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

D6.5 Final Report on Creativity and Science and Mathematics Education for Young Children

www.creative-little-scientists.eu

The project CREATIVE LITTLE SCIENTISTS has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for research, technological development and demonstration under grant agreement no 289081.

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Chapter 1: Introduction

Creative Little Scientists is a 30-month EU funded comparative study working across nine participating countries: Belgium, Finland, France, Greece, Germany, Malta, Portugal, Romania and the UK. The project focuses on the relationships and synergies between science and mathematics education and creativity in preschool (children aged 3+) and early primary school (up to the age of 8). *Creative Little Scientists* seeks to document current reality in the nine partner countries of the study, through survey and classroom focused research. The study aims to mainstream good practices by proposing changes in teacher education and classrooms encompassing curriculum, pedagogy and assessment.

This Final Report aims to synthesise and communicate the final findings of *Creative Little Scientists* project to all relevant stakeholders (researchers, academics, policy makers, teacher educators, curriculum designers, school leaders, teachers) in a highly informative, thought- and action-provoking way.

Initially in this chapter the elements which contributed to the focus of the study are summarised, namely the core drivers for the work. This is followed by a presentation of the project objectives and an outline of the research work plan. The chapter concludes with an outline of the chapters that follow.

1.1 Core drivers for *Creative Little Scientists*

The project was informed by at least four key drivers that set the context for an increased research focus on science and mathematics education and creativity in the Early Years classroom:

- The role of an economic imperative in education.
- The role played by science, mathematics and creativity in the development of children and of citizens.
- The role of Early Years education in building on children's early experiences and in promoting positive skills and dispositions.
- The role of a digital or technological imperative within education.

1.1.1 The economic imperative

Research and policy literatures reveal that there are economic factors driving the focus on science and mathematics education as well as the inclusion of creativity in the classroom. Research highlights that views about the aims and purposes of

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education are fundamentally affected by a range of key external factors beyond the classroom: social, political, historical and significantly, economic.

Today's knowledge economy dictates an imperative for countries to train scientists capable of competing globally (European Commission, 2006) and the European Commission emphasises the role of educators in this, with the European Commission documents (2007a, 2007b) identifying basic competence in science as a part of the spectrum of key attributes contributing to individuals' personal fulfilment and development, active citizenship, social inclusion and employment. By 2010, the *"Report of Council conclusions on increasing the level of basic skills in the context of European cooperation on schools for the 21st century"* (Brussels,11/2010) argued that attaining the new, ambitious benchmark set under the "ET2020" strategic framework would require more effective national initiatives. The European Commission (2011a) report emphasised the need for educators not only to foster science learning with confidence but to be able to reflect on their teaching and students' learning – reflecting a strong European perspective that educators have a vital role to play in developing creativity in science education.

The research call for Horizon 2020 which seeks to build a competitive and strong Europe with particular reference to the sciences technology and innovation, explicitly acknowledges the potential for the arts and humanities to help foster the development of creativity integrated with the development of products and services built on scientific knowledge (Horizon 2020, 2014).

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. However, this increased demand is in tension with a trend for the younger generation to show decreased interest in science and technology education.

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, and in contrast, 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 within 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

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Burn (2010), in describing a number of 'rhetorics' of creativity include: 'creativity as economic imperative' and define this as "advancing the economic prospects of the nation by creating a more flexible workforce" (2010:41). This is similar to the idea that individuals must compete in the global knowledge economy, as suggested above.

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 mathematics and science, and who are also literate citizens in these areas. Economic factors therefore are significant, as are comparisons between countries' achievements 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. Indeed, in the Early Years it is important to consider other reasons for greater attention to the relationships between science, mathematics and creativity.

1.1.2 Development of the child and citizen through science and/or mathematics

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

There is growing recognition that scientific literacy plays an increasingly critical role not just for 21st century society, but for individuals (Harlen, 2008). Developing scientific and mathematical literate 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). Zohar (2006) argues that high quality scientific thinking is one of the key goals in contemporary schooling, especially when facing a vast quantity of information and in 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).

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The aim of science and mathematics education is not therefore simply to create future experts in the field (Millar and Osborne, 1998). Rather, it is important also to teach young people something about science – often termed 'Nature of Science' – as well as developing an understanding of the major concepts of science.

1.1.3 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 an important part of childhood, a perspective offered several years earlier by Craft (2002) in relation to the Early Years of education.

As a dimension of fostering creative citizens, 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) and John-Steiner's (2000) work and has been developed by many in education, most 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 Craft, Gardner and Claxton (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) and Craft (2013, in press) more recently focused on wise, humanising creativity, emphasising collaborative and communal engagement with the ethics of creativity.

1.1.4 The technological imperative

Science, mathematics and creativity have evolved through rapid advances in digital technologies, which are shaping new literacies. Shaffer and Kaput (1998) argue that as mathematics is inseparable from the tools we use, such as calculators and computers, 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 (e.g. 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

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more elements in their patterns (Moyer-Packenham et al., 2008) or gaming, with children using hand held as well as fixed console digital technology to collaborate with others in generating content and understandings (Craft, 2011, 2012).

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).

1.1.5 Changing perspectives on young children and the importance of Early Years education

Alongside these wider societal concerns, the project was 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, which identifies rights not just to provision and protection, but also to participation (Mayall, 2006). In the last couple of decades, new research methods have highlighted young 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, 2002; Laevers, 2005).

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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.

1.2 Project Objectives

In the light of the above, the *Creative Little Scientists* project is a very timely intervention which set out to shed light on the intersection of science and mathematics education for young children with creativity, setting **an overall twofold aim**:

a) to provide Europe with a clear picture of existing and possible 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

b) to transform the knowledge generated through this into a concrete contribution towards the training 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.

