teach science in the colleague teachers' classroom with the support of a teacher educator. In this article, it was well documented that pedagogical knowledge is enhanced with sustained guided and mentored practice in real teaching settings. Also the work of Goebel et al. (2009) served 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.

Professional development which is firmly set within a setting should not be overlooked, and many of the studies emphasized the effectiveness of the Professional Learning Community (Schollaert, 2011). This builds on Wenger's Communities of Practice (2006) as groups of people who share a concern or passion for something they do, and learn how to do it better as they interact regularly. In CPD terms this may involve colleagues working together, observing lessons and giving and receiving feedback, co-planning, sharing of resources, mentoring, conducting action research and assessing together. Through this colleagues may learn from one another, guided by a more experienced other i.e. the lead professional. This collaborative learning culture can offer CPD opportunities through structured and informal interaction, although discussion should where possible be guided by a more knowledgeable other. In the same vein, whilst on-site professional development may allow for a tailor made context specific approach to CPD there is also the need for it to connect with a larger vision or initiative, otherwise there is a danger that processes could remain inward looking and necessary changes fail to be made. Peer support may be one way of addressing this, in which networking across and within schools can offer different levels of support, such as social, emotional and professional.

A more traditional approach of CPD would be through external support, where external experts introduce new and innovative ideas and act as a critical friend in regards to schools' current

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practices. 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). 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 towards application in classroom (Clift and Brady, 2005; Risko et al., 2008).

Collaboration between CPD teachers is also seen as valuable where participant are asked to plan, develop and deliver diverse kinds of educational resources, allowing for opportunities for CPD teachers to discuss their attitudes and abilities with one another. In support of this is the work of George and Lubben (2002) who found that science teachers were empowered by face-to-face workshop sessions in which they developed their own materials. Levine (2011) and Timperley (2006) noted that teachers should engage in 'deprivatised' practice in order to create a resource that promotes individual reflection and group learning. Jui-Chen and Hung-Jen (2010), Kenny (2010) and Appleton and Kind (2002) all suggest that more attention should be placed on the role of CPD teachers planning and transforming curriculum materials for classroom instruction. According to Frisch (2010) the role of the teacher educator is as much to support and scaffold the student, and guidance should be available to help students adapt curriculum materials.

The emergence of ICT based support has resulted in computer-supported collaborative learning (CSCL) in which resources and experience can be shared between settings. To illustrate, results from Dalgarno and Colgan (2007) showed that elementary mathematics teachers viewed the technology-facilitated sharing and communicating Connect-ME community as valued support. Referring to the perspectives of the teachers participating in the Connect-Me educational programme, virtual learning platforms and social media are conceptualized as enablers for the collegial sharing of self-directed, multi-purposed, convenient, and sustainable support. So far, the potential of ICT to enable educational change towards a creative school environment is far from fully exploited. However, CPD could draw upon examples of ICT being used in ITE to develop reflective practice.

C2.4 Summary of approaches to CPD

Although there appears to be a common expectation for teachers to participate in CPD it is not clear how much this professional duty is fulfilled. Similar to ITE there is considerable variation in the level of CPD on offer and the types of organisations that provide this. Further examination of the systems for CPD is indicated.

There is a range of strategies for delivering CPD, and these should be responsive to the specific needs of the participants and context, in

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addition to responding to the wider needs of the field of education in general. CPD should not be something imposed on CPD teachers; rather it should be a collaborative process which involves the teachers themselves in its planning and implementation. Some of the aspects which need to be considered include the level of participants' science and mathematics knowledge, as well as their pedagogical knowledge and experience.

C3. Issues for Teacher Education in Science and Mathematics

Although ITE and CPD have been discussed separately in the previous sections there are many issues which are common to both of them – unsurprising since one leads in theory seamlessly to the other. Issues in common across ITE and CPD include attitudes towards science and mathematics, subject and pedagogical knowledge and the role of creativity.

C3.1 Attitudes towards science and mathematics

The beliefs and attitudes of teachers towards mathematics and science are significant, since they are key to the way in which they are likely to teach the disciplines, which in turn will influence the beliefs and attitudes of the pupils which they teach (Zacharos et al., 2007; Downing and Filer, 1999; Yimaz-Tuzin, 2007). Howes (2002) suggested that through research student teachers' skills, attitudes and beliefs can be identified which in turn might influence the teaching practices of teacher educators.

There is strong evidence for an increased focus on science education in ITE, particularly given the different attitudes which ITE teachers displayed towards science as identified in this research. Science appears to evoke some strong emotions with Bleicher (2009) identifying four distinct categories within a group of ITE elementary school teachers: fearful, disinterested, successful and enthusiastic. In this study the categories increased differently in science content knowledge, science teaching, self-efficacy and confidence to learn science. It was identified that fearful teachers were less confident and showed less attainment in content knowledge than the other categories whilst disinterested students showed fewer gains in content knowledge – this would surely impact on a ITE teachers' capacity to teach science effectively until these issues were resolved. Since both Loughlan (2008) and Downing and Filer (2009) observed that ITE teachers views of science are frequently influenced by their own experiences of science education, particularly the influence of their own teachers, there remains a strong argument for such a negative cycle to be reversed through better science education for ITE teachers.

In relation to science, a number of the studies focus on ITE teachers' understanding of the nature of science. Akerson, Morrison and McDuffie (2005) used a reflective science method course to improve and retain new views of the nature of science. They suggest a combination of

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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.

Answering the question what is the best way to assist elementary science teachers through CPD programmes, the studies of Klein (2001) and Cheng (2001) revealed that elementary science teachers need guidelines for (1) strategies for using hands-on activities, and (2) questioning skills 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.

Sundberg and Ottander (2008) suggested that it takes one full year of exposure to activities before a change in attitude can be seen. However, Yilmaz-Tuzin (2007) noted an increased confidence amongst elementary teachers following participation in science methods and content courses, whilst Ucar and Sanalan (2011) saw an increase in students' SVAS (students views about science) scores in programmes with higher science methods course hours. Whilst this may not immediately impact on teaching outcomes, the increase in self-efficacy must in some way go towards increasing the students confidence to teach.

A similar picture emerged in mathematics where several researchers identified a negative attitude towards mathematics and some anxiety towards the teaching of it (Zacharos et al., 2007; Brady and Bowd, 2005; Isiksal, 2009). Brady and Bowd (2005) noticed that anxiety associated with teaching mathematics can be described as a cyclical phenomenon stating that, "the negative experiences with formal mathematics instruction led many participants to discontinue their study of the subject, or discouraged them from pursuing formal mathematics instruction beyond that which was necessary to fulfil high school graduation or university 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 student" (2005:45).

Vacc and Bright (1999) revealed elementary school teachers' beliefs about teaching and learning mathematics can be changed significantly using Cognitive Guided Instruction[5], an approach correlated with problem-based learning, during a mathematics method course. However they noticed that the student teachers were unable to apply CGI in their teaching.

[5] In CGI classrooms students spend most of their class time solving various problems by creating their own solutions instead of following a set of procedures provided by an outside source (teacher or textbook).

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It should then be the remit of teacher educators to address some of the issues identified here through curriculum design and field experiences. Firstly the negative attitudes towards the subjects need to be addressed, so to break the cycle as identified by Brady and Bowd (2005), a view supported by Brigido et al. (2010), who suggested a study of emotions in the context of initial teacher education, and Bleicher (2009) who advised the development of different instructional interventions to prepare all ITE teachers even the fearful ones.

C3.2 Subject knowledge and pedagogical knowledge

Garbett (2003) identified **the problem of inadequate science content knowledge as a key issue amongst elementary ITE teachers, and of more concern was their own lack of self-awareness** which would surely impact on their capacity to provide appropriate science experiences for young children. Subject knowledge and content is important, however ITE teachers should also receive instruction in methods and application. Yilmaz-Tuzan (2007) suggested that science methods courses should provide opportunities to learn about different methods and practice them as appropriate, ideally through field experience. Teacher educators have to provide student teachers with teacher education experiences that highlight general principles of practice, and as ITE teachers develop beliefs of science and mathematics teaching on their in-class experiences, teacher education must model new (innovative) pedagogy (Weld and Funk 2005).

Beliefs about science is also an issue for CPD with teachers. In the spirit of the constructivist approach many science teachers need to alter the way in which they instil subject knowledge into their learners, and rather than imparting knowledge they are required to teach children to become better learners, that is learners for life (Schollaert, 2011). In order to achieve this, teachers need to become experts in learning, understanding how learning works by becoming expert learners themselves i.e. good role models.

C3.3 Creativity in science and mathematics

Studies reveal a rather wide view of creativity in science and mathematics among teachers and ITE teachers. These span seeing the focus of creativity in science and mathematics: linking with the arts, practical engagement, use of exciting materials and activities, inquiry-based, key processes such as combinatorial thinking or divergent thinking, or harnessed to digital technologies.

In a Greek study Kampylis et al. (2009) found that many ITE teachers recognised that facilitating creativity was part of the teachers' role but they did not feel well trained or confident enough to fulfil this. Newton and Newton (2009) identified that primary ITE teachers had a narrow conception of creativity in science lessons, and saw creativity as something more associated with the arts. Their view of creativity in science was around the use of practical investigations which may well be

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reflective of their own experience of learning science as previously mentioned. In a similar vein, they saw the most engaging lessons as being the ones which involved the practical application of science, this being the most effective way of gaining willing, attentive participation in science lessons. Newton and Newton (2009) suggested that linking the word creativity with 'productive thoughts' in science education could draw attention to a wide view of what creativity in science can offer. Similarly Bolden et al. (2010) stated that conceptions of creativity in mathematics need to be addressed and developed directly during ITE teacher education.

Action research cited in teacher education literature on the relationship between creativity and teaching children science and mathematics suggests practitioners tend to see creativity concerned with supplying specific resources or activities, rather than processes (Worthington, 2011; Kampylis et al., 2009; Bolden et al., 2010). Other studies see an integration of science/mathematics and creativity, through the application of story books (Harkness and Portwood, 2007; Frisch, 2010), and through the arts and drama (Palmer, 2009; Tselfes and Paroussi, 2008). Findings from this research showed science viewed with fresh eyes, where students experienced the 'fun' aspect of science necessary to teach science to young children, as well as removing the concept of science from its pedestal of theories and formulas. In using stories, instructors were able to see where students were unclear or confused about a concept, and enabled students to see 'science content in context' (Frisch 2010). In linking mathematics with the arts through aesthetic workshops, Palmer (2009) saw a change in student teachers' own understanding of mathematics subjectivity resulting in more positive inclination to the subject.

In one study, mathematics, science, inquiry, and creativity were 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. They promoted higher level reasoning and creativity, as ITE teachers learned to reflect on and question the big ideas they observed in play to develop practice that extends learning along a conceptual continuum of inquiry. These researchers referred 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.

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

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stages: uncertainty, visioning, realization, and readiness. However, a clear conceptual distinction between creativity and mimicry still needs to be made while some practising primary teachers need to widen their view to see constructing a scientific explanation as a creative incident (Newton and Newton, 2010).

Based on interviews of EU teachers attending professional development courses, the OECD Talis survey (2009) on creative learning and innovative teaching found the majority of teachers argue technology has improved their teaching and that ICT can be used to enhance creativity. 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.

C3.4 Summary of attitudes towards science and mathematics

This section raised the important issues of attitude and knowledge (both subject and pedagogical). One of the characteristics noted in the creativity literature review was a willingness to take risks. If the teachers are already fearful of science and mathematics they are less likely to be willing to take risks when teaching these subjects. Therefore, both identifying the attitudes of the teachers and considering ways of addressing these will be important in *Creative Little Scientists*. The importance of both subject and pedagogical knowledge has already been raised. The ways in which these are developed will impact on participants' underlying beliefs about science and mathematics. These beliefs should be made explicit and articulated. However, it is not just the knowledge about mathematics and science which is important. Knowledge about creativity, creative approaches and what these mean in the context of early years science and mathematics are also vital. The issue about defining creativity has been raised in the literature reviews for creativity and for science and mathematics. There needs to be a shared understanding of what these are in *Creative Little Scientists*. This includes a shared understanding of the relevant pedagogies and the role that resources, the environment and digital technologies have in promoting a creative approach to learning.

C4. Interventions

The literature review identified a number of interventions that have been deployed to overcome some of the issues identified above. The interventions included specific methods lessons or tools used in science and/or mathematics method or content courses to improve knowledge and skills or change attitudes and beliefs of student teachers; field experiences or mastery experiences to improve mathematics and science teaching and confidence; reflective practices to improve reflective skills and integrated approaches. As a general observation it was seen that the **interventions were most successful where a combination of**

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content and methods courses were used (Palmer 2008). Schoon and Boon (1998) identified that science content courses alone appeared to be unsuccessful in changing student teachers' attitudes whilst Hecter (2011) advises a collaboration between education departments and science departments in order to a more holistic approach in science content courses prior to method courses. A similar observation is made by Goulding, Rowland and Barber (2002) who stress the importance of both subject knowledge and pedagogical knowledge in teaching mathematics.

C4.1 Field experience

The ITE requirements in the *Creative Little Scientists* countries all include school placements so field experiences are clearly valued. Field experiences, mastery and/or vicarious experiences could well be seen as the more traditional intervention used to improve the ITE teachers' confidence and ability to teach mathematics and science. According to Howitt and Venville (2007) **school placement is seen as the most positive factor in preparing ITE teachers confidence to teach science**, while Bintas (2008) described it as a vital means for students to gain confidence in mathematics.

In studies, researchers used a variety of strategies to capitalise on field based work, including co-teaching (Siry and Lang, 2010), video conferencing (Plonczak, 2010) and the 'knowledge quartet' (Rowland, Huckstep and Thwaites 2005). The co-teaching approach saw student teachers teaching science alongside the classroom teacher and course instructor, before entering into small group discussions with pupils regarding their understanding of the science concepts taught. Students in the study observed an increased confidence through shared delivery, whilst also developing a new understanding about the ways in which children learn science. The video conferencing saw another approach to utilising field experience, whereby students were observed using questioning in mathematics via videoconferencing; a diagnostic approach to their questioning skills was enabled through this method.

Gunning and Mensah (2010) noticed that short mastery experiences, microteaching lessons and one science night demonstration, also offer valuable learning experiences. Bautista (2011) reported 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 showed that personal science teaching efficacy and science teaching expectancy beliefs increased significantly over the semester, however it provides no information about how long ITE teachers maintain the high levels of self-efficacy.

A further example of field experience approach involved vicarious modelling in the classroom led by science specialists. In this study Varma and Hanuscin (2008) noted that ITE teachers experienced a wide range of instructional and assessment strategies, although it was not clear how well this experience enabled them to envision how to create a stimulating

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and inquiry-rich environment for science in a general classroom not how to integrate science with other disciplines such as mathematics.

It is then, without a doubt, that **field experiences and mastery courses are invaluable in terms of giving students first hand experiences to apply their knowledge and skills in a real-life scenario. However, as noted previously it is of utmost importance that the experiences presented to students are of the highest quality, which encourages creative and innovative approaches rather than stifles them**.

C4.2 Inquiry

Many of the studies suggest that inquiry or problem based learning is an effective way in which ITE teachers develop a better understanding of the nature of science. The findings of Weld and Funk (2005) suggested that when student teachers are taught science inquiry they recognise how much more there is to know about science as well as how much there is to know about teaching it effectively, Haefner and Zemba-Saul drew similar conclusions suggesting that scientific inquiry supported the development of a more appropriate understanding of science and scientific inquiry. Several models of scientific inquiry were advocated (Isabelle and de Groot, 2008; Carin, Bass and Contant, 2005; Howitt and Venville, 2009). Carin, Bass, and Contant's (2005) proposed a 5-E Model of science instruction relevant to teaching science as inquiry (Engagement, Exploration, Explanation, Elaboration, Evaluation). Creativity is present particularly in the Engagement phase, where the teacher engages activities and stimulates curiosity and the Exploration phase, where students have a concrete physical experience, observe properties, establish relationships, and ask questions. The 'engage, explore and explain' model was also used by in the study of Howitt and Venville (2009). Moreover the learning experiences of ITE 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.

The purpose of scientific inquiry models is predominantly to improve student teachers' conceptions of inquiry in order to influence their practice as suggested by Leonard et al. (2009), while Etherington (2011) mentioned the need to discuss previous conceptions learned in high schools before starting an open inquiry course. In this particular study, a problem-based learning approach, as a pedagogical mode of learning open inquiry science, seemed to impact on ITE teachers' motivation to teach science ideas within a real world context and to define, frame and recognize what is required of an open-inquiry learner. This open 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.

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Findings from the research would suggest that a scientific inquiry problem based learning approach to science can help to define, frame and recognise what is required of an open-inquiry learner, and can be seen as a method of teaching and practicing science wherein the curiosity and desire to understand the world are nurtured, and talents, interests, creativity and skills are fostered (Leonard et al., 2009; Etherington, 2011). Roehrig et al. (2011) found that sustained, culturally-based CPD can advance the quality of science teaching to a more child-centred approach if teachers are enquirers themselves. Similarly Varma et al. (2009) found that when multiple inquiry-based experiences, from guided to open, are integrated into a science course ITE 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. A word of caution must be issued here, however, since Varma et al. (2009) also found that inquiry-based projects were not in fact sufficient for ITE teachers to feel confident to use inquiry in their own classrooms. Both Etherington (2011) and Luera and Otto (2005) stressed the importance of time to move ITE teachers from passive to active learners, and to increase the belief of the ITE teacher in his or her ability to teach science.

In a similar vein, Vacc and Bright (1999) revealed that elementary school teachers' belief about teaching and learning mathematics can be changed significantly using Cognitive Guided Instruction (CGI), a problem based approach, during a mathematics methods course, although they were unable to use the tenets of CGI in their teaching. It is then important that students are not only taught the strategies to use themselves, but are also shown how these skills can be transferred to the classroom.

Most of the projects studied in the research focused on changes in observable teaching practices as a result of teacher participation in CPD, this frequently involved the implementation of specific materials to be used in schools and on course. 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), whilst 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 a CPD programme for science and technology teachers.

Howes (2008) relates how Dewey's explication of 'educative experiences' was applied to design settings in which children's interests are piqued and purposes for learning inspired. Teaching science 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

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Teachers' beliefs about science in general were measured using the Science Teaching Efficacy Belief Instrument. The study showed that inquiry-based teaching required doing hands-on activities, helped students enjoy science, built upon students' prior knowledge, promoted cooperative learning, helped retain content knowledge, and developed 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 CPD teachers.

C5. Summary of Research on Interventions

There is, then, much evidence to suggest that **a creative approach to teaching science and mathematics, incorporating an inquiry or problem based learning approach can be as effective as the more traditional laboratory practices approach**. This is not to say that it is not a challenge designing such a curriculum, and often requires the removal of barriers and expectation as few students see any correlation between science and mathematics and creativity.

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D. ISSUES FROM REVIEW OF COMPARATIVE EDUCATION

Creative Little Scientists is a comparative research project involving a transnational study of science and mathematics and the promotion of creativity in the early years of education. Comparative education can be envisaged as an interdisciplinary area of study that encourages scholars to engage in a comparative analysis that is both cross-national and contextual. The role of comparative education and comparative research is not only to produce the different perspectives of different countries and increase awareness, but it is also a way to learn from each other and to build global understanding of educational issues, from viewpoints of policy, practice and research. The comparative exercise thus goes beyond measuring who is the best to identify best practices which can serve as reference to other countries wanting to improve their own education systems.

D1. Aims and Impact of Study Situated in Comparative Education

European integration and global competition have increased the need for comparative research and the European Union finances such research within its member countries (Keränen, 2001; Novoa and Yariv-Mashal, 2003). International organizations like UNESCO, OECD and the EU are interested particularly in science, mathematics and technology education because of the key roles these have in a knowledge based, competitive, technologically oriented global economy.

D1.1 Type of comparative education

An early definition for comparative education focused on two areas: thematic studies and area studies (Bereday, 1957 in Välimaa, 2010). In thematic research some contents or phenomena are compared in different places while in area studies the focus is on some particular region or country. Currently, it seems that comparative education research is a combination of these two. Thematic issues are considered and researched from several countries' perspectives and comparisons can range from ethnic, age, religious to gender groups (Arnove, 2007). Similarly Gordon and Lahelma (2004) described current initiatives in comparative education as cross-cultural studies in which the particular phenomenon is investigated in different contexts. One criterion for comparative education is that at least two countries should be studied and compared. The *Creative Little Scientists* project has this type of focus since it is considering the themes of creativity, science and mathematics within the specific age group of early years (3 to 8 years old) across nine EU countries.

Comparative education can also be defined as:

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1) research programmes that study one country or region at a time within the context of a broader agenda using such studies to compare the results of the studies across time and space;
2) international research that builds on others' studies of the same issues, with the intent to construct a larger comparative study on that theme;
3) studying various countries or regions using the same methods of data collection and analysis;
4) comparative analysis on large international data sets already available or created from national data sources.

The main approach for *Creative Little Scientists* is the third of these aspects. The literature reviews have identified a wide range of international studies related to creativity, mathematics, science, early years education and teacher education, although few studies have included all of these aspects. Therefore, the research instruments and questions may draw upon some of these studies, relating to the second aspect above. As part of the literature reviews for the *Creative Little Scientists*, participants were asked to identify aspects of education policy in their country or region which related to creativity in science and / or mathematics in the early years and teacher education. This may lead to the final aspect described above through the creation of an international data set created from the national data from each participating country.

Comparative Education encompasses several components, outlined in the typology below in Figure 3. Definitions of each type are in the glossary of key terms in the Appendix to this Conceptual Framework. However, the terms presented overlap, are not mutually exclusive and are not commonly agreed by researchers in the field (Halls, 1990). The differences between the concepts of comparative education and international education are not always clear. Perspectives on comparative education and international education are often interrelated, because taking an international perspective in research frequently demands comparing aspects which are not specific to one's own national system (Carnoy, 2006).

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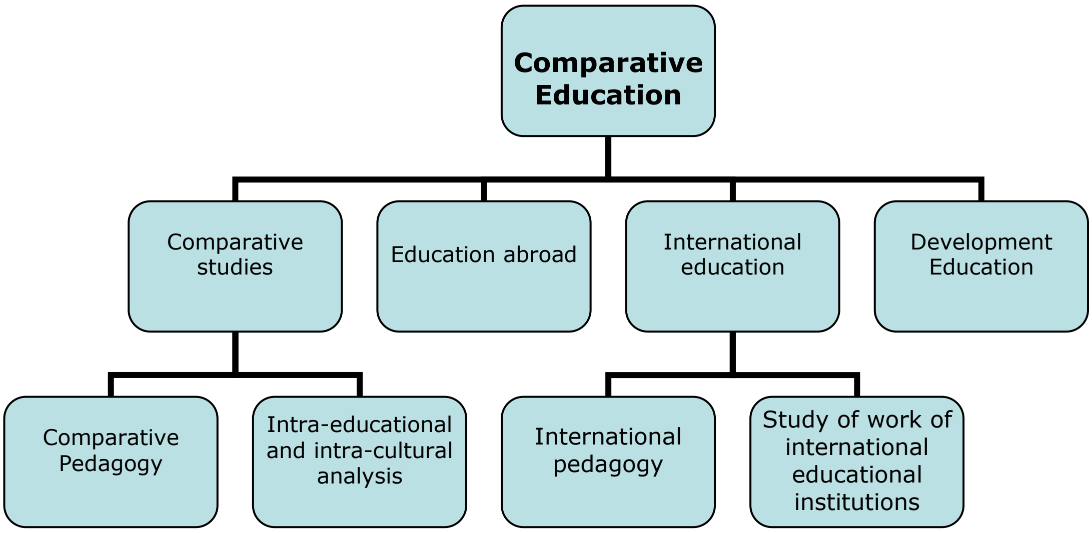

Figure 3: A Typology of Comparative Education

The type that is **most relevant to *Creative Little Scientists* is Comparative Pedagogy, which aims to identify processes of teaching and learning within schools and classrooms in different countries**. Comparative Pedagogy mainly focuses on one particular theme through international assessments designed to measure learning in multiple countries. The aims of Comparative Pedagogy include: (a) cross-national comparisons that target a variety of educational policy issues and / or practice; (b) provision of 'league tables' that rank-order achievement scores by nation or region or other variables; and (c) within-country analyses that are then compared to how other countries operate at a sub-national level. It is the first of these aims that is relevant to *Creative Little Scientists*.

D1.2 Trends in comparative education

There have been trends in comparative education that have reflected the changes in the economic world, as well as the development of distinct conceptions of knowledge (Halls, 1990; Novoa and Yariv Mashal, 2003; Swing, 2006). Novoa and Yariv Mashal (2003) identified four periods during which comparative education gained legitimacy and popularity, as shown in Table 2.

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Time	Period	Explanation
1880s	Knowing the other	Curiosity about the educational processes in other countries
1920s	Understanding the other	Knowledge production, schooling and education compared through international co-operation
1960s	Constructing the other	Comparative studies of different countries / regions; education for social and economic progress
2000	Measuring the other	Creating international tools and comparative indicators to measure efficiency and quality of education

Table 2: Historical perspective on comparative education based on Novoa and Yariv-Mashal, 2003

D1.3 Defining concepts

Another issue for the *Creative Little Scientists* project is defining concepts, such as early years, creativity and inquiry. Individuals in different cultures and languages may think about concepts and problems in different ways and one particular concept could have different meanings in different countries or jurisdictions (Crossley and Watson, 2003). Comparative education provides insights into these differences and can act as a bridge to enhance understandings and communication across countries which can only be achieved when there is a good understanding of different systems and ways of working (Arnove, 2007). Some glossaries have already been developed such as the Terminology of European Education and Training Policy (CEDEFOP, 2008) and quality in education (CEDEFOP, 2011), which may provide a common reference to work with.

D1.4 Different conceptions of early years education

OECD has carried out two comparative studies; both called Starting Strong (OECD 2001, 2006). The 2001 study provides a comparative analysis of major policy developments and issues in 12 OECD countries - Australia, Belgium, the Czech Republic, Denmark, Finland, Italy, the Netherlands, Norway, Portugal, Sweden, the United Kingdom and the United States - highlighting innovative approaches and proposing policy options that can be adapted to different national contexts. The study puts forward eight key elements for equitable access to quality early childhood education and care: a systemic, integrated approach to policy development and implementation; a strong and equal partnership with education; a universal approach to access, with particular attention to children in need of special support; substantial public investment in services and the infrastructure; a participatory approach to quality improvement and assurance; appropriate training and working conditions for staff in all forms of provision; systematic attention to monitoring and data collection; a stable framework and long-term agenda for research

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and evaluation. One priority identified is the need to improve recruitment, training and remuneration of early childhood professionals, particularly of staff responsible for development and education of children under three.

The second OECD study (OECD, 2006) was a follow-up of the first, including the same countries and an additional eight: Austria, Canada, France, Germany, Hungary, Ireland, Korea and Mexico. This second study focused on the same eight aspects included in the first study with a greater focus on the governance of ECEC systems; the impact of financing approaches on quality; and contrasting pedagogical approaches. The study highlighted how support for the view that early childhood education and care should be seen as *a public good* is growing, and has received a strong impetus from the research of education economists.

Eurydice network (providing information on and analyses of European systems and policies, as of 2011 consisting of 37 national units in 33 countries), tackles early childhood education and care with respect to tackling social and cultural inequalities (European Commission, 2009a). This particular study documents distinct risk groups and identifies two main forms of organisation in early childhood education and care (ECEC) in these countries: care provided in unitary settings and the much more widespread system of age-banded provision[6].

The widespread perception in these reviews of early childhood education and care as a 'public good', including from the research of education economists may have contributed to the acceptance of the *Creative Little Scientists* project. There are differences however: the 2006 OECD report noted that that there were differing approaches to early childhood education that were culturally based. France and the English speaking world have adopted a 'readiness for school' approach, which although defined broadly focuses in practice on cognitive development in the early years, and the acquisition of a range of knowledge, skills and dispositions. In countries inheriting a social pedagogy tradition (Nordic

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[6] The Eurydice study looks at 30 different countries and examines the available cross-national data and national policies on early childhood education and care (ECEC). There are several possible at risk groups identified, whose distribution varies across the European countries: single parent households with small children (about 9%); non-national children (3 % of under 6 in Europe); and households with a child under the age of 6 lives on the poverty threshold (17 %). In most countries, women's engagement in the labour force is clearly linked to the age of their children. Many European women with a child under the age of 3 withdraw from the labour market. Women with children aged 3 to 6 years have still lower than average economic activity rates, but most European women are prepared to take up gainful employment when the youngest turns 6. This withdrawal from the workplace could be partly explained by the lack of available provision for young children. Two main organisational models for ECEC services were identified: the first model involves provision for young children is provided in unitary settings, organised in a single phase for all children of pre-school age; and the second model, which is the most widespread in Europe, ECEC services are structured according to the age of the children (normally for children aged 0 to 3 years and for children aged 3 to 6 years). The opening hours of ECEC services have two broad approaches: subsidized ECEC more or less fully compatible with the working hours of parents or be available only on a part-time basis. In the majority of European countries ECEC settings generally provide extensive opening hours that take account of the needs of working parents, including some flexible arrangements (evenings, nights and/or weekends). In the majority of countries, intervention is targeted at groups on the basis of defined social, economic or cultural criteria. Support involves: Special language training programmes; Appointment of extra staff in mainstream settings; and Provision of separate settings/sections for specific groups. Staff caring for the ages 0-3 tends to be less qualified than those caring for the older ages.