Through this, **in the long term** the project aims to enhance science and mathematics education in Europe in at least two ways. **First**, by supporting the emergence of appropriate learning outcomes in science and mathematics, helping to avoid the emergence of misconceptions and stereotypical images about science and mathematics in children, and attracting children's interest to science and mathematics. **Second**, by connecting science education with Europe's wider educational goals of improving the basic skills and promoting creativity in all children today and in the near future which subsequently can lead to the development of entrepreneurial skills and the ability to innovate in tomorrow's adult citizens.

To achieve this aim, the *Creative Little Scientists* project brought together **a consortium** comprising expertise of the highest level and quality in the areas of science and mathematics education in Early Years, creativity in education, cognitive psychology, and comparative educational studies. This consortium designed and carried out a research programme which comprehensively integrates elements of comparative research, in-depth field research and curriculum design. The research was carried out in a sample of nine European countries (Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania, and the UK), which were carefully selected to represent a wide spectrum of educational, economic, social and cultural contexts, as well as a wide spectrum of practices regarding science and mathematics

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education in general, science and mathematics education in Early Years, and creativity in education.

In this context, the research was operationally defined in terms of the following **specific objectives**:

- **To define a clear and detailed Conceptual Framework** (D2.2[1]) comprising the issues at stake and the parameters which needed to be addressed in all stages of the research. This was achieved through extensive reviews of policy-related and research-based literature at the beginning of the project. The literature reviews comprehensively and consistently covered areas as diverse as science and mathematics education with a focus on pre-school and first years of primary school, creativity in education, creativity as a lifelong skill, related teaching and teacher training approaches, as well as relevant issues from the wider areas of cognitive psychology and comparative education.
- **To map and comparatively assess existing approaches** to science and mathematics education in pre-school and first years of primary school (up to the pupil age of eight) in the nine sample countries, highlighting instances of, or recording the absence of, practices marrying science and mathematics learning, teaching and assessment with creativity (D3.4). Such practices were mapped and compared consistently on the basis of a **List of Factors** (D3.1) which was developed in the light of the Conceptual Framework to define the scope, aspects to be addressed, and the dimensions for the comparison. To achieve this, the consortium conducted:
  (a) **desk research** looking at records of policies, curricula, reports and assessments of school practice in the nine sample countries (D3.2); and
  (b) **a questionnaire survey** aiming to gain insights into teachers' conceptualisations of science, mathematics and creativity education in real school life and in a range of contexts in the nine sample countries (D3.3).
- **To provide a deeper analysis of the implications of the mapped and compared approaches** which would reveal the details of current practice and provide insights into whether and how children's creativity is fostered and the emergence of appropriate learning outcomes in science and mathematics is achieved (D4.4). This part of the research was accomplished through **in-depth fieldwork** involving the use of questionnaires, interviews, focus groups, and observations with teachers and children.

[1] The accomplishment of these objectives has been recorded in project reports (or deliverables), indicated in this Final Report by the letter D and a number (e.g. D2.2). These reports can be found on the project's website (www.creative-little-scientists.eu).

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- **To propose a set of curriculum design principles as concrete guidelines for European initial teacher training and continuous professional development programmes** (D5.2), which would foster creativity-based approaches to science and mathematics learning in preschool and the first years of primary education. The proposed principles are accompanied by **illustrative teacher training materials** (D5.3) aiming to clarify their applicability in complex and varied European educational contexts, thus facilitating implementation, evaluation and further development across Europe. This work was based on the findings of the above mentioned theoretical, comparative and in-depth field research, as well as through a process of continuous involvement of real-life communities of stakeholders from the nine sample countries (teachers, principals, teacher trainers, curriculum designers, policy makers, parents) in focus group discussions and testing and validation of the formulated curriculum design principles, implementing the methodology of curriculum design research.
- **To exploit the results of the research at the European level as well as at national and institutional level**, making them easily available to educational policy makers and other stakeholders, especially teacher training policy makers and institutions. This work had a special focus on teacher training, and is completed through the synthesis of all research outputs and their transformation into this Final Report on Creativity and Science and Mathematics Education for Young Children (D6.5) and also the Set of Recommendations to Policy Makers and Stakeholders (D6.6).

Figure 1 below shows the above described accomplished objectives and related stages of research in the *Creative Little Scientists* project.

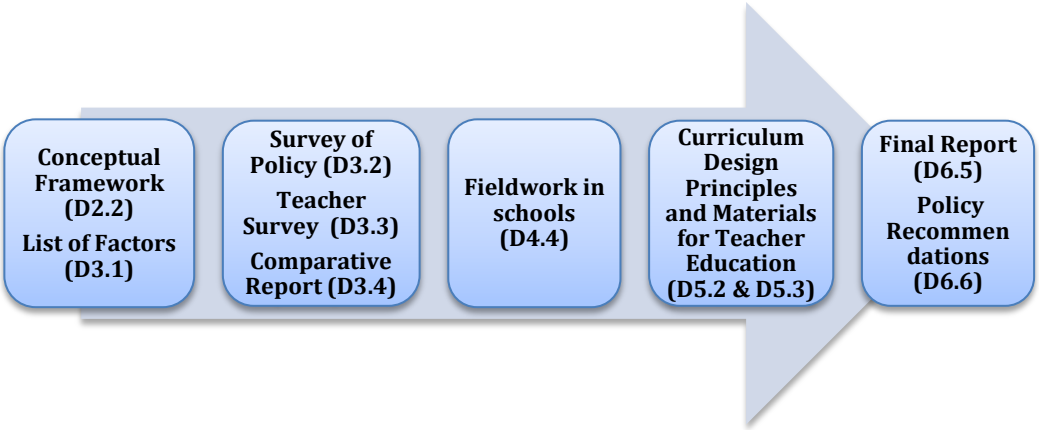

Figure 1.1: Accomplished objectives and related stages of research in the* Creative Little Scientists *project

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1.3 Outline of the Final Report

The subsequent chapters, then, present more specific detail of each stage of the *Creative Little Scientists* project. Represented in chronological order, each chapter presents the findings at each phase of the research which when drawn together demonstrates how the final conclusions emerged.