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and Central European countries), the kindergarten years are seen as a broad preparation for life and the foundation stage of lifelong learning.

D1.5 Gaps in comparative studies

The literature review identified many relevant comparative studies. There have been comparative studies about pre-school education (e.g. Ojala and Talts, 2007; Sheridan, 2009; Niikko and Havu-Nuutinen, 2009; Sylva et al., 2006). Some of these focus on concepts relevant to *Creative Little Scientists*, such as teacher professionalism (Hujala et al., 2009), technology education (Rasinen et al., 2009) and children's early numeracy (Aunio et al., 2008), but the studies are limited in number and many are narrow in focus. The TIMSS and PISA studies focus on science and mathematics but not on early years. There have been some smaller scale comparative studies that have analysed children's conceptions of scientific ideas (Prokop et al., 2009; Reiss et al., 2002; Eloranta and Yli-Panula, 2005; Atran, 1994), which have indicated that young children's conceptions of scientific phenomena are context dependent. There have also been comparative studies about mathematics (van de Grift, 2007; Ee et al., 2006) some which have identified differences due to language (Ho and Fuson, 1998; Geary et al., 1996) and societal attitudes towards mathematics (Andersson et al., 2010). The Eurydice Network has produced analysis of European education systems and policies, which includes reports related to science education (European Commission, 2006; 2011a), mathematics education (European Commission, 2011b) and early years education (European Commission, 2009a). They have also produced a report which touched on creativity (European Commission, 2009b) but this was in the context of art and culture education. Several comparative studies have focused on creativity terms in curricula and policy documents (Heilmann and Korte, 2010; Shaheen, 2010; Bertram and Pascal, 2002).

D1.6 Summary of issues for aims and impact of *Creative Little Scientists*, a comparative study

The *Creative Little Scientists* project has been financed by the European Union with the idea that increasing creativity in the early years in science and mathematics education could have a positive impact on encouraging children to pursue careers in science and promote research and innovation. However, it will be difficult to determine impact of the project given the long time scale between children in early years education and those children as adults pursuing careers. An additional difficulty is that national and local aims may differ so they may not be willing to adapt their curriculum based on wider needs. Even if they do adapt their curriculum, cultural differences may mean that foreign elements may not produce the desired results.

There are many different aspects of comparative education. The key terms for the *Creative Little Scientists* project are comparative education, comparative pedagogy, thematic studies and cross-cultural studies. The

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trends in comparative education raise issues for the *Creative Little Scientists* project. **Some of the motivation for this study has come from studies such as TIMSS and PISA mentioned in section B4, which are part of the 'measuring the other' trend. However, as identified in the literature review on creativity, creativity does not fit easily into this quantitative measurement paradigm. Therefore, this project may have more in common with the 'constructing the other' trend or even restart a trend of understanding the other.**

An important aspect of comparative education is developing a shared understanding of terminology. There will need to be a glossary for the project, which may be able to draw upon previously developed glossaries. Beyond terminology is the need to understand the concepts underlying the terms. Differences in the conceptualization of early years were identified, with the school readiness and social pedagogy models highlighted. These raise important questions for *Creative Little Scientists*. Will a common approach to developing creativity in early years science and mathematics work in both of these approaches to early childhood education? Some of the countries in Creative Little Scientists (Greece, Romania, Portugal and Malta) were not included in the OECD study of early childhood education. Will they fit into one of these models or are there more conceptions of early childhood education which need to be considered? The different ages to which the term early years applies might also have an impact. An Ofsted report (2003) on the education of six year olds in England, Denmark and Finland found that many of the English teachers were less secure than their Finnish or Danish counterparts about the nature and purpose of the curriculum for six year olds, feeling caught between the approaches of the early years curriculum which finishes at five years old and the National Curriculum, with national high stakes testing at seven years old.

Overall there has been limited focus on science or mathematics education in the early years in comparative studies. The lowest ages included have tended to be primary education, within which the later stages of early years education are included. International studies often remain at the level in which pupils' knowledge or other achievements are scored, without focusing on the educational processes involved in science or mathematics. There is a particular paucity of comparative studies that focus on the nexus of science, mathematics, early years and creativity so *Creative Little Scientists* will be addressing a gap in the existing research.

D2. Comparative Studies: Science, Mathematics, Creativity

Although it was identified in the previous section that there are research gaps in science, mathematics, creativity and the early years, there have been comparative studies which have related to some aspects of these. This section, drawn from the comparative education literature review, focuses on some which have examined the place of creativity in the curriculum and teachers' understanding of it; large scale tests of pupils' mathematical and science knowledge; students' and teachers' attitudes

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towards mathematics and science; and teacher education. Some of these studies have also been discussed in the other literature reviews; certainly the issues are not exclusive to comparative education.

D2.1 Perceived relevance of creativity

The *Creative Little Scientists* project has an underlying premise that creativity is important and relevant to science and mathematics education in the early years. This is not necessarily a common belief. A study of the curricula of 27 EU countries (Heilmann and Korte, 2010) found that the term creativity was found most frequently in subjects like arts and music rather than mathematics and science and was slightly more common in secondary rather than primary curricula. There were mentions of creativity as a skill, such as creative thinking and creative problem solving, which did apply across subjects, including mathematics and science. A review of the early years curricula in 20 countries (Bertram and Pascal, 2002) found that creativity was a central aim in only four of the countries examined. A study of the curricula of 16 countries (Shaheen, 2010) reported that in several countries the role of creativity in education was valued, including China where it had become one of the priority aims of education. However, the term creativity focused on different things in different areas (creative thinking in the USA, imagination in Singapore). Hong and Kang (2009) studied secondary science teachers' conceptions of creativity in the USA and South Korea. The findings were similar in both countries, with most identifying novelty (86%) as the major characteristic of creativity, with problem solving also featuring prominently and inquiry approaches suggested as an appropriate pedagogy. However, there were cultural differences. The South Korean teachers were more likely to consider ethicality when judging creativity and they emphasized pedagogies that supported thinking skills and collaboration, while the US teachers focused on emotional support and emphasized individuality. Wang (2011) compared differences in creative thinking between student teachers in Taiwan and the USA. The Americans scored higher on elaboration, which Wang believed was due to the emphasis on self-expression in education in the US.

D2.2 Influence of TIMSS and PISA

Although the TIMSS and PISA studies do not include children in the early years they still impact upon the early years because they influence curriculum decisions for all age groups, with the assumption that a strong foundation for future mathematics and science learning needs to be established in the early years and primary education. TIMSS takes place every four years so the next round of testing will take place in 2015. PISA takes place every three years so there should be studies in 2012 and 2015. However, since these both study older children it will be longer before any children who took part in the *Creative Little Scientists* project, or were taught subsequently in settings influenced by the project, were old enough to participate in TIMSS or PISA.

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TIMSS tests both content domains and cognitive domains in mathematics and science as Table 3 summarises.

Mathematics Content domains	Mathematics Cognitive domains	Science Content domains	Science Cognitive domains
Number	Knowing facts and procedures	Life science	Factual knowledge
Algebra	Using concepts	Chemistry	Conceptual understanding
Measurement	Solving routine problems	Physics	Reasoning and analysis
Geometry	Reasoning	Earth science	
Data		Environmental science	

Table 3: Content and cognitive domains focused on in TIMSS

PISA tests the students' abilities to apply science and mathematics to real life problems and situations in a variety of contexts (Anderson et al., 2010). This includes skills of analyzing, reasoning and communicating.

D2.3 Attitudes towards science and mathematics

The international comparative study ROSE (relevancy of science education) of secondary students in 40 countries found that attitudes towards science and technology were mainly positive but that young adults, especially females, in the richer countries (Northern Europe and Japan) were more ambivalent and sceptical about science, while those in developing countries saw science as beneficial to their careers and countries (Sjøberg and Schreider, 2010). The main results produced a negative picture of secondary science education, although there were differences by country and gender. The findings which are particularly relevant to *Creative Little Scientists* are that science was perceived as less interesting than other subjects, it had not convinced them that science and technology were important for our way of life and it had not increased the pupils' curiosity (Sjøberg and Schreiner, 2010). The negative attitude noted in the ROSE study was the focus of IRIS (Interests and Recruitment in Science), a collaborative EU funded research project addressing the challenge that few young people (women in particular) choose education and career in science, technology, engineering and mathematics (Fidler and Dillon, 2011). Recruitment of science teachers is also a problem (OECD, 2005).

D2.4 Teacher Education

Comparative education in teacher education has emerged as an area of study in teacher training in recent years, with many countries currently seeking to include international perspectives and global education in their curricula, including teacher education curricula (Holden and Hicks, 2007; Willard-Holt, 2001). However, Wilson (2005) found that comparative education was rarely taught on British initial teacher education

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programmes. Previously Watson (2001) noted that there was little appreciation of how comparative education can add to development of the teacher competences that are the focus of British initial teacher education programmes. There are other challenges for the inclusion of comparative education in initial teacher education, mainly due to limited usable data about teacher education programmes in research studies, such as the lack of a precise number of students in the programme, the hours allocated to each area of study, the qualifications within the faculty, a good follow-up system for graduates, and the costs of running the programme. This calls for better teacher education programme databases to be able to develop useful accountability systems (Tatto and Senk, 2011). As part of the literature reviews *Creative Little Scientists* has started to gather information about teacher education programmes in the participating countries.

Different ways of organizing teacher education affects perceptions and conceptions of teaching and learning (Sternberg, 2007; Hujala et al., 2009) and can relate to the philosophical thinking on which education is based. This is why teacher education has an essential role in the *Creative Little Scientists.* Eurydice (European Commission, 2006) reported differences in the amount of content and educational background of the teacher-trainers for prospective science teachers. The information gathered already in *Creative Little Scientists* suggests that this is true for primary teacher-trainers generally, not just in science.

Tatto and Senk (2011) conducted a comparative study of teacher education in mathematics in 17 countries. International collaboration allowed them to collect valid and reliable cross-national data about the students' content and pedagogical knowledge from the various teacher preparation programmes. They found that preservice primary teachers in high achieving countries had more opportunities to learn tertiary and school level mathematics. However, the teacher preparation programme may not be the only variable to consider. Lindemann-Matthies et al. (2011) researched biodiversity education for ITE primary teachers in four European countries. They found that the Swiss participants, who had received the least preparation in all aspects, were as or more confident than the other participants in most of the outdoor activities studied. In general they found that actual experience of outdoor teaching and using an inquiry teaching approach during initial teacher education contributed to the student teachers' motivation to use similar approaches with their future pupils. This relates to studies reviewed in Task 2.4 about teacher education.

OECD (2010a) identified the need to better articulate the links between initial and CPD teacher education. A different OECD study (2010b) of secondary teachers found that professional development varied considerably in the countries studied, in both type of professional development and levels of participation. Teachers with lower qualifications were less likely to participate in professional development.

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D2.5 Summary of comparative studies: science, mathematics, creativity

The studies indicate that creativity is a focus in some, but not all, countries' curricula. However, this may be conceived in different ways and may be perceived as relating to the arts more than science and technology. Aspects of the underlying culture may influence teachers' ideas and practices related to creativity.

The literature reviews for science and mathematics education and creativity have identified a range of definitions for creativity. It will be important to consider how much they relate to the cognitive domains that are tested in TIMSS and PISA. Problem solving has been identified as a relevant term to creativity in science and mathematics but it is questionable whether this includes 'solving routine problems', as opposed to non-routine problems that require original thinking rather than following a set procedure.

The negative attitudes toward secondary science may not reflect the attitudes of early years children but this possibility must be considered. Since the majority of early years teachers are female, gender, of both pupils and teachers, may be another issue for *Creative Little Scientists* to consider.

The issues identified in comparative studies of teacher education have implications for the preparation of materials for teacher education in the final stages of the *Creative Little Scientists* project. What level or levels of professional development will be involved? What approaches will be taken? Will it be possible to ensure that those in most need of this professional development have access to it? What model or models of professional development will meet the needs of diverse organizations offering teacher development in the participating countries?

D3. Research Needs: Comparative Education Review

The research needs in comparative education highlighted by the comparative education literature review included:

- Focus on early years and transition between pre-school and the early phases of primary school bearing in mind how to capture the breadth of the early years spectrum of 3 to 8 when the pre-school period and school starting age varies so widely across the partner countries in the study, as does pre-school provision.
- Focus on the research into the learning and educational processes in classrooms to be able to compare a) the teaching and learning, b) learning climate and c) pedagogical strategies in science and mathematics education.
- Focus on how formative assessment can contribute to promoting creative approaches in science and mathematics education in the early years.

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- Capture the role and significance of creativity in science and mathematics education in partner countries and underline the need for definition of the concept in the project.
- Clarify the role of the differences in teacher education among the partner countries and its meaning for the science and mathematics education in early years education.
- Identifying the alternative approaches in partner countries to creativity, science and mathematics education and developing reflective methods, to help envisage alternatives to develop education in other countries.

D3.1 Considerations for reliability and validity

There are several questions that need to be considered to ensure the reliability and validity of comparative studies. There are questions about whether the description is of a homogenous reality and how well it takes account of the local context (Keränen, 2001), specifically how well the structure, culture and geographical location are taken account in the comparisons (Välimaa, 2008). Official data sources may provide data that aim to show the positive aspects of education, presenting a biased picture (Crossley and Watson, 2003). In the literature reviews details about national policies and curricula were gathered but these may not reflect the curricula as it exists in schools. There is also the danger that when data is derived out of its context it may not be understood properly and misleading justifications can be made (Sternberg, 2007). To overcome these challenges, comparative education always includes several viewpoints that are taken into account when making deep analysis. However, the educators and researchers may have preconceptions and stereotypes that result in bias (Crossley and Watson, 2003).

Other difficulties are that the sample may not be representative and it may not be possible to account for all variables. For example, a comparative study by Kaya and Rice (2010) focusing on Singapore, Japan, Australia, Scotland and the USA found that student background characteristics were consistently related to science achievement. Similarly OECD (2010) found that student background had a key influence on mathematics achievement. Therefore student background may be a relevant variable when considering the sample.

D3.2 Summary of research needs in comparative education review

The gaps identified in comparative education related to the project indicate that the early years aspect will be particularly important. The role and significance of creativity in science and mathematics education, how this is defined and how it relates to the educational processes will be key areas. In addition to focusing on early years itself, these issues also need to be considered in the context of ITE and CPD for early years teachers.