A summation of the chapters is as follows:

Chapter 2 presents the project's Conceptual Framework, setting out the theoretical ground behind the research and articulating its implications for the work in terms of foci, context and methodological issues.

Chapter 3 presents an overview of the methodology followed in the different stages of the research.

Chapter 4 presents a summary of the findings in the first stage of the research, that is of the mapping and comparison study of recorded and reported approaches to science and mathematics education in pre-school and first years of primary school (from pupil age three to pupil age eight) in the nine sample countries.

Chapter 5 presents a summary of the findings in the second stage of the research, that is, of the deeper analysis of current practice and its implications for science and mathematics learning and children's creativity.

Chapter 6 presents a synthesis of the findings as answers to the project's research questions.

Chapter 7 presents the proposed curriculum design principles and related desirable teacher outcomes for initial teacher education and teacher continuing professional development.

Finally, Chapter 8 focuses on what has been gained from the research undertaken across the different phases of the *Creative Little Scientists* project, in relation to both research outcomes and processes and identifies emerging issues and possible directions for future researchidentifies issues and directions for future research and development.

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Chapter 2: Conceptual Framework

The project's Conceptual Framework, which was based on a series of literature reviews, focused on the relationships and synergies between science and mathematics, Early Years education and creativity, and encompassed attention to initial teacher education and comparative education in this regard. It set out the theoretical ground and articulated possible implications for the work in terms of foci, context and methodological issues. The Conceptual Framework, which this chapter seeks to summarise, drew together key areas for focus and suggested an appropriate methodological approach for the research.

Initially this chapter outlines the conceptual challenges that stem from the core drivers for the work identified in Chapter 1. This is followed by an exploration of common themes across science, mathematics and creativity in Early Years education and attention is paid to the research literature about teachers' conceptualisations of these. The central section of the chapter focuses upon an exploration of the commonalities identified in teaching and learning with regard to Inquiry Based Science Education (IBSE) and approaches that foreground creativity (CA). The project identified significant synergies in this regard and these are detailed and examined in turn. The challenge of responding to these related pedagogical approaches and achieving a balance between structure and freedom in Early Years educational settings is also considered. Next, research literature about policy and policy makers' conceptualisations of science, mathematics and creativity in Early Years education is examined. Following this section, attention is afforded to both initial teacher education and comparative education with regard to the core foci of the work. The chapter concludes with an examination of the project's research questions.

2.1 Conceptual challenges for *Creative Little Scientists*

There were a number of conceptual challenges relevant to the project as a study of science, mathematics and creativity in the Early Years. These included the nature of the concepts, teachers' own conceptualisations, beliefs and stances in relation to science, mathematics and creativity in education.

2.1.1 Conceptualisations of science and mathematics education in Early Years education

In science and mathematics it is possible to consider both knowledge and the processes involved in gaining that knowledge. Duschl et al. (2007) identify four strands of scientific proficiency that are interwoven in learning and teaching:

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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.

These strands reflect an increasing recognition of the importance not just of pupils' engagement with scientific concepts but also of the need to develop their understanding of the 'nature of science' and 'procedural understanding' (Duschl et al., 2007; Eady, 2008; Harlen and Qualter, 2004; Kallery, Psillos, and Tselfes, 2009). 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).

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). 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 Alibseli, 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

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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 mathematics and science education that the dichotomisation of 'process' and 'content' may obscure 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 of education 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, concepts 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.

2.1.2 Conceptualisations of creativity in Early Years education

How creativity is evidenced in education is discussed in a number of different ways. These discussions focus on the characteristics of creativity and, like the epistemological foundations, the ultimate purpose of what is being evidenced. Banaji and Burn (2010) as mentioned in Chapter 1 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;

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- the creative affordances of technology and;
- the creative classroom.

Creative genius focuses mainly on acts that are widely accepted as creative or groundbreaking, 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, 2009). 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) and reflects arguments made by Craft (2002). Similarly 'creativity and cognition' suggests that creativity is tied to act(s) of individual(s) and related to 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.

There remain then three rhetorics that can be seen as reflecting the idea of creativity as instrumental and of developing the individual: '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'). Whilst these seem more remote from Early Years education on one level, evidence of these rhetorics can be traced in policy documents across Europe.

2.1.3 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 sections, in early science and mathematics, process skills and attitudes associated with inquiry are emphasised but with increasing recognition of their inter-relationship with conceptual

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development, while in the creativity literature this is framed towards looking at the processes of creative activity and what this enables.

2.1.4 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.

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 models, develop formalisms and to approach conceptualisation. Reflecting on 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

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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 (Zacharos 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, 2009; Millar and Osborne, 1998).

2.1.5 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, 1966, 1969). 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

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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, Craft, 2013, Craft, Cremin, Burnard, Dragovic and Chappell, 2012; Craft, McConnon and Matthews, 2012; Cremin et al., 2006, Cremin et al, 2012) have investigated creativity as a culturally situated concept. These confirm and document creativity 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, Cremin et al, 2012). 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) 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, 1998, Brolin 1992, Chappell et al., 2008) suggest that intrinsic motivation 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).

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, a focus on inquiry and investigation, and generation of and critical reasoning between alternative conceptions in the light of existing, widely accepted explanations and strategies. These common elements are 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.

The project offered opportunities to explore more fully this common ground that science and mathematics education in pre-school and early primary education share with creativity.

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2.1.6 Research about teachers' conceptualisations of science, mathematics and creativity

The literature reviews related to creativity in education and science and mathematics education in the Early Years, which appeared as Addenda to the Conceptual Framework (D2.2), and indicated that teachers' conceptualisations and their values and stances towards science and mathematics education and creativity appeared to 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.