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In addition to the need for shared understanding, comparative studies bring particular challenges. For *Creative Little Scientists* this means that official data needs to be related to actual practice, collected through questionnaires and observations. The national data should be analysed through multiple viewpoints, including both participants from that nation and participants from other nations. In terms of sample the *Creative Little Scientists* project will need to determine which variables have to be considered in order to decide what would constitute a representative sample. This is made more complex because of the differences in the organization of early years education in the participating countries.

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E. IMPLICATIONS OF LITERATURE REVIEWS FOR *Creative Little Scientists*

As indicated earlier in this document, *Creative Little Scientists* seeks to implement research which will:

- provide Europe with a clear picture of existing and possible excellent practices, as well as their implications and the related opportunities and challenges, in the intersection of science and mathematics learning, and creativity in pre-school and the early years of primary education (up to the pupil age of eight); and
- transform knowledge generated through this into concrete proposals for the initial and continuing professional development of preschool staff and primary school teachers so that they are empowered to exploit the potential of creativity-based approaches to early years science and mathematics learning.

The intention of the project, then, is to provide advice for teacher education and guidelines to policy makers, although its emphasis will be on generating the knowledge required to be able to do this, through documenting and analysing cutting-edge practices.

In this section of the Conceptual Framework to the study, the implications of all four contributory literature reviews are considered for *Creative Little Scientists*. We begin by discussing the diverse drivers and conceptualisations and acknowledging three over-arching issues which run 'vertically' through what we propose as the three major areas for *Creative Little Scientists*. These over-arching issues are:

- *Diverse drivers and conceptualisations*
- *The comparative dimension*
- *Teacher preparation and development*

These run through each of the three focus areas (discussed in E.1, E.2 and E.3) of

- *capturing curriculum focus and design;*
- *evidencing practice;*
- *developing practice*.

The vertical strands need to be taken into account by *Creative Little Scientists* in devising the *Creative Little Scientists* desk study, survey (both in WP3), classroom-based observations (WP4) and the preparation of materials for teacher education (WP5).

Firstly, in terms of diverse drivers and conceptualisations, as indicated earlier, the *Creative Little Scientists* project has been financed by the European Union with the idea that **increasing creativity in the early years in science and mathematics education could have a positive impact on encouraging children to pursue careers in science and promote research and innovation.** Whilst this is not possible to

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document within the frame of the project it is recognised that this remains a driver, alongside others, including the economic imperative, the development of the child and the citizen, a desire to develop competencies and respond to rapid changes in technology. A further driver for the project is the paucity of comparative studies that focus on the nexus of science, mathematics, early years and creativity so *Creative Little Scientists* will be addressing a gap in the existing research.

The ways in which teachers, policy makers and initial teacher education students conceive of science, mathematics and creativity in education varies considerably, both within and across countries. Their conceptualisations are influenced by the drivers in this arena and are also shaped in response to their conceptions of childhood and child development. The early years is framed differently in the 9 countries involved which is an issue for ITE and for the project as a whole. This connects to the comparative literature in relation to conceptions of school readiness and social pedagogy. Many of these conceptualisations will be culturally influenced. Therefore, as comparative education it will be important for the team conducting the analysis to include participants from within as well as beyond the culture in which the data is collected.

In addition it will be important to recognise that **whilst early years is conceptualised differently across the nine countries of the study, there is a growing evidence base demonstrating the complexity of young children's capabilities, with increasing recognition of children's rights as active agents.** This evidence chimes with child-centred theories of early childhood and of course brings implications for practice and also research.

In terms of the comparative dimension, clearly as an international study *Creative Little Scientists* affords the opportunity for investigation in multiple contexts enabling the building of a map of provision and possibilities in the content areas of the study. It has already been suggested in section D1.1 of this Conceptual Framework, that the main approach adopted in this project will be using the same data collection and analysis approach, in multiple national contexts.

Applied to policy and practice within classrooms as well as within teacher education, this comparative dimension opens the possibility of recognising the roots of the project as informed by a desire to 'measure the other' and yet acknowledging the potential here to 'construct the other' or even to re-start a trend of 'understanding the other'. It is suggested that constructing or understanding the other, encompasses practices in early science and mathematics education (and the nature and extent of their engagement with creativity), as well as the nature and rationale for initial and CPD teacher education in relation to these. Some of the key issues identified and articulated in section D of this Framework are suggested as key areas of focus in E1.3 and E2.2. However, additionally the project team should consider the extent to which attention can be paid to:

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- transition from early years to primary level in different national and other contexts, and also
- developing reflective approaches to envisaging the development of new practices, emerging from identifying alternative approaches in partner countries to creativity, science and mathematics education.

In terms of teacher preparation and development, ***Creative Little Scientists*** **provides an opportunity to explore the link between teacher development and effective preparation to teach creative science and mathematics in the early years.** Factors emerging from the reviews are that links between:

- cognitive and affective elements of mathematics and science learning and teaching must be recognised and developed;
- the development of teachers' professional identity and reflective practice should be encouraged to support further professional development and practice;
- ITE and CPD teacher education in a partnership approach should be recognised as most important in supporting 'life-long' teacher development.

These three aspects, diverse drivers and conceptualisations, comparative education and teacher preparation and development, run vertically through each of the three major areas which it is proposed the study focuses on:

- capturing curriculum focus and design;
- evidencing practice;
- developing practice.

E1. Focus Area 1: Capturing Curriculum Focus and Design

A key task in *Creative Little Scientists* will be to articulate conceptualisations of early science and mathematics education, including IBSE, and also creativity in relation to these in the early years. This will need to be done at a conceptual level in relation to the literatures (a task well under way through the literature reviews on science and mathematics education – Addendum 1 out of 4 - and creativity - Addendum 2 out of 4 - and to be added to in the desk study section of WP3 which focuses on mapping and comparing existing practices to science and mathematics education in the early years) but also through documenting teachers' perspectives in practice (through the survey in WP3 and through classroom research in WP4). It will need to surface in the ways in which teachers go about curriculum design (as emergent from literature review 2.4). This section therefore sets out aspects of domain conceptualisations and teachers' conceptualisations which will need to be developed during WP3 and then WP4 and aspect of curriculum design particularly relevant to WP5.

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E1.1 Domain conceptualisations

The reviews on mathematics and science, creativity, teacher education and comparative education help to form the domain conceptualisations. Significant are the different conceptualisations of the nature of science education, mathematics education and creativity in education and how this impacts on creative teaching and learning approaches.

The reviews in science and mathematics education, recognise the importance of scientific literacy and the role of process skills and with the review on creativity also recognise the need to further develop nuanced understandings of creativity in science and mathematics education. Drawing on child-centred philosophy of early childhood education, the authors suggest **a focus on opportunities for how young children's ideas, experiences and curiosity evolve in mathematics and science, as well as their meaning-making and generativity.** The review on early science and mathematics education recognises a need to explore **how discourses of study in mathematics and science education map on to one another. It also argues for a focus on promoting scientific literacy** thus emphasising not only scientific knowledge but also the synergy between scientific process skills that effectively support the development of understandings related to the nature and processes of science[7], at the same time recognising that **creative teaching in science is distinct from scientific creativity and children's creativity in science and mathematics education**. The importance of developing scientific and mathematical process skills that lead to procedural knowledge is recognised in the review on science and mathematics education by the increase in inquiry and problem-based approaches to learning in science and mathematics.

The review of creativity highlights the *appropriateness of three particular approaches for this study, to build models, understand children's agency and to develop complex understandings* of creative learning and teaching in early science and mathematics. The first of these, the **cognitive** approach, seeks to construct models to explain mental processes. Drawing on such models developed within the cognitive paradigm may help the researchers in this study to characterise creative teaching and learning. The second, the **humanistic** paradigm, focuses on how creativity enables people to make something of their lives, by making self-chosen change. As discussed earlier, a key driver of the study is the engagement of young children in science and mathematics, seeking to build lifelong positive attitudes. Therefore, it will be important for the study to explore ways in which creative self-realisation or self-actualisation, may be fostered in learning and teaching in relation to these domains. Finally the **confluence** approach with its emphasis on complex systems, provides a framework for the study in highlighting the multiple components that converge in creativity, including domain

[7] These reflect tensions between child-centred, humanist philosophies, and those informed by social and economic concerns (Shuayb and O'Donnell, 2008).

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knowledge of science and mathematics, intrinsic motivation, emotional engagement, personality, environment and so on.

Epistemologically, the review of science and mathematics education reveals the growing recognition of *cognition as embodied* – in other words that children's thinking is grounded in perceptual, social and emotional experiences. Children's thinking plays out in relation to the context / environment. There has been growing recognition of the importance of affective factors and embodiment theories argue that it is not possible to separate thinking from perceptual and emotional experiences. Therefore, the confluence approach is particularly appropriate.

It will be important in *Creative Little Scientists* to acknowledge links between cognitive and affective aspects of learning, revealed in different ways in the review on science and mathematics education, teacher education and comparative education. These aspects of learning could be linked with achievement in the early years in *Creative Little Scientists*. Whilst there have been several studies comparing pupils' achievements in science and mathematics in several countries, these focus on later years of schooling and there is a lack of studies which focus on early years comparison and the comparisons of the educational processes of science and mathematics learning. In addition, according to the previous studies, it seems that challenges of science and mathematics learning are linked to questions of motivation among girls and boys as discussed in Section D[8]. *Creative Little Scientists* may be able to shed some light on the lived experience of pre-school and primary children in relation to these issues.

The relationship between IBSE and creativity affords scope for the project as science inquiry and investigative approaches link to the problem solving and problem finding developed by those who seek to teach for creativity and teach creatively. The dynamic relationship between these two sets of teaching approaches is indicated in the literature and appears to be worth further exploration empirically, as existing literature indicates. The reviews suggest **there are relationships with regard to play and exploration, dialogue and collaboration, questioning and**

[8] The international comparative study across 40 countries titled relevancy of science education (ROSE) focuses on attitudes of secondary students in science and technology (Sjøberg and Schreider, 2010). Its purpose is to gather and analyse information from learners about factors that have a bearing on their attitudes to and motivation to learn science and technology. Concrete examples relate to a variety of science and technology out-of-school experiences, interests in learning different topics in different contexts, prior experiences with and views on school science, views and attitudes to science and scientists in society, future hopes, priorities and aspirations as well at young peoples' feeling of empowerment with regards to environmental challenges, etc. The results create many possible interesting comparisons between the younger generation and adults across countries. The overall picture is that attitudes to science and technology among adults and young people are mainly positive, but in the richest countries (Northern Europe, Japan) young people are more ambivalent and skeptical than adults. By contrast, youths in developing countries still view science as potent forces in their careers as well as their country. There is a growing gender difference, with girls, in particular in the richest countries, being more negative (or skeptical, ambivalent) than boys. Similar findings have been found in comparative studies in other fields of science education, for example bioenergy (Halder et al., 2011). In addition, the results reveal also that school science in many countries fails. Although results vary across countries and between genders the main results can be summarized as follows: School Science is less interesting than other subjects; science has not opened pupils' eyes to new and exciting jobs and has not increased career chances. Science has not increased appreciation for nature; it has not taught to the pupils how to take care of their health. In addition, science does not harness pupil curiosity nor has it shown them the importance of science and technology for our way of living (Sjøberg and Schreiner, 2010).

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curiosity and, to a lesser extent, reflection and reasoning which have great potential for further exploration in WP5. The role of teacher scaffolding and involvement, as well as the challenges involved in balancing intervention and collaboration, are also relevant. Additionally, the extent to which teachers and initial teacher education across the countries involved engage in versions of IBSE or adopt CA is not known, nor is their understanding of such approaches in the early years and so should be explored in WP3, 4 and 5.

E1.2 Teachers' conceptualisations and attitudes

The exploration of teachers' aims and purposes in both WP3 (general intentions) and WP4 (related directly to practice) would gather teachers' explicit and implicit perspectives on such issues as their learning objectives, aims and purposes of creativity in science and mathematics education, how these are supported and developed following initial teacher education and how novice and expert pedagogues engage. Also included in the classroom focused work in WP4 and possibly the survey in WP3, will need to be shifts from pre-school to primary education across the consortium, how these relate to inquiry based and problem based learning in science and mathematics; perspectives on creativity in relation to perceived purpose. This might also **probe into teachers' identities; how they see themselves as teachers, scientists and mathematicians and their degrees of assurance towards science and mathematics teaching and similarly toward creativity.**

A particularly important aspect to bear in mind will be the link between the cognitive and affective among teachers themselves. The reviews for teacher education and comparative education identify the link between cognitive development in both mathematics and science and attitudes and the need for integration between the cognitive and affective aspects in learning, so that how a teacher feels about a subject has an effect on both subject knowledge and pedagogical knowledge. Context variables and non-behavioural components such as beliefs, decisions, perceptions, and self-concepts tend to be associated with actual teacher behaviour

The review of literature in teacher education identifies the approaches to teacher education that support teachers' understanding of the nature of science and mathematics, for example a combination of metacognitive teaching strategies coupled with explicit reflective nature of science instruction (Akerson, Morrison and McDuffie, 2005), inquiry based science approaches and problem-based learning in mathematics.

The reviews indicate that teachers, often working in performative cultures, tend to lack confidence and subject knowledge in science and mathematics and some demonstrate negative or fearful attitudes. Additionally, there is a concomitant lack of professional awareness about the role of creativity in science and mathematics and limited research into creative approaches in mathematics and science. Furthermore, there appears to be a gap between teachers' subject and pedagogical content knowledge in this area, which for example may adversely affect

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confidence and is exacerbated by different policy and teacher institutional factors. This poses problems and challenges in relation to professional understanding and praxis. Related to this issue of limited subject and pedagogical content knowledge are process / content issues and the balance and relationship between the two. The pedagogical knowledge includes teachers' professional understanding of the role of collaborative and collective engagement and learning, as well as their use of appropriate resources, including digital technologies.

During WP4 in particular, the *Creative Little Scientists* project could help to evidence children's and teachers' lived experience of creativity in early science and mathematics education; attitudes, skills and, pedagogical knowledge - and thus make visible and seek to bridge any existing gaps, the intention behind WP5.