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 will also shape their pedagogy (Fleer 2009). In investigating pre-school teachers' educational practice Einsdottir (2003) shows that their educational beliefs and knowledge of child development have a fundamental impact on their teaching. 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.

Work by Forrester and Hui (2007) revealed that teachers' own values are highly influential in relation to nurturing creativity, while Woods and Jeffrey (1996) highlight the humanist approach, openness to emotions and strong moral and political investment of creative teachers. 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, Cremin et al. (2006) noted that teachers, particularly those influenced by particularly constructivist views of learning, viewed the children as active meaning makers. This has been seen in the mathematics education literature too, with Durmus (2011) noting 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). Goldstein views such inconsistency in early childhood education as inevitable – "a fact of life in the open-ended, complicated teaching profession" (1997: 21), yet it can create tension

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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 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 than positive school experiences and demonstrating discomfort and a lack of assurance (Brady and Bowd, 2005). Primary pre-service teachers also had a narrow conception of creativity in science lessons, perceiving it as more associated with the arts (Newton and Newton, 2010). 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).

2.2 Exploring teaching, learning and assessment with a focus on Inquiry Based Science Education (IBSE) and approaches that foreground creativity (CA)

In addition to the examination of the ways in which creativity, science and mathematics are conceptualised in research, by the professional, 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. So attention is now given to teaching and learning with a particular focus on IBSE and approaches to education which foreground creativity, described here as 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 mathematics as well as science, the latter is also being used to include a number of teaching and learning practices.

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. (2010) argue are associated with the term inquiry – '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)'

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(2010:3). According to Drayton and Falk (2001:25), 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 knowledge. The US National Research Council (2000) identifies five attributes of learners in Inquiry Based 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. An inquiry-based approach Linn, Davis and Bell (2004:4) suggest 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". 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), 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 that are employed in

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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.

2.2.1 Exploring synergies and differences in IBSE and CA

The previous sections explored how teaching and learning using IBSE and approaches which foreground creativity (Creative Approaches, CA) can enhance learning. 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). This might happen individually or in collaboration.

While there is 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, 2004); 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., 2007).

Researchers of creative approaches highlight the role of innovation, originality, ownership and control (Woods and Jeffrey, 1996, Jeffrey and Woods, 2003) and

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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 approaches as both the imaginative and innovative arrangement of curricula and teaching strategies in school classrooms and the development of students' creative capacities" (2011:264).

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 that seek to foster particular aspects of children's learning.

The common synergies identified were:

- **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 engagement 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 their creativity as well as their own questions and ideas about scientifically relevant concepts.
- **Questioning and curiosity**, which is central to IBSE and CA, recognising across the three **domains** of science, mathematics and creativity that creative

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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 are 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 children's needs, rather than feel pressured to meet a given curriculum.
- **Assessment for learning,** emphasising the importance of formative assessment in identifying and building on the skills attitudes, knowledge and understandings children bring to school; supporting and encouraging children's active engagement in learning and fostering their awareness of their own thinking and progress.

2.2.1.1 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 children as young as two 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.

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" (2008:629). 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

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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.

Many empirical studies within the wide field of science, mathematics and creativity research which were examined in the literature reviews which supported the Conceptual Framework, suggest that open-ended exploratory contexts are well suited to fostering learner creativity and learning in science and mathematics (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 (1971) calls the deep play of childhood, appeared to prompt an openness that 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 reinterpreting children's 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 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

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boundaries and take risks. Additionally, though somewhat differently, Metz (1998) argues that in relation to developing scientific concepts through investigation, 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:46), 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.

2.2.1.2 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 on hands-on 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, 2008; 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

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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, 2009) 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 science and mathematics; and has begun to be explored in the creativity literature (Cremin et al., 2012).

2.2.1.3 Dialogue and collaboration

Another area of synergy between the research literatures focused on creativity and on IBSE in science and mathematics 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 also to emphasise the validity of alternative points of view (Coltman, et al., 2002), their perspectives are not simply misconceptions. In school, IBSE involves problem solving activities with peers, which are often highly collaborative, and affords 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 science and mathematics. The communication of ideas and ways of thinking allows children to listen to others' strategies and ideas and 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 on 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).

Much creativity research recognises that creative processes are essentially social and necessarily collective and collaborative (e.g. John Steiner, 2000; Littleton and Mercer,

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2013; 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; Vass, 2007; Wegerif, 2005). 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. 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 et al., 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 German 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 creativity. 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, 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

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enough space/opportunities for the children to experiment and work on their own or in peer groups.

2.2.1.4 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). 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 to a dimension of more or less student directedness or agency (see Figure 2.1 below). Barrow discusses how this scale reflects teacher approaches that range from student-directed open inquiry approaches, to a 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; Glauert, 2005 Goldin-Meadow, 2009; Beghetto and Kaufman, 2007; Chappell, 2008).

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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 or other source
Learner 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 given all 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 2.1: Essential features of classroom inquiry and their variations (Barrow, 2010: 3)

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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 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.

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.

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 that 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

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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, or in the case of Craft et al. (2012) practitioners passing the problem back to the learners to foster their decision making and agentic actions. McWilliam (2008) however in acknowledging that for decades teachers have been expected to position themselves as 'custodial risk minimisers', suggests that they have potentially limited the autonomy and agentic space offered to children.

2.2.1.5 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), while others suggest 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).

In contrast, Harris and Williams (2007) show that if young children 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

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and are still in use today (Uzsynka, 1998) including 'gestalt holistic assessment' introduced by 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).

When considering creativity in the classroom, 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, might there be 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. 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. This is supported by Chappell et al.'s (2008) work, which identified that questioning of different kinds and for different purposes can act as a support to children's inquiries and learning.

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.