Both the review of science and mathematics education and the review of creativity emphasise the growing significance of the *sociocultural situating of learning,* recognising that cognitive development occurs through children's participation in activities and social practices, thus emphasising the importance of relationships and cultural tools. In addition, the reviews on teacher education and comparative education, highlight a need for *creativity in teaching to inspire children and to generate interest in mathematics and science* although creativity in teaching is of course, as discussed in Section B, distinct from teaching for creativity. As indicated earlier in the Conceptual Framework, a central premise of the literature review focusing on teacher education is that teachers hold a key role in promoting, encouraging and nurturing creativity in classrooms, and that teacher education is of major importance in enabling this capability in teachers. Meanwhile the comparative education review reveals that whilst creativity has been included widely within educational policy documents[9], with high educational and societal value placed on it. A review by Bertram and Pascal (2002) of early years curricula in 20 different countries revealed that only in four countries (Italy, Japan, Korea, Sweden) was the centrality of creativity in children's learning and thinking one of the aims of early childhood education. The review on teacher education highlights the need to attend to teachers' perspectives. In the primary years, creativity is it seems predominantly focused on establishing a motivating learning environment that promotes thinking skills. The *Creative Little Scientists* project will need to explore ***how teachers conceive of and nurture creativity in early mathematics and science education***.

The *development of professional identity* as discussed in Section C, has links to self-regulation, ownership, lifelong learning, role of systematic reflection, teachers as researchers and the role and importance of

[9] A survey of 16 countries in Europe, America and East Asia revealed creativity and art embedded in curriculum in each (Shaheen, 2010) with aims which focus on skills, conditions or abilities to develop creativity. In US education aims focus on applying strategies for creative thinking and similarly Hong Kong refers to higher order thinking skills. The Singapore curriculum expects pupils to become creative and imaginative while in China it has become one of the priority aims of education. Although Shaheen also suggests that in Ireland, Scotland and Turkey the role of creativity in educational policy statements is less explicitly stated.

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classroom-based research. Reflective practice is an important aspect of the teaching profession and is developed from ITE throughout the teaching career with reflection triggering prior knowledge and linking with new ideas; thus teachers are researchers and innovators. The development of reflective practice is, in many ways, self-regulated.

As discussed in Section C, the literature review on teacher education argues that teacher development should not only focus on changing behaviour, competencies or beliefs, but also take into account future teachers' professional identity and their mission as a teacher on a more profound level (Korthagen, 2004). This professional development is related to concepts of 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). Section C of this Conceptual Framework discusses the need for teacher education programmes to integrate practice and theory building on teachers' own beliefs.

The nature of the links and partnerships between ITE and in-service education and conceptualisations of and attitudes to creativity in early science and mathematics education can also be drawn from the synthesis of the literature reviews. In a collaborative ITE and CPD professional development programme the features of effective engagement could be incorporated. **It is possible that extending the programme to include ITE teachers could widen student teachers' conceptions of engagement and increase their repertoire of teaching behaviours** (Newton and Newton, 2011) and help teachers and ITE teachers to update teacher skills and learn from peers. This could occur through a constructivist learning format in which CPD teachers as lifelong learners collaboratively plan, develop and deliver diverse kinds of educational resources. In this respect, it is assumed that professional development designers deliberately create experiences in which ITE and CPD teachers share and discuss their attitudes and abilities with one another and with other education institutions.

E1.3 Curriculum Design

There are similarities and differences across Europe in curriculum design as identified in the literature reviews and highlighted in Section C above. Significant amongst the differences is the amount of teacher autonomy in designing the curriculum and deciding which pedagogical approaches are best for specific learning contexts. If teachers are to gain proficiency in curriculum design, it seems to follow that, not only should they have good subject and pedagogical knowledge, effective pedagogical skills and an understanding of the social and cultural dimensions of education (European Commission 2007), but they need to understand the curriculum they are expected to teach (European Commission 2011a) and the background to the design of the curriculum. Further, if teachers have

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some autonomy in curriculum design their attitudes towards the subject and subject pedagogy may be improved; the importance of breaking the negative cycle of competence and confidence is highlighted in studies (e.g. Bleicher, 2009; Brady and Bowd, 2005; Brigido et al. 2010). Attention to curriculum design and implications for teacher education will form a focus of WP5.

E2. Focus Area 2: Evidencing Practice

The contributing reviews highlight that although across Europe and at individual country level, creativity is framed to some degree (differently in each context) at policy level, and science and mathematics are framed more extensively, little is known about patterns of learning and teaching in these areas in the participating countries. Thus the second major area, then, which the project will need to address, is the evidencing of science and mathematics practice in the early years and its relationships to creativity.

This will involve some investigation of how the problem finding and problem solving inherent in IBSE is being adopted across Europe in relation to science and mathematics in the early years, and in relation to potential creative dimensions of these in learning and teaching.

Given the span of age being researched (3-8 years old), the **research might use as lenses Banaji and Burn's (2010) creative classroom discourse with its focus on teaching and learning, and also the discourse they identify as widespread in education of play and creativity with its emphasis on exploratory playful engagement**.

E2.1 Policy perspective

In WP2 much work has already been undertaken on the nature of the curriculum frameworks for science and mathematics, and also the policy framing for creativity. These discussions have been undertaken from the perspective of the nine countries involved in *Creative Little Scientists* and also at European level. In evidencing practice through policy framing and classroom activity, the study will bring to the fore tensions between policy, practice and research. For example, as discussed in E1.3 above, there are current tensions between:

- policy at national level that structures the curriculum and focuses on conceptual knowledge;
- policy and practice at regional and school levels, as policy is interpreted and adapted for specific regional and individual contexts;
- research into pedagogical approaches that indicate that inquiry and problem based approaches are more effective in developing scientific and mathematical literacy.

The literature reviews have highlighted the role of IBSE and CA and the further potential for these in pre-school and early primary education. In WP3 there will be a further opportunity to develop through the desk

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study an understanding of policy, curriculum design at national, regional and institutional / school level. In WP3 and WP4 there are further opportunities to develop understanding of how practices in the nine participating countries articulate with the policies and the research into these practices. The questionnaire element of WP3 will enable the study to document teachers' perspectives on this articulation.

The reviews have highlighted common goals across the countries participating in *Creative Little Scientists* in teacher education (Snoek and Zogla, 2009) but also differences in policy and practice in teacher education (at both ITE and CPD levels). For example, the evidence from the research and policy statements in the literature review of Comparative Education (Addendum 4 out of 4) suggests that many professional development programmes succeeded in making an impact due to multidimensional support delivery to teachers following intensive training for context-specific purposes. WP3 will be able to explore the features of these programmes and map how such programmes impact on practices at regional and institutional levels.

E2.2 Classroom level

At classroom level, the empirical work undertaken through the survey in WP3 but to a greater extent through the classroom work researching teaching and learning undertaken in WP4, will need to explore the three areas of learning, pedagogy and assessment in science and mathematics education in the early years and their intersections with creativity. **Researching teaching and learning would foreground children as active agents, recognise multimodal expression and experience, include for example exploration of the kinds of activity undertaken, roles undertaken by adults and children** including the scaffolding which occurs during dynamic interaction between teacher, materials and children, the sorts of resources used, the role of exploration, questioning and argument, and how teachers assess creativity in science and mathematics education in the early years. The proposed foci in each of the three key areas of learning, pedagogy and assessment are now discussed in closer detail.

E2.2.1 Learning

The classroom focused part of the project (WP4) will need to include a focus on the following four areas discussed in section B: play and exploration, motivation and affect, dialogue and collaboration, and questioning and curiosity, in early science and mathematics education.

In relation to play and exploration, there appears to be consensus among scholars that playful exploration and experimentation is inherent in young children's activity (e.g. Larsson and Halldén, 2010; Gopnik, Sobel, Schulz and Glymour, 2001) and that it is also at the core of IBSE and CA in the early years. The three forms of playful 'experimentation' described by Poddiakov (2011): 'personal experimentation [mental]', 'utilitarian experimentation [physical]' and 'social experimentation', connect to

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research in young children's 'possibility thinking' (Burnard et al., 2006; Cremin et al., 2006; Craft et al., 2012). The extent to which the research into play and exploration has impacted on practice will be explored in WP3. The provision of open-ended, exploratory contexts and sufficient time and space, together with rich stimulating environments indoor and outdoor, seem to be important in enabling children's science, mathematics and creativity. There is an opportunity for WP3 and WP4 to explore the extent that these strategies and approaches are evidenced in classrooms.

In relation to motivation and affect, existing research highlights that playful exploratory contexts for learning in relation to science, mathematics and creativity foster agentic motivation and positive attitudes (Koballa and Glynn, 2008) and the hands-on experience can enable children to see the relevance of science and mathematics to their lives (ibid and Kramer and Raber-Keberg, 2011). The aesthetic dimension seems also to be important in prompting curiosity and can prompt scientific inquiry to explain phenomena (Milne, 2010); and the power of narrative has also been highlighted as enabling creativity in different domains (Bruner, 1986; Craft et al., 2012; Cremin et al., 2006; Paley, 200; Sawyer, 2004a, 2004b). **The study will need to document how motivation and affect are entwined in the classrooms involved in *Creative Little Scientists*.**

In relation to dialogue and collaboration, it is clear that research focusing on IBSE and CA highlights the significance of dialogue and collaborative learning and the core role of language and dialogic engagement has been highlighted in fostering creativity in the classroom. Inter-subjective co-construction and collaboration seems to be nurtured in dialogic contexts. **The balance between teacher-supported dialogue which may include ground rules, puppets or training, and child-initiated engagement has been highlighted as a possible area for focus** in that it is claimed that children may be skilful in engaging with science and mathematics and in developing creative ideas, in the absence of teacher support (e.g. Kramer and Rabe-Kleberg, 2011; Naylor et al., 2007). This is further discussed under pedagogy below.

In relation to questioning and curiosity, the study will need to explore the role of children's and teachers' questions, as discussed in section B3.6 above. In particular, the documented tension between children's innate curiosity, their reflection and reasoning and orientation toward problem finding and problem solving, and the potential of the educational process to stifle this, their questioning and their engagement in mental play (Nickerson, 1999) will need to be explored. Yet, the potential for teacher questioning to achieve high levels of involvement and learning (e.g. Craft, 2002; Cremin et al., 2009; Robertson, 2009; Rojas-Drummond and Zapata, 2005) will also need to be explored in the study. **The role of context, and the balance between children's and teachers' questions as well as the kinds of questions posed, will need to be**

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teased out together with how teachers model and foster positive attitudes toward curiosity and questioning.

E2.2.2 Pedagogy

The classroom focused part of the project (WP4) will need to include a focus on how teachers engage in scaffolding young children's learning in science and mathematics in the early years. **Both IBSE and CA include a focus on exploratory problem finding and problem solving and studies reveal that the ways in which teachers scaffold their creativity, their conceptual knowledge and their meta-cognitive strategies is important to nurturing children's capacities. This seems a particularly rich area for exploration given the sensitivity of the balance between teacher instruction and child-led investigatio**n highlighted by Bonawitz et al. (2011) and also Kramer and Rebe-Kleberg (2011) discussed in B3.8 both of which suggest the significance of sensitive 'standing back' (Cremin et al., 2006) and close observation by teachers of children's learning. Recent studies which explore the complexity of co-authoring between children and teachers (e.g. Craft et al., 2012) suggest that documenting practice needs to be sensitive to ways in which power relationships in the mathematics and science classroom may vary and may enable children's conceptual development as well as their creativity in these domains.

Related to the scaffolding of children's learning, is the role of teachers in assessment for learning. **The study will need to explore how teachers collect assessment data and use it for learning and teaching**. Assessment for learning takes a holistic perspective on children's learning in science and mathematics education, recognising multiple ways in which children show what they can do and understand, and involving children in feedback so as to inform next learning. The project will need to ascertain how widespread such practices are across the early years spectrum investigated, in the nine participating countries in *Creative Little Scientists*.

As indicated above, **teasing out the inter-relationships between the fostering of creativity within mathematics and science and the innovative and creative practices of practitioners will also need to be scrutinised and characterised.**

E2.2.3 Assessment

Given the profile of TIMMS and PISA and the European emphasis on developing ways of monitoring creativity in children and young people, empirical work in *Creative Little Scientists* in this regard appears to be fruitful. Currently the cognitive domains of TIMSS and the problem solving approach in PISA have some connections to creativity. However, it could be beneficial for the project to seek to broaden the assessment and evaluation of science and mathematics through employing a creativity lens in the context of inquiry. As indicated in section B4, whilst there are pressures on the education of older children toward summative

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and comparative assessment, the emphasis on young children's learning journeys and therefore the value of formative use of assessment, with sensitivity to context including multimodality, which increasingly frames learning in early science and mathematics, is mirrored by a concern to recognise complexity in the evaluation of creativity.

In all three domains (science and mathematics education and creativity), a contextualised, closely-observed, relational and sensitive approach to formative assessment is emerging in both practice and research. In other words, approaches that directly inform learning and teaching and emphasise the learner's trajectory, which contrast with summative assessment which summarises performance over time for the purposes of both comparison and reporting or accountability.

However undertaking formative assessment of creativity within science and mathematics education is not well developed or articulated in practice or research. In section B4, it was argued that a componential approach to understanding children's creativity (context-sensitive, used formatively, emphasising complexity and recognising the locus of judgement as encompassing the creator/s) is more appropriate than psychometric approaches (using de-contextualised tests for summative and comparative purposes). **Exploring therefore the sensitive and formative assessment of creativity in science and mathematics education would form a valuable focus in *Creative Little Scientists***. Such formative assessment should emphasise multi-modality, multiple components, locus of judgement (including involvement of children), use of formative assessment for learning. It should also acknowledge the potential interaction of formative and summative assessment for comparative purposes, and potential tensions between these and between componential and psychometric approaches to the assessment of creativity.

E3. Focus Area 3: Developing Practice

The *Creative Little Scientists* project aims to document how early years practitioners nurture science and mathematics and how creativity is evidenced in what they do. From the analysis produced through the conceptual and empirical work it seeks to offer guidelines, recommendations and curricula to develop practice in these areas. As such, it will need to focus mainly on areas E1 and E2, in other words documenting conceptualisations and curriculum design and classroom practices across the early years span in the nine partner countries in the study. Informed by the review of the literature which provides an insight into policy guidelines that influence learning and teaching approaches and teacher education, WP5 will as indicated provide information to make informed recommendations about how practice can be changed to further develop creativity in science and mathematics in the early years. To offer such guidelines for development the synthesis of the reviews indicates the following focus areas about the way practitioners nurture science and

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mathematics and how creativity is evidenced in what they do (offered in no significant order):

- There are relationships with regard to play and exploration, dialogue and collaboration, questioning and curiosity and, to a lesser extent, reflection and reasoning which have great potential for further exploration in WP3 and WP4 and to a degree WP5.
- WP3 and WP4 have the potential to evidence children's and teachers' lived experience of creativity in early science and mathematics education; the attitudes, skills and, pedagogical knowledge and thus bridge any existing gaps.
- *Creative Little Scientists* can contribute to the research gap that exists in understanding early years practitioners' sense of professional identity with respect to creativity in early mathematics and science.
- The development of effective links between ITE and CPD teacher education offers additional framing to the study of creativity in science and mathematics education and thus offer important foci within the project.