2.2.1.6 Reflection and reasoning

In terms of reflection and reasoning, there is rather more in the science education research literature evidencing the importance of these skills within IBSE than in CA. IBSE seeks 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

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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 that 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 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 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. This may be considered

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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" (2004:491). 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" (2004:492). In contrast, children's metacognitive awareness of their own creative thinking in the Early Years has not been widely researched.

The complex synergies between science, mathematics and creativity in Early Years education are conveyed diagrammatically in Figure 2.2, which seeks to highlight the dynamic relationship fostered by the teacher, in particular through scaffolding young children's learning.

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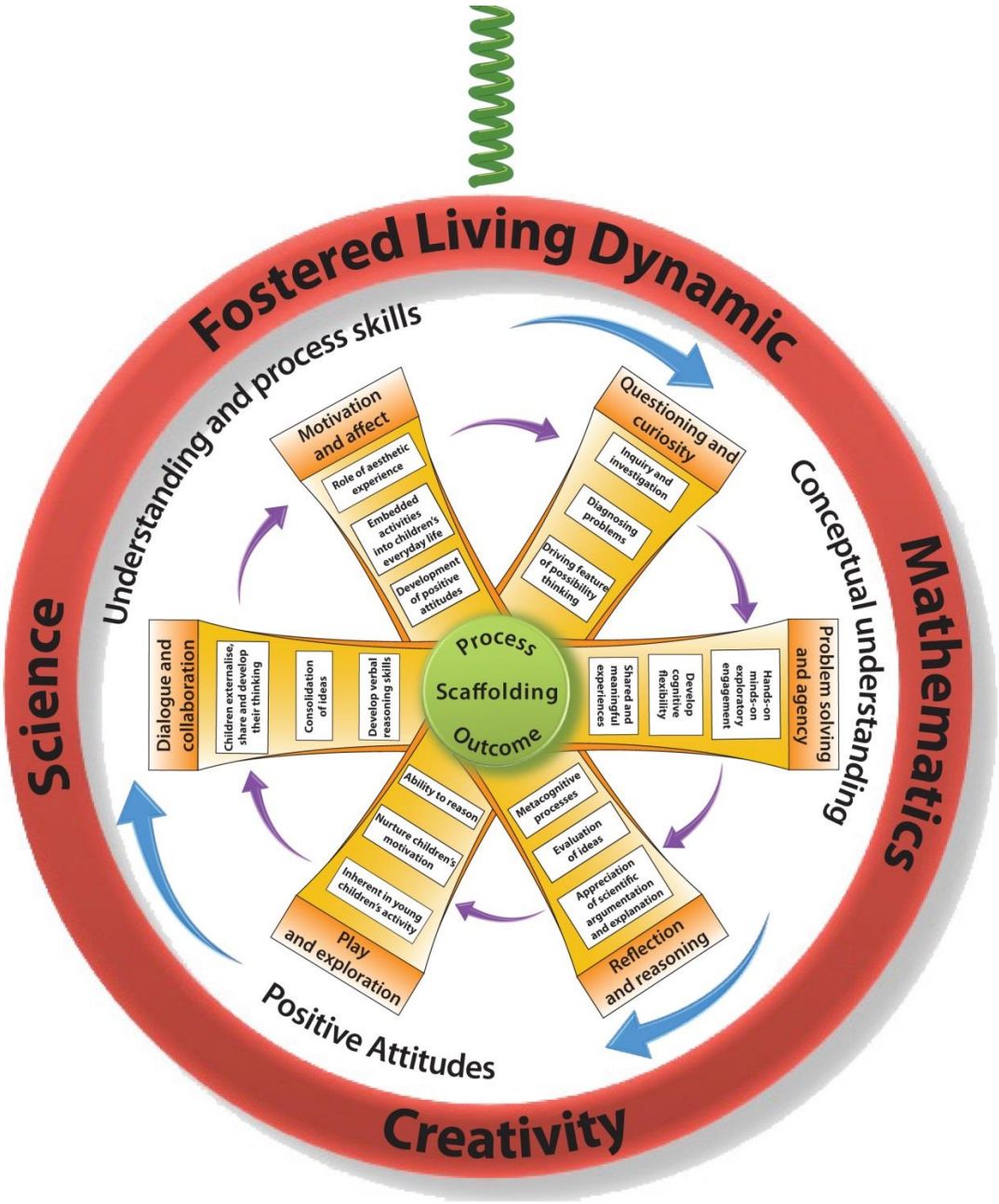

Figure 2.2: A diagram to represent the pedagogical synergies between creativity, science and mathematics in Early Years education

2.2.1.7 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 largely on the teacher's role in scaffolding children's learning. Scaffolding has been considered

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beneficial for young children fostering their independence as inquirers and problem-solvers (Rittle-Johnson and Koedinger, 2005; 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, 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 of the 'House of Little Scientists', 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 paying little attention to 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 the 'standing back' strategy (Cremin et al., 2006) as part of CA. 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

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suggested or enacted by the children. Whilst the teachers in the 'House of Little Scientists' study, 'stood back' for other reasons (often due to lack of assurance and scientific knowledge) the effect appears to have been the same – the young children 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 for IBSE and CA to foster 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. 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.

The challenge for teachers then 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.

2.2.1.8 Assessment for learning

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.

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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 (Glauert, 2009b). Insights from recent research highlight the need to develop assessment approaches sensitive to the capabilities of young children (Robbins, 2005). Calls have been made for the development of multimodal approaches to assessment in early mathematics and science activity (e.g. Glauert, 2009a) 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 (Feldhusen 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).

The assessment of creativity 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 Center, 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.

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, 65 countries and economies were involved in the 2012 wave. Both produce summative data through specially

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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administered tests. 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 science and mathematics 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 (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 science and mathematics, 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).

Thus 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 how 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 has been possible to reconcile such testing through a range of strategies encompassing

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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.

2.2.2 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, 2004b) 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 science and mathematics classrooms represents a significant challenge.

In relation to constraining factors, the significance of teachers' dispositions and attitudes on task construction has been noted (Craft et al., 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 may 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 provide 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

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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.

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 to 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.

Furthermore, 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.

It is clear that IBSE and CA to education in the Early Years should not be seen in juxtaposition, but rather in dynamic relation. With regards 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.

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2.3 Research literature about 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, degrees of regulation and the official status of documents vary 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 included 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, 2011b).

What creativity means in practice, as in science and mathematics education varies. As indicated earlier, there is a version of the 'content vs. process' conceptualisation evident in creativity discourses with some emphasising outcomes more than others according to the emphasis on instrumentalist vs. self-actualisation narratives (Heilmann and Korte, 2010).

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 which 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.

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It is worth noting that discussing policy and policy makers' interpretations of science and mathematics education and creativity is not straightforward but was explored within the project. How these curricula initiatives are enacted in the classroom afforded another issue of significance for the project, this was subsequently explored during the empirical, classroom-based phase of the project.

2.4 Initial teacher education and continuing professional development

Another aim of the project was to make a contribution to initial teacher education (ITE) and continuing professional development (CPD). The relevant literature review highlighted a variety of models in relation to ITE, with varying balances of higher education and school-based learning, although with a general trend toward the latter. All ITE examined included school practice but the balance between theory and practice varied considerably, along with the order in which these are developed with both concurrent and consecutive models being evident. A particular challenge for the project was that ITE takes place at different levels across the nine countries involved, while the qualifications of teacher educators range 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 science and mathematics within these varies. In some countries personal characteristics are also considered and the structure of ITE is heavily 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 had implications for the project.

An important consideration was the compatibility of approaches developed in the empirical work with the teaching competences required in the various countries, to facilitate take-up. IBSE is an important concept underlying the project; however the literature review on teacher education revealed there was little explicit mention of this in ITE legislation and documentation. This may indicate that IBSE 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. The inquiry or problem-based dimension to teacher education was an important focus in the studies reviewed; these suggested that such approaches offer pre-service teachers an effective way for developing a better understanding of science.

A review of policies from across Europe found that there was a range of approaches to and levels of CPD, and types of organisations offering it. Whilst there appeared to be a common expectation for teachers to participate in CPD, it was not clear from the

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literature how far this professional duty is fulfilled. Research literature acknowledged strengths and weaknesses in different models. Field and mastery approaches were strongly endorsed by the literature for both ITE and in-service provision although research also showed the importance of responding to teachers' needs rather than imposing training on them.

Finally, the research literature highlighted the need to acknowledge the influence of teachers' beliefs and attitudes, the potential challenges posed by lack of subject knowledge and possible negative attitudes and the need to offer professionals working with young children practical strategies, support in developing questioning skills to develop higher level thinking, and reflective approaches to their own work with children. Curriculum design was an important dimension here. In relation to creativity and creative approaches in science and mathematics, it was clear that teachers and pre-service teachers have a rather wide view of what this might mean. This includes how inquiry-based approaches integrate with creativity in science and mathematics.

2.5 Comparative dimension of *Creative Little Scientists*

European integration and global competition have increased the need for comparative research and the European Union 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.

Addendum 4 to the Conceptual Framework (D2.2), highlighted a typology of comparative education that suggested that the project adopted an approach of studying various countries or regions using the same methods of data collection and analysis, informed by international research. It was suggested that the focus of the research project was comparative pedagogy that 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 needed to encompass varied conceptualisations of Early Years education including recognising the differing balances between education and care in the participating countries and a wide span of purposes, 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 developed during a research period when the dominant approach to comparative education was focused on 'measuring the other'; i.e. creating

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international tools and comparative indicators to measure efficiency and quality of education. Indeed some of the motivation for this study came 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 was 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'. In taking this approach, the project needed to address issues with respect to representativeness, reliability and validity in relation to the comparative dimension.

One aspect of the comparative dimension recognised in particular was the differently-positioned curriculum framing for science, mathematics and also creativity, as well as acknowledging a range of definitions of creativity.

2.6 Focus areas for Creative Little Scientists

The diverse drivers of this project, its comparative design and its concern to offer advice regarding teacher education ran 'vertically' through each of the three areas which it was agreed the study would focus upon:

1. Capturing Conceptualisations
2. Evidencing Practice
3. Developing Practice

Focus Area 1: Capturing Conceptualisations

A key task addressed by this study was to articulate conceptualisations of early science and mathematics education including IBSE and creativity in relation to the Early Years. This was undertaken at a conceptual level in the Conceptual Framework, and also at an empirical level through the survey of teachers' perspectives and classroom studies. There were three aspects of curriculum focus and design that were explored:

Domain conceptualisations: The study investigated the different conceptualisations of early science education, early mathematics education and how these reflected or encompassed creativity in relation to both learning and pedagogy. This included exploration of both IBSE and creative approaches (CA).

Teachers' conceptualisations and attitudes: The study aimed to capture teachers' explicit and implicit perspectives on the development of science and mathematics education in the Early Years and their articulation with creativity.

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Curriculum design: The study aimed to attend to teachers' subject and pedagogical knowledge and skills in additions to exploring the extent of teachers' professional autonomy through which their attitudes and subject pedagogy may be improved. Attention was subsequently given in particular to curriculum design and the implications for teacher education. This was informed by the outcomes of empirical research in relation to teachers' current views and practices.

Focus Area 2: Evidencing Practice

Whilst the contributing literature reviews highlighted 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 was known about patterns of learning and teaching in these areas in the participating countries. With this in mind, the second major area, then, which the project needed to address was the evidencing of practice. This involved some investigation of how the problem finding and problem solving inherent in IBSE was 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 project used Banaji and Burn's (2010) creative classroom discourse, with its focus on teaching and learning and its emphasis on exploratory playful engagement, as a 'lens' for the research.