There are clearly opportunities to articulate the links between, explore the dynamics of and identify the current gaps within initial and CPD teacher education; for example, how to attract and retain more diverse student teachers; what is the development of professional identity with respect to science, mathematics and creativity. There are also opportunities to explore gaps in the research that focuses on the nature of early years education and its relationship with early care in the different partner nations in *Creative Little Scientists* and the nature, or type, of comparative education. The reviews also indicate opportunities to explore and compare policy guidelines that influence learning and teaching approaches and teacher education.

The discussion on education and care practice in Section D suggests that the focus of *Creative Little Scientists* is a thematic study considering the themes of creativity, science and mathematics across the early years (3 to 8 years old) across nine EU countries. As such and through both WP3 and WP5, *Creative Little Scientists* should be able to create an international data set created from national data from each participating country. At this early stage it is already evident that in the curricula there are potential tensions between instrumentalist and self-actualisation discourses (Gibson, 2005), the former being an important strand in European Union policy. These will need to be teased out further during the study.

It is suggested that the main approach of the project will be to reveal practices. The contribution to professional and practice development made by the project will thus emerge from its findings. It is proposed that the study will adopt a design which

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documents and analyses rather than having an intervention design. See further discussion on this in Section F.

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F. METHODOLOGICAL ISSUES FROM LITERATURE REVIEWS

In this section the methodological issues that have arisen from the literature reviews are considered. Methodological issues arising from classroom-based studies in science and mathematics education are discussed, then creativity research is considered. Next, methodological issues emerging from studies of teacher education and comparative education are addressed in turn, before looking to the commonalities across these four fields. Finally in this section, possible implications for the *Creative Little Scientists* project are considered.

F1. Researching Science and Mathematics Education: Methodological Issues

The fields of science and mathematics educational research are vast and encompass a wide range of methodologies. In this sense, the idea of 'commonalities' in science and mathematics educational research may be somewhat misleading, for when there is such a large body to draw on, examples can always be found to support any argument. Aiming to classify research simply by methodology in this case then will not add deeply to our understanding of the field. What may be more illuminating is to look at the various areas of science and mathematics education that have been researched and look to identify commonalities within each of these. In the literature review, amongst the many themes that emerged, there were two areas of research that appeared to be of interest for the study; early education and preschool, and inquiry-based education.

Early education and preschool educational research appears to look largely at cognitive and child-development issues. The wide range of cognitive development theories has led to a number of different methods and approaches to research being developed in order to explore these concepts. As recent work has aimed to highlight the potential limitations of trying to capture children's thinking through traditional static media such as paper (Ellerton and Clements, 1997) there has been a move away from traditional pencil-and-paper based testing as a measure of learning or cognitive development. **This has made it necessary to develop more qualitative methods, such as a 'multi-modal approaches' that focus on the wide range of ways that children express their embodied thinking** (Glauert, 2009b). These approaches may include children's physical interactions, their gestures and their speech. Indeed, recent work has highlighted how children use gesture to support cognition (Goldin-Meadow, Nusbaum, Kelly and Wagner, 2001) and are often able to express their understanding of certain concepts through modes such as gestures before speech (Goldin-Meadow, 2009). These approaches all require a much more intensive input from the researcher than perhaps straightforward pencil-and-paper testing may have done. Careful observation of classroom activity is needed in order to collect data that can be relied upon as representative of particular

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children. As such, while in the past cognitive research was largely quantitative in nature, there has been a recent increase in studies using qualitative or mixed methodologies, along with an increase in studies of early years science.

Inquiry-based learning revolves around the notion of investigation in science and mathematics (Drayton and Falk, 2001) and may be particularly important for this study. In much of this research, both in science and mathematics education, the term 'inquiry' is often used alongside 'creativity' and therefore may provide an initial insight into how it might be possible to examine creativity in the science and mathematics classrooms.

There is a growing body of research into children's explorations and inquiry processes in the early years – mostly qualitative that highlights young children's motivations and capacities to engage in inquiry. In contrast classroom based research into inquiry–based learning in later years is largely quantitative as studies aim to look for the impact that particular inquiry-based interventions may have on student learning. It appears that these are either action research or short interventions such as Akerson and Donnelly (2010) who carried out a 6-week intervention programme examining young children's views of nature of science, using explicit reflective instruction and contextualized and decontextualized guided and authentic inquiry, while Simsek and Kabapinar (2010) used an inquiry-based learning intervention to examine the effect on children's science process skills and attitudes.

There are opportunities, then, in *Creative Little Scientists* to develop more qualitatively focused approaches to researching, encompassing the processes of learning and not only the outcomes.

F2. Researching Creativity: Methodological Issues

F2.1 Creativity research methodologies

Creativity research has undergone an explosion across the paradigmatic spectrum over the last sixty years. Mumford (2003) describes a wide range of methodologies and methods, and definitions and interpretations of creativity, that have developed over the last 60 years from Guilford's seminal speech (1950). These described by Mumford are all, however, within the field of psychology and social-psychology. Creativity research has expanded far further, into a wide range of academic fields, for example to the field of neuropsychology, through observing brain activity during periods of 'being creative' (e.g. Fink, Benedek, Grabner, Staudt and Neubauer, 2007; Howard-Jones, 2002, 2005). Academic interest in creativity has, of course, also expanded to educational research.

Empirical research undertaken in the field of educational research spans both positivist and interpretivist paradigms and therefore both quantitative (in which control groups are used, for example Peters, 1998,

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in New Zealand and Kamberelis, 1999 in the USA), and qualitative methodologies - for example, Troman (2008), and Troman and Jeffrey (2008) in England, and Paley (e.g. 2001) and also Sawyer (e.g. 2004b) in USA. Additionally, there are studies undertaken using mixed methods, particularly those interested in teachers' attitudes (Harkness and Portwood, 2007; Smith, 1996; Westby and Dawson, 1995). Interestingly however, little research in the field of creativity in the early years appears to be undertaken in the critical paradigm, which may reflect both the age range (up to the age of eight) and perhaps also cultural beliefs around the world in relation to the education of the youngest children. Current methodological approaches and interests can largely be split on geographical grounds. Research undertaken in the United States and Far East tends to be undertaken more in the positivist paradigm. Much positivist creativity research revolves around the testing of creativity, with the Torrance Tests of Creative Thinking (TTCT) holding particular sway in the USA, while in Hong Kong the Wallach-Kogan tests are more prevalent. Much of this research involves developing ways of increasing participants' creativity, as measured by their test scores. This highlights the point made by Fendler (2007) that particularly in the USA, educational research must show some sign of 'what works' in education. In Europe, the focus has been more mixed, with a much larger focus on interpretative approaches and methodologies.

However it may be that neuroscience has an emerging role to play in researching creativity, for example, work by Howard-Jones (2002) and Garaigordobil and Berrueco (2011) have looked at the effect of play on creativity in the classroom, using quantitative methods of pre- and post-assessments, with both studies suggesting that sustained periods of regular play in early years settings increase creative thinking in young children. Despite the apparent contradiction in choice of methodologies, the *Creative Little Scientists* team suggests this complements arguments made from an interpretive perspective, that research approaches tend to reflect the perspective that play is the context for creativity in the early years (for example, Bancroft et al., 2008, Craft et al., 2012) and that children's representations afford opportunities for insight into young children's creativity.

As well as the tension between positivist and interpretivist paradigms (and therefore between quantitative and qualitative methodologies), there is a potential tension in focus as the next section goes on to consider.

F2.2 Challenges for research on creativity

Looking at the studies above, it may be possible to characterise research into two different foci. The first is research that identifies creativity as the main topic of interest and is the focus of the research. Examples of this would be the studies into TTCT and Wollach-Kogan tests, where the focus of research is specifically on creativity scores, and also the work on Possibility Thinking, where the aim of the research is to identify the

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processes or mechanisms of creative activity in the classroom. In *Creative Little Scientists*, this would involve studying creativity within the context of science and mathematics education, for example looking at how young children evidence or exhibit various characteristics of creativity in their science activity. The second focus would involve using identifiers of creativity more as an indicator or measurement tool with a view to examining further aspects of (in this case) learning or child development. Examples of these might be the text-making studies by Pahl (2007) or Canning's (2010) work on outdoor play, where children's creative outcomes/activity may be used as indicators of progression over time. **In *Creative Little Scientists* this approach would mean creativity is seen as a lens for analysing practice and learning in science and mathematics**.

The distinction becomes important when considering the focus of the *Creative Little Scientists* project. It is important to establish which avenue this study will take – whether it is a study of the concept of creativity in the context of science and mathematics education or whether creativity is used more as a lens for analysing practice. This is discussed further below.

F3. Teacher Education: Methodological Issues

F3.1 Teacher Education Research Methodologies

As with much educational research, the field has changed and evolved over time, reflecting the changes in approaches to teacher education. These approaches have focused largely on the respective roles of theory and practice in the training of ITE teachers and development of CPD teachers and the extent to which each, or rather the combination of both, increase the effectiveness of teaching practice. This has led to studies focusing on ways in which these programmes can be improved upon. Research in both qualitative and quantitative arenas has explored this, looking at case studies of teachers' practice (e.g. Korthagen, 2004; Korthagen and Kessels, 1999) and intervention studies (e.g. Clift and Brady, 2005; Risko et al., 2008).

One area of research that has seen particular attention is the attitudes, perceptions and beliefs of practitioners towards various concepts in education, due to their impact on pedagogy and teaching practices and to their potential implications for professional development. Particularly in science and mathematics educational research, studies have largely been qualitative in nature, with data collection often by means of teacher interviews, focus groups, and/or surveys, and grounded theory used for data analysis (e.g. Downing and Filer, 1999; Ireland, Watters, Brownlee and Lupton, 2011; Yilmaz-Tuzin, 2007; Zacharos et al., 2007), however more quantitative methods, such as questionnaires and surveys have been also been used to examine teachers' perceptions about learning (e.g. Diakidoy and Kanari, 1999; Duell and Schommer-Aikins, 2001; Fraser, 1982).

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Action research has emerged in recent years as a significant methodology for development, intervention, and change. Under this approach, practitioners themselves are the researchers, rather than the researched, with the aim of exploring their own teaching practice. This allows the voice and interpretations of the teacher-researcher to permeate throughout the research process. In qualitative research, this lends strength to claims of trustworthiness and reliability, issues discussed in more detail below in F5.6.

F4. Comparative Education Research: Methodological issues

F4.1 Construction of comparative education

Comparative education as a phrase first gained prominence in the 1950s however its roots lie far further back in the late 19th century, when research reflected scholars' curiosities towards other countries and educational processes. Since then it has undergone a number of changes both in focus and in methodology in the intervening years, reflecting the changes of the economic world and the development of conceptions of knowledge (Halls, 1990; Novoa and Yariv-Mashal, 2003; Swing, 2006), as individuals and indeed countries seek to create international tools and comparative indicators to measure the efficiency and the quality of education. Comparative education can be divided into two subsets – firstly thematic research, where particular phenomena are highlighted, measured and compared across international boundaries and secondly area studies where the focus is on a particular region or country.

There have been a number of approaches attempting to 'measure the other' over the last decade that are common to both subsets. Case studies provide a rich and multidimensional way to theorize comparisons, but at the same time do not limit the possibility of new viewpoints. Case study comparisons between educational approaches in different countries are common (e.g. Aunio et al., 2008; Hong and Kang, 2010; O' Sullivan, Wolhuter, and Maarman, 2010; van de Grift, 2007), as are comparisons from different areas of the same country (e.g. Cooper and Dilek, 2001, Einarsdóttir, 2003). Central to both thematic and area studies in comparative educational research is the need to collect similar data from the various sites as it is only then that comparisons across the data set may be made. Thus in qualitative studies, data are typically collected through observation and/or semi-structured or structured interviews (in order to ensure that similar ground is being covered in all sites). Quantitative methods are also used in this field, for example the work of van de Grift (2007) who made observations of over 800 lessons in four countries. Lessons were rated according to a devised scale, and this data set was then statistically analysed.

However, the more noted studies in comparative education appear to be large-scale, international comparisons of quantitative data. These types of study provide vast quantities of data that individuals, and indeed

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governments, can use to inform practice and policy. Two particularly pertinent international studies in science and mathematics are the '*Trends in International Mathematics and Science Study*' [TIMSS] (Mullis et al., 2003) and the '*Programme for International Student Assessment*' [PISA] (OECD, 2010c). Both of these studies are huge (TIMSS with 60 participant countries and PISA with over 70 participant countries) and both evaluate attainment in particular areas of mathematics and science in order to draw international comparisons. As a result of these attainment scores, comparisons, league tables and relative progress (in comparison to other countries) may be calculated.

F4.2 Challenges for research in comparative education

There are a number of methodological challenges involved in comparative education. When constructing and implementing comparative educational research, there are issues of cultural or contextual issues that need to be addressed. For example language, or rather translation, may be an issue in some cases, especially when designing questionnaires or surveys. What is meant by even the most basic words can be obscured when translated from one language into another. Furthermore, particular words may carry more cultural significance in one language than another – Sternberg (2007) highlights this with the example of the word 'intelligence', a highly value-laden word and which is interpreted in different cultures to mean different things. Thus while questionnaires and surveys are common tools in comparative education, there are potential challenges of socially desirable responses or translation problems.

As with any field of research, there are a number of limitations depending on the methodology used. Large-scale surveys such as PISA (OECD, 2010c) and TIMSS (Mullis et al., 2003) are unable to recognize and elaborate the role of language or differentiate on the basis of cultural dependencies or socio-scientific issues (Goldstein, 2004), that is ideas about science (the processes and practices of science), and may only provide limited explanation for variation in individual achievement (Stromquist, 2005). Furthermore, it does not provide possibilities to analyse developmental trends or the validation of developmental hypotheses (Krapp and Prenzel, 2011). Smaller, more qualitative studies, while potentially being able to examine these issues, are extremely intensive and therefore are limited in their sample size. With this comes issues of representativeness and generalisation. There must therefore be a trade-off between these factors, leading to continuous debate about the relevance of qualitative and quantitative methods in comparative studies.

There appear then to be three main challenges of comparative education research:

- Establishing similarities and differences within common research units across a range of countries, each with individual cultural and contextual influences;

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- Establishing how analysis can be conducted using common philosophical, theoretical and methodological decisions;
- Finding theory and respective method which support each other and are able to reveal rich and deep information of the context while still supporting the development of theory (Välimaa, 2011).

F5. Methodological Issues for *Creative Little Scientists*

There are six sets of methodological issues that emerge from synthesising the literature reviews: language and meaning, the selection of sample, research approaches and methods, the balance between science, mathematics and creativity, the nature of comparative research being undertaken and addressing reliability, validity and trustworthiness.

F5.1 Language and meaning

The three challenges for comparative education highlighted by Välimaa (2011) appear to be especially pertinent to the *Creative Little Scientists* study and may all be described as challenges around establishing common language and common meanings in the research. The first challenge, to develop a common set of linguistic understandings across the countries involved in the study, seems especially important. The word 'creativity' has often been described as a 'value laden' term (Huckstep and Rowland, 2001) and its meaning can potentially be unclear. Developing a language for researching and conceptualising creativity in the context of early mathematics and science across nine partner countries in Europe may be challenging; a starting point for defining creativity is given in the Glossary (Appendix 1) however it will be seen that already there are tensions between possible interpretations. **Considering 'value laden' terms across cultures with varying value systems is something of which to be particularly wary**. Indeed, even what might be considered as a fairly uncontroversial term 'Early Years education' means different things across Europe, with each country having different ages for children starting school discussed further in F5.2. The second point that Välimaa raised was to ensure that when data collection and analysis occur, they are done so using common or accepted philosophical, theoretical and methodological decisions. The extensive literature reviews conducted before empirical work started will hopefully have gone some way to addressing this issue, however it is important to recognise that throughout the study this may arise. Similarly, the work done before the empirical study commenced may also help address Välimaa's third point, the need to find a methodology that is able to gather in-depth information of each site while at the same time still supporting the development of theory in relation to the interface between creativity, science and mathematics in the early years classroom.

F5.2 Sample

The Description of Work for *Creative Little Scientists* sets out two types of data collection; one in WP3 involves a survey of early years educators in

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the participating countries and the second in WP4 involves classroom-based empirical research in five to ten sites in each participating country. Decisions will need to be made on size and scope of each sample and a dimension of this will be how to capture the breadth of the early years spectrum of 3 to 8 when the pre-school period and school starting age varies so widely as does pre-school provision. It may be that the project needs to encompass the entire range at the survey stage but that it will need to focus in depth certainly in the second phase of the empirical work, on each end of the spectrum (at the upper end, 7- to 8-year-olds, and at the lower end, the highest pre-school age of 4-5).

F5.3 Research approaches and methods

With a tension between possibilities offered by revealing lived experience and at the same time the opportunity to draw comparisons across participating countries in this study, it is suggested an interpretive approach will offer a means of closely documenting experience, building on other early years studies in relation to science, mathematics and creativity. Within this framing there is a survey element built in to the research design as submitted in the bid for the project. ***Creative Little Scientists* will thus seek to reveal lived perspectives but by using the survey tool, comparisons will be able to be made.**

Within the interpretive paradigm, the conceptual focus articulated above suggests a socio cultural framing to the *Creative Little Scientists* research study. Rogoff's three foci of analysis (Rogoff, 1997) cited in Robbins (2005) may provide an appropriate socio-cultural methodological tool, considering three aspects:

- personal (focus on the child and what they are doing)
- interpersonal (interactions with peers, teachers), and
- contextual (resources, physical arrangements, teacher beliefs, institutional factors).

When considering research approaches and methods, there will be a number of methodological factors that must be considered. These may include particular needs to:

- Develop research approaches sensitive to capabilities of young children including those which could involve children in the research process. The project may be developing and testing criteria and approaches to assess opportunities for learning and the potential for creativity, however there may be a need to move beyond broad generalisation.
- In sampling, to attend to children's backgrounds[10].
- Identify and capture contextual factors in empirical work. These factors are widely recognised to have substantial influence on

[10] In fact, this issue did not arise in the Literature Reviews however it does seem important to attend to this in the study in seeking variety as well as depth.

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teaching and learning, therefore there is the need to explore a wide range of contexts and establish which dimensions are to be examined.

- Gain a sense of teaching approaches and opportunities for learning. This will need to examine teaching over time, not just a momentary snapshot.
- Establish both what is possible to know from questionnaire surveys and how this will aid what knowledge is being sought. Attempts to gain insights into teachers' views and practices may be challenging; approaches to teaching are often implicit. Qualitative ways to capture teachers' views and dynamic of teacher decision-making need to be established as well as identifying national patterns.
- Develop research approaches that learn from previous comparative research studies and fill the gaps in comparative research findings, ensuring *Creative Little Scientists* research is both valid and reliable as well as trustworthy (a term more commonly used for interpretive work; see below).
- Develop approaches that recognise synergy between education and care practice and between cognitive / affective development.
- Recognise need for sensitivity to potential differences between teachers' stated beliefs and practice and therefore to treat with caution self-reported data about this.
- Develop approaches that document, analyse and develop curriculum design.
- Recognise increasing awareness of the effectiveness of a partnership approach to ITE and CPD teacher education and importance for both pre- and CPD education of developing professional identity.
- Find ways to capture writing up 'worked examples' so as to convey rich complex realities and the potential for creativity in varied contexts.
- Recognise the team's own potential biases as researchers.
- Devise teacher training materials and activities to support IBSE and creativity in mathematics and science that avoid a recipe approach and that promote awareness of alternatives and teacher decision-making.

In addition, research similar to van de Grift's study (2007) that uses both qualitative and quantitative methods within an overall interpretive frame that emphasises lived experience may be of particular interest to the *Creative Little Scientists* project. Indeed, Sayer (2008) suggests that both qualitative and quantitative methods may be valuable for research and can in turn be engendered in the process of development work; both

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approaches are already built into the research design of *Creative Little Scientists* as articulated in the original research proposal.

Sensitivity to what young children can do and understand will be important in *Creative Little Scientists*. New approaches to observation and assessment, such as the multi-modal assessment described by Glauert (2009b), have meant that emphasis has shifted from the child being required to show the researcher what he or she is capable of by way of some sort of validation, onto the researcher. **The researcher must take the responsibility to learn from the child through close attention to a wide range of facets.** It will be important to consider this when designing research instruments for the study, and also the analytic approaches.

Related to this is the question of whether *Creative Little Scientists* will be documenting experience, or seeking to set up an 'intervention' study. Given the gap in knowledge about how very young children learn science and mathematics across the nine partner countries and how (if) creativity is involved in this, it seems **the documenting and analysis of practice must be the priority of the project.** The establishment of possible intervention studies or other approaches such as further literature-led analyses would be subsequent research designs for future studies which could appropriate the findings of this initial mapping (which is of course informed by the literature reviews undertaken in WP2 as a foundation for the project, and the further desk study in WP3).

F5.4 The balance between science, mathematics and creativity

When considering mathematics, science and creativity in the early years, the research encompassing all three is fairly scarce, therefore looking to other studies to build on directly is not possible. However, the discussion in section B highlighted synergies between IBSE and CA, identifying the following as common to both approaches:

- Play and exploration
- Motivation and affect
- Dialogue and collaboration
- Questioning and curiosity
- Problem-solving and agency
- Reflection and reasoning
- Teacher scaffolding and involvement
- Assessment for learning
- Tensions in developing contexts for inquiry and exploration

These may therefore provide rich analytic contexts in which to situate the science and mathematics education research. Each of these provides exciting opportunities and potential avenues to explore within the science and mathematics classrooms and children's inquiry work within them.

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As discussed in F2.2, there are two possible framings for researching creativity. Of particular interest perhaps for the *Creative Little Scientists* project is the second of these, looking at how studies have used creativity more as a context for research, rather than necessarily the subject of research itself. **It is proposed that *Creative Little Scientists* seeks to identify and characterise how early science and mathematics are fostered and what if any creativity is evidenced in so doing.** In so doing the study will produce a map of lived experience in providing early years science and mathematics education and will also articulate what creativity in early science and mathematics might look like.

It should also be noted that as discussed earlier, in section B approaches to researching creativity in education may include a focus on children's creativity and/or creativity in teaching. This study will need to be open to documenting both in the context of science and mathematics teaching.

F5.5 Type of comparative study

In its attempt to investigate the concepts of science, mathematics and creativity across a number of European countries, the *Creative Little Scientists* study can be described as a thematic study in comparative education. This has a number of implications on the study, not least the impact of language and meaning discussed above in F5.1. In order to address this, we may want to look at similar comparative studies in early years, or in science and mathematics education and creativity.

When looking across the various research areas however, we can see that the early years phase can often be left out of discussions in the key areas that this study aims to look at. There are relatively few comparative studies in the early years, while mathematics and science education and creativity seem to be underrepresented. Why this might be is an important point to examine. The aims or ultimate purposes of research need to be considered. For example, Lester and William (2002) suggest that for research to be influential in terms of policy, it must be able to make generalizable claims and recommendations. As we have seen, much of the research into creativity is qualitative and can make no claims to generalizability (nor does it seek to). However, Fendler (2007) has suggested especially in mathematics educational research political pressures often dictate this generalisation is a necessity. We may see here potential clues as to why research in these respective fields is lacking; investigating children's capabilities in ways that may be considered to be valid is demanding, time consuming and thus expensive. For the *Creative Little Scientists* project then, a balance must be sought between collecting rich a data set through methods that may be demanding and time consuming and the constraints that accompany thematic comparative educational research. Importantly, the qualitative data gained from the research methodologies discussed above do offer a richness of lived experience, albeit bringing key challenges which are addressed below in F5.6.

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F5.6 Addressing reliability, validity and trustworthiness

There are several questions that need to be considered to ensure the reliability and validity of comparative studies. There are questions about whether the description is of a homogenous reality and how well it takes account of the local context (Keränen, 2001), specifically how well the structure, culture and geographical location are taken account of in the comparisons (Välimaa, 2008). Official data sources may provide data that aim to show the positive aspects of education, presenting a biased picture (Crossley and Watson, 2003). In the literature reviews details about national policies and curricula were gathered but these may not reflect the curriculum as it exists in schools. There is also the danger that when data is derived out of its context it may not be understood properly and misleading justifications can be made (Sternberg, 2007). Other difficulties are that the sample may not be representative and it may not be possible to account for all variables. To overcome these challenges, comparative education always includes several viewpoints that are taken into consideration when making deep analysis. However, the educators and researchers may have preconceptions and stereotypes that result in bias (Crossley and Watson, 2003). For *Creative Little Scientists* this means that official data needs to be related to actual practice, collected through questionnaires and observations. The national data should be analysed through multiple viewpoints, including both participants from that nation and participants from other nations. In terms of sample the *Creative Little Scientists* project will need to determine which variables have to be considered in order to decide what would constitute a representative sample. This is made more complex because of the differences in the organization of early years education in the participating countries.

It is also important however to understand that if this study is framed in an interpretive context, considering the study's trustworthiness (Lincoln and Guba, 1985) may be more appropriate, encompassing credibility, transferability, dependability and confirmability; each of these can be addressed through a range of strategies.

F6. Proposed Research Approach in *Creative Little Scientists*

In terms of the overall research approach, we propose *Creative Little Scientists* adopts the interpretive paradigm, within which we would include the initial survey of teachers' perspectives to help focus the classroom-based data collection. This latter will use methods such as observation (including video material), digital images, outcomes produced by children including written work, audio recording of children's learning, discussions with children and teachers (perhaps also including parents), journal entries by teachers. Given the depth and breadth of literature emphasising the need to acknowledge what children know and can do, it may be prudent to explore the collecting of qualitative data alongside teachers to enable co-interpretation. The emphasis on

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understanding what children can do and how teachers enable this, may suggest a phenomenological approach highlighting a self-actualising perspective. The sample should include classrooms across the 3-8 spectrum in each country bearing in mind the differences in provision in each. We may need to consider sampling in depth two age groups, one at the end of the project's age range spectrum, so perhaps one group of 7-8 year-olds and the other at the highest preschool age possible (4-5[11] or 5-6).

It is proposed that the project seeks to capture excellent or exceptional practices in WP4. These will be identified by drawing up a set of criteria drawn from the literature reviews on science and mathematics in the early years and creativity in education in the early years. Methods of identifying sites in which such practices may be found will include peer, policy maker, senior practitioner or professional association recommendation, published reports citing good practice, previous or current involvement in other research studies with relevant research foci, balance between site foci, and willingness of staff to engage with researchers in making sense of practice.

The implementation of the research approach will occur in three phases as follows.

Phase 1: Work Package 3 (start of March until end of October 2012)
During the first phase, WP3, led by UEF and involving all partners, desk research (led by IOE) and also a survey (led by EA) will be undertaken. The desk research will focus on analysing records of policies, curricula, reports and assessments of school practice in the nine sample countries, and the survey will offer insights into the conditions pertaining in early years settings. The survey will be devised collaboratively and then translated; it will be made available online through SurveyMonkey. Guidelines for analysis will be agreed between partners. This phase will generate a number of deliverables including a report on existing approaches in relation to practices and conditions in real school practice, culminating in a comparative report which highlights emerging issues, specific context-related aspects etc. that will need deeper investigation in WP4.

Phase 2: Work Package 4 (start of November 2012 until end June 2012)
During the second phase, WP4 led by IoE and EA and involving all partners, will provide a deeper analysis through classroom based research with each partner undertaking research in a number of case study sites, each offering exceptional or exemplary cutting edge practice in relation to science and mathematics explored with the lens of creativity. Criteria for identifying sites will be drawn from the conceptual framework and from WP3 although provisional sites will be

[11] Although in England this is already the Reception class, in some ways the first year of school.

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identified during WP3 (around June 2012) giving partners time to build relationships. The methodology for this in depth field work will be developed further during an internal training workshop undertaken in November 2012 appended to the third Project Meeting to be held in London. Instruments and the analytic approach will then be confirmed and refined enabling field work (which will include a focus on both children and teachers) to be undertaken from December 2012. Instruments (not yet fully defined) are likely to include observation, interview, methods such as Mosaic Method or Laevers' Involvement Scale that seek to make visible non-verbal engagement by children as well as children's own perspectives. Analysis within-country will be completed by the end of April 2013, and a report on practices drawing together the findings across all countries, will be completed by end June 2013 together with a set of exemplary Case Studies.

Phase 3: Work Package 5 (start of March 2012 until Nov 2013)
WP 5 which focuses on a set of curriculum design principles (tested out in focus groups, reformulated, validated in new focus groups and refined enabling selection of exemplary teacher training materials) as concrete guidelines for European ITE and CPD programmes, is led by AUC throughout. It comprises the proposition of 'prototypical' curriculum design principles for teacher education (by end September 2012), the development of guidelines and curricula for teacher training (by end of August 2013) and the development of exemplary teacher training materials (by end of November 2013).

Running throughout the project, led by EA from the outset (October 2011) until the end of the final month (March 2014), is **WP6, the dissemination and exploitation** plan which specifies the methodology for the design, implementation, co-ordination and monitoring of all project activity aimed at disseminating its concepts and outputs to all stakeholders and the exploitation of it outcomes at European, international, national, regional/local and institutional level. The project thus seeks to both disseminate to stakeholders through multiple methods from website to other e-methods, to leaflets, newsletters and papers, and to exploit outcomes making these easily available in a range of media and forms. The project will culminate in a range of activities (June 2013), a final report and recommendations (February 2014), recommendations to policy makers and stakeholders (February 2014), and a final international project workshop (March 2014).