The evidencing of practice was undertaken at the level of policy and also the classroom, as follows.

Policy perspective: Work undertaken during the literature reviews 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 was explored through the policy and teacher surveys and through the in-depth fieldwork, as well as being drawn upon in the approaches and guidelines devised for teacher education.

Classroom perspective: The empirical work undertaken through teacher survey and fieldwork, explored the three areas of learning, teaching and assessment in science and mathematics education in the Early Years and their intersections with creativity. Researching teaching and learning foregrounded children as active agents, recognised multimodal expression and experience, and included, for example, exploration of the kinds of activity and the roles undertaken by adults and children. The latter encompassed the scaffolding which occurs during dynamic interactions between teacher, materials and children, and the sorts of resources used, as well as the role of exploration, questioning and argument, and assessment.

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Focus Area 3: Developing practice

The third area of focus agreed was the development of practice by offering guidelines, recommendations and curricula informed by the analysis of the two areas above. These identified research gaps and thus indicated ways in which the project could contribute to developing practice. In this regard, the project sought to contribute by:

- Exemplifying practices related to play and exploration, dialogue and collaboration, questioning and curiosity and, also reflection and reasoning.
- Evidencing children's and teachers' lived experience of creativity in early science and mathematics education; attitudes, skills and, pedagogical knowledge, seeking to bridge any existing gaps.
- Articulating priorities for initial and in-service teacher education with respect to creativity in early science and mathematics.

Although the development of practice was a goal of the project, to enable this, the project focused primarily on revealing and analysing practice. The contribution to professional and practice development made by the project thus emerged from these findings and thus the study adopted a design which documented practice rather than one based on intervention.

2.7 Research questions

The *Creative Little Scientists* project aimed 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). As a consequence the study sought to produce a description or map of lived experience in Early Years science and mathematics education and to articulate what creativity in early science and mathematics looked like.

The definition of creativity in science and mathematics developed originally based on the Conceptual Framework was: *Generating alternative ideas and strategies as an individual or community and reasoning critically between these.* This definition was soon refined, following the suggestion of the project's external expert, to: *Generating alternative ideas and strategies as an individual or community and reasoning critically amongst these and between them and existing, widely accepted explanations and strategies.* The latter guided and underpinned all project work and deliverables. However, through discussions with stakeholders during the Final International Project Conference it was further refined to:

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Generating ideas and strategies as an individual or community, reasoning critically between these and producing plausible explanations and strategies consistent with the available evidence.

This definition and its previous versions need to be understood alongside the 'Little c creativity' definition (Craft, 2001), as in the diagram below (Figure 2.3) insofar as this effort toward originality and value through imaginative activity drives creativity in other domains including early science and mathematics.

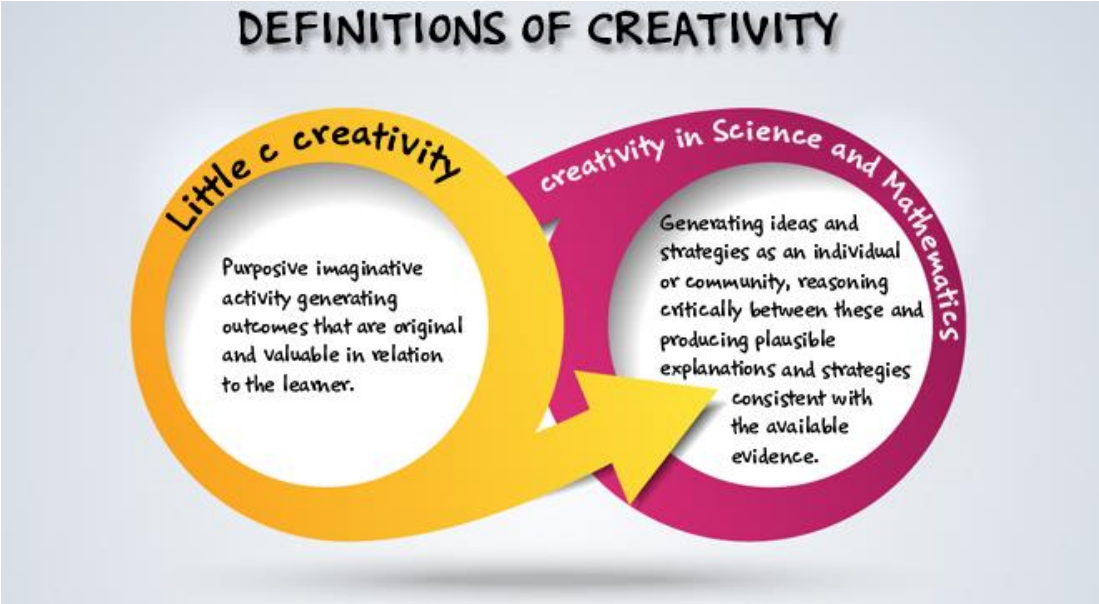

Figure 2.3: 'Creative Little Scientists' definition of creativity in Early Years science and mathematics education

To reflect the conceptual and research foci and methodological framing developed in the Conceptual Framework, the research questions, as noted above, were framed around:

- *capturing conceptualisations;*
- *evidencing practice;*
- *developing practice.*

and were:

RQ1. *(Mapping conceptualisations):* How is the teaching, learning and assessment of science and mathematics in Early Years across Europe conceptualised by teachers and policy? 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.

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RQ2. *(Probing practice):* In what ways do approaches foster young children's interest in science and mathematics. How do teachers perceive their role in doing so?

RQ3. *(Probing practice):* What approaches are used in the teaching, learning and assessment of science and mathematics in Early Years across Europe? 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.

RQ4. *(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?

The research design needed to be sensitive to how responses to these questions might vary with age and hence the proposal sought to span the age range in classroom samples, and the comparative dimension of how they may vary with cultural context was built into the plan.

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Chapter 3: Research Methodology

As mentioned in Chapter 1 *Creative Little Scientists* was an intensive research project which comprehensively integrated elements of comparative research, in-depth field research and curriculum design in the nine participating countries in Europe, seeking to emerge findings that can be extrapolated, exploited and disseminated at the European level more generally.

As articulated in the Conceptual Framework, summarised in Chapter 2, the first research question was focused on mapping conceptualisations in relation to classroom practices in preschools and early primary education, and the second and the third on probing practice in such settings in science and mathematics education using the lens of creativity. This reflects the distinction in relation to the curriculum, made for example by van den Akker (2007), between the curriculum as *intended* (RQ1), as *implemented* (RQ2) and as *attained* (RQ3). The final question (RQ4) drew on both the mapping and probing questions and sought to apply what had been learned so as to develop practice through teacher education (in relation to ITE and CPD).

The following sections outline the research strategy and design as well as the methods used for collecting and analysing the data to address all four research questions of the project. They also present the rationale behind the choices made concerning methodological issues and document any limitations of the research.

3.1 Operationalising the Conceptual Framework: the List of Factors

The Conceptual Framework (D2.2) identified sub-questions running across all project research questions that probe:

- **Aims/purpose/priorities**, including teachers' explicit and implicit perspectives and identities as scientists and mathematicians, and in relation for example to: aims and purposes of creativity in science and mathematics education; how science and mathematics are taught and learned in relation to other domains of knowledge; how these shift from preschool to primary across the consortium; how these relate to inquiry-based science education (IBSE); views of creativity in relation to perceived purpose.
- **Teaching, learning and assessment**, including learning activities, pedagogy and resourcing, and in relation for example to: multimodal expression and experience; learning activity types; resources used; dynamics between adults and

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children; exploration; questioning and argument; also how teachers assess creativity in early science and mathematics education.

- **Contextual factors**, including ethos, teacher characteristics and teacher general education and knowledge, skills and confidence, curriculum, institutional factors, home-school links and the wider cultural background, location, grouping, time.

These three broad strands were broken down into more narrowly-defined dimensions drawing on the framework of curriculum components 'the vulnerable spider web' (van den Akker, 2007, p.39), which focus on key questions about aspects of learning in schools: Rationale or Vision; Aims and Objectives; Learning Activities; Pedagogy (or Teacher Role); Assessment; Materials and Resources; Location; Grouping; Time; Content. These were complemented by dimensions focusing on aspects of teachers and teacher education.

Within these dimensions and sub-questions a number of factors were identified (D3.1 List of Mapping and Comparison Factors), drawing on the Conceptual Framework (D2.2) and encompassing the key features and processes of science and mathematics teaching, learning and assessment, highlighting those in the common conceptual ground between creativity and inquiry based science and mathematics education.

These factors were employed across the project:

a) to provide the scope and parameters for mapping and comparing existing approaches – see the Report on Mapping and Comparing Recorded Practices (D3.2), the Report on First Survey of School Practice (D3.3) and the Comparative Report (D3.4); and

b) to code current practice and select illustrative episode in the fieldwork – see the Report on Practices and their Implications (D4.4).

Moreover, the curriculum dimensions (van Den Akker, 2007) used to categorise the curriculum- related factors were also used as a basis for the development of the curriculum design principles for teacher education. In other words, the use of these dimensions and factors not only reflects their strong relationship with the theoretical knowledge established though the literature review, but also the consistency in approach between the comparative research, the field work and the production of the curriculum design principles and guidelines for teacher education

Table 3.1 shows these dimensions, sub-questions and factors in each strand.

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Table 3.1: Dimensions, Sub Questions and Factors

	Dimensions	Sub questions	Factors important to nurturing creativity in science and mathematics in the Early Years
Aims/purpose/priorities	**Rationale or Vision**	Why are they learning?	• science economic imperative • creativity economic imperative • scientific literacy and numeracy for society and individual • technological imperative • science and mathematics education as context for development of general skills and dispositions for learning
	Aims and Objectives	Toward which goals are the children learning?	• Knowledge/understanding of science content • Understanding about scientific inquiry • Science process skills; IBSE specifically planned • Capabilities to carry out scientific inquiry or problem-based activities; use of IBE/PBL • Social factors of science learning; collaboration between children valued • Affective factors of science learning; efforts to enhance children's attitudes in science and mathematics • Creative dispositions; creativity specifically planned
Teaching, learning and assessment	**Learning Activities**	How are children learning?	*Focus on cognitive dimension incl. nature of science* • Questioning • Designing or planning investigations • Gathering evidence (observing) • Gathering evidence (using equipment) • Making connections *Focus on social dimension* • Explaining evidence • Communicating explanations
	Pedagogy	How is teacher facilitating learning?	• Role of play and exploration; role of play valued • Role of motivation and affect ; Efforts made to enhance children's attitudes in science and mathematics • Role of dialogue and collaboration; *collab. between children valued* • Role of problem solving and agency ; use of IBE/PBL, Children's agency encouraged • Fostering questioning and curiosity - Children's questions encouraged • Diverse forms of expression valued • Fostering reflection and reasoning; children's metacognition encouraged • Teacher scaffolding, involvement, Sensitivity to when to guide/stand back

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	Dimensions	Sub questions	Factors important to nurturing creativity in science and mathematics in the Early Years
	Assessment	How is the teacher assessing how far children's learning has progressed, and how does this information inform planning and develop practice?	*Assessment function/purpose* • Formative • Summative • Recipient of assessment results *Assessment way/process* • Strategy • Forms of evidence ; excellent assessment of process +product, Diverse forms of assessment valued • Locus of assessment judgment – involvement of children in peer/self assessment
Contextual factors (Curriculum)	**Materials and Resources**	With what are children learning?	• Rich physical environment for exploration; Use of physical resources thoughtful; Valuing potential of physical materials; • Environment fosters