This can be represented as a flow diagram, below:

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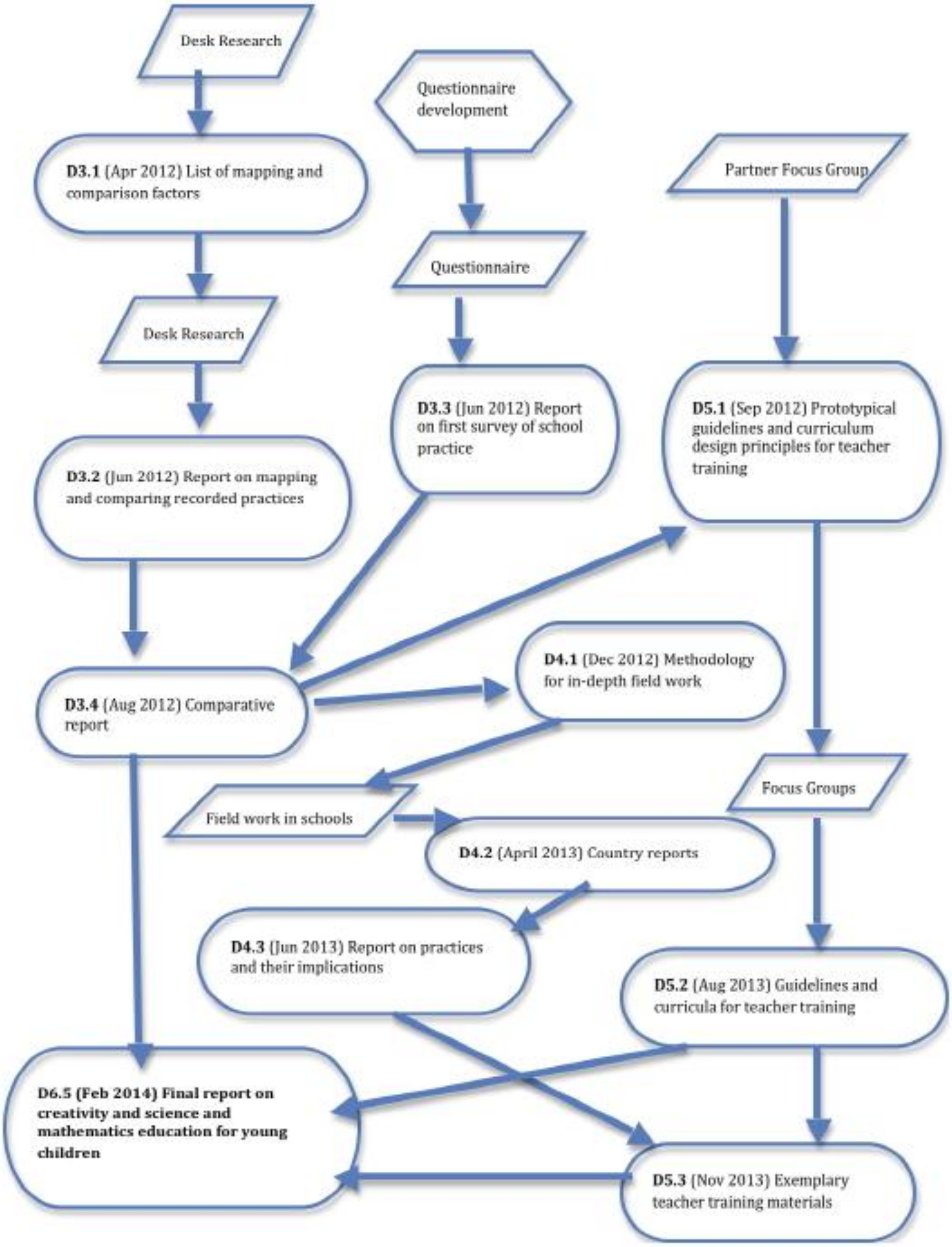

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G. PROVISIONAL AREAS FOR RESEARCH QUESTIONS

The conceptual and research foci and methodological framing discussed in sections B, C, D, E, and F above, suggest possible research questions are framed around the three areas of:

- *capturing curriculum focus and design*
- *evidencing practice*
- *developing practice*.

Provisional questions are offered prior to the desk study and questionnaire being undertaken in WP3 of *Creative Little Scientists* which will no doubt help to focus these still further in anticipation of the classroom focused fieldwork in WP4. These were confirmed and refined during discussion at the Consortium's 2nd Project meeting in Paris in March 2012.

The first question is focused on mapping conceptualisations in relation to classroom practices in preschools and early primary education and the second and the third on probing practice such settings in science and mathematics education using the lens of creativity. The final question draws on both the mapping and probing questions seeking to apply what has been learned so as to develop practice (in relation to CPD and ITE).

The research questions apply to the age span 3-8, and are likely of course to draw out differences within this early years phase which includes both pre-school and school provision. It should be noted that the questions probe *both* children's creativity and the creative pedagogy of teachers/early years practitioners.

1 *(Mapping conceptualisations):* How are the teaching, learning and assessment of science and mathematics in early years in the partner countries conceptualised by teachers and what role if any does creativity play in these? This would include how teachers conceptualise objectives and outcomes as well as how policy frames these.

2 *(Probing practice):* What approaches are used in the teaching, learning and assessment of science and mathematics in early years in the partner countries and what role if any does creativity play in these? This would include the exploration of opportunities and challenges for development of skills and attitudes associated with creativity.

3 *(Probing practice):* In what ways do these approaches seek to foster young children's learning, interest and motivation in science and mathematics, and how do teachers perceive their role in doing so?

4 *(Drawing on mapping and probing questions):* How can findings emerging from analysis in relation to questions 1-3 inform the

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development of practice in the classroom and in teacher education (ITE and CPD)?

Clearly the study will need to consider how do answers to the above questions compare with what is suggested in current research and policy.

Sub-questions running across all RQs might be a focus on

Aims/purpose/priorities (including teachers' explicit and implicit perspectives and identities as scientists and mathematicians in relation to e.g. aims and purposes of creativity in science and mathematics education, how these shift from pre-school to primary across the consortium, how these relate to IBSE and PBL, views of creativity in relation to perceived purpose)

Contextual factors (including ethos, teacher characteristics, curriculum, institutional factors, home-school links and the wider cultural background)

Teaching and learning (including multimodal expression and experience, documenting activity types, resources used, dynamics between adults and children, exploration, questioning and argument, also how teachers assess creativity in early science and mathematics education).

It is suggested that, in WP4, the focus is on sites of exceptional practice. This will enable the project to document, analyse and disseminate excellence at the cutting edge of creativity in early science and mathematics. As discussed the research design will need to address how responses to these questions vary with age, and clearly built into the study is the comparative dimension of how they may vary with cultural context. The study will, it is hoped, foreground children's agency, and emerge, in relation to the research questions, models which acknowledge complexity.

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GLOSSARY OF KEY TERMS

Term	Definition
Academic tradition	Also known as 'application of theory' approach (Zeichner, 2010; Korthagen, 2010; Schepens et al., 2009). In this approach teacher education institutions provide the knowledge through various, often fragmented courses, whilst schools provide the settings for students to apply the theory to practice.
Action research	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 is demanding of professionals who need support and training in undertaking it.
Cognitive Guided Instruction	An approach correlated with problem based learning that develops mathematical thinking through instruction influenced by teachers' knowledge, beliefs and practices.
Collaborative learning	Collaborative learning is a situation in which two or more people learn or attempt to learn something together. Following Schollaert (2011), collaborative activities are clearly learning activities of the professionals that constitute a professional learning community.
Communities of practice	Groups of professionals/ practitioners with common aims who support each other in development of practice/ professional development.
Comparative education	Field of study that examines education by comparing educational theory and practice in different countries. This overarching term includes research about education in foreign countries and international education, as well as teaching and learning in the academic field of comparative education.
Comparative pedagogy	Aims to identify processes of teaching and learning within schools and classrooms in different countries; mainly focuses on one theme Intra-educational and intra-cultural analysis: Comparison focuses on education at the various levels, and also systematically researches, for example, the historical, social, cultural, political

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	forces and compares the resultant outcomes in two or more systems, areas or even globally.
Componential assessment of creativity	An approach to the assessment of creativity which is a context sensitive balance of process and product, is formative. Componential assessment is used by individuals as well as pairs and groups. It involves learners and teachers and those making judgements may include the children themselves.
Constructivist teaching	An approach to teaching whereby the learner (child or teacher) constructs meanings as a result of practical experience, collaboration and dialogue. It should be noted that some would argue constructivism is an approach to learning as indicated so it is not meaningful to talk of 'constructivist teaching'.
Creativity[12]	We propose *Creative Little Scientists* will focus on little c, or personal, or everyday, creativity, i.e. purposive imaginative activity generating outcomes that are original and valuable in relation to the learner. In the literature, the following definition is used in relation to creativity in Science and Mathematics: "'generate alternative ideas and strategies as an individual or community, and reason critically between these". The project will afford opportunities to reconcile these.
Development Education	Production of information and plans to assist policymakers, particularly in 'new nations', to develop appropriate educational methods and techniques, the training of personnel to implement programmes
Didactics	Didactics has different meanings across Europe; from the study of teaching approaches/ similar to pedagogy to an approach that is very formal/ inclined to lecture/ teacher dominant approaches. The understanding of didactics used in this study is drawn from the German concept of 'didaktik' meaning theory and practice of teaching and learning.
Early Years	Birth to 8 years of age incorporating kindergarten, nursery, pre-school, elementary school, primary school, early years.

[12] The terms within this definition in particular will be further clarified in relation to meaning of 'imaginative', 'purposive', 'outcomes', 'originality', 'value' and locus of judgement. These have all been explored in the context of literature on 'little c' and 'mini-c' creativity cited in this review.

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Education Abroad	Describing and analyzing aspects of one or more school systems from countries other than your own.
Educational Design	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).
5-E model of science instruction	(Engagement, Exploration, Explanation, Elaboration, Evaluation) as proposed by Carin, Bass and Contant (2005).
Hybrid teacher educators	Teacher Educators who incorporate knowledge from communities into ITE teacher education.
Innovation	Creativity with the goal of profit / profitability (usually meant in an economic sense; though may be interpreted more widely)
International pedagogy	Study of teaching multinational, multicultural and linguistic minority pupils; also international understanding of peace education and ecological education aiming to formulate international teaching norms
Initial teacher education (ITE)	Professional education and preparation for preschool and primary school teachers organized by a college, university or specialized school in order to obtain the necessary qualification to teach in preschool and primary school contexts.
Inquiry	What scientists do (e.g., investigating using scientific methods) How children learn science (e.g., actively inquiring) A pedagogical approach (e.g., using investigations)
Inquiry-Based Science Education	An approach to learning that that emphasises children's understanding and skills in finding out and evaluating information around them (European Commission, 2011).
CPD education	Professional development that happens whilst the teacher is qualified, normally whilst an employee.
Intra-educational and intra-cultural	Comparison that focuses on education at the various levels, and also systematically researches, for

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analysis	example, the historical, social, cultural, political forces and compares the resultant outcomes in two or more systems, areas or even globally.
International pedagogy	Study of teaching multinational, multicultural and linguistic minority pupils; also international understanding of peace education and ecological education aiming to formulate international teaching norms
Lead teacher/ lead professional	A CPD term for a more experienced teacher dedicated to improving teaching and learning and sharing information, helping to create a collaborative culture of teachers as learners, and improving student learning.
Learning outcomes	The desired/ expected outcomes of learning as identified by the curriculum and the teacher.
Mathematical processes	Artz and Armour Thomas (1992) develop a cognitive-metacognitive framework identifying six categories in problem solving: read, analyze, explore, plan/implement, and verify. In another framework, Mayer (Mayer, 1985) identifies four components of mathematics problem solving: translation, integration, solution planning, and execution. These mathematical processes can be seen as a grammar for science.
Pedagogical Knowledge	Knowledge about teaching (for example, planning, learning outcome, differentiation, assessment) that a teacher needs to develop in order to teach affectively.
Pedagogical Content Knowledge	Pedagogical Content Knowledge or PCK is specific knowledge needed by a teacher in order to teach a subject, such as science and mathematics
Possibility Thinking	PT involves the generative shift from what is to what might be, through 'what if?' and 'as if' thinking and manifests individual, collaborative (shared) and communal (jointly 'owned') creativity.
Pre-School	Provision for young children prior to beginning in compulsory education. This can span education and care. The ages of pre-school provision differ across Europe and even within countries. Pre-school education includes home-based care, such as child minders and nannies, as well as private, voluntary and state-funded nursery provision. Whilst some pre-school provision (such as day nurseries) combines education with childcare, enabling parents

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	to work, other provision is focused on children's learning or education (for example, play group, nursery or kindergarten classes) and some (for example early music groups, or parent and toddler groups) are designed for children to participate in with their parents.
Problem-based Learning	An approach to inquiry that starts from a problem to be solved. See also Inquiry-Based Science Education (IBSE).
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. The concerns both ITE teachers still in training, which can be viewed as not yet qualified. CPD teachers can be considered to be qualified.
Professional identity	Reflective sense of self identity in relation to working role, involving by definition metacognition about one's perspectives on practice.
Realistic-approach to teacher education	This takes into account the causes of the theory and practice divide (Korthagen et al. 2001), the emphasis here being on the student teachers' experience, concerns and existing gestalts.
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.
Science processes	The range of processes involved in the development and testing of ideas in science in an inter-related way. These include o*bserving, interpreting, hypothesising, raising questions, planning, measuring, recording and communicating, critically reflecting.* Duschl et al. (2007) group these processes into different phases in an investigation: *Generating evidence* – asking questions and formulating hypotheses, designing experiments, *Observing and recording* and *Evaluating evidence.* *Communication* is considered one of the essential elements of IBSE, that the learner communicates

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	with audience(s) and justifies explanations (Assay and Orgill 2010: 63).
Scientific literacy	Scientific literacy involves the application of science in everyday life: recognising the impact of science and technology on everyday life; being able to understand and reflect critically on media reports about science and technology; being able to reason and make informed decisions about personal and societal issues related to science and technology; being able to evaluate scientific evidence.
Study of the work of international education institutions	Concerned with policy matters, such as establishment of international qualifications and promoting international exchanges and agreements (Halls, 1990: 24).
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 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).
Teacher training institutions	Colleges, Universities or Teaching Schools that are involved in the initial training and education of teachers.

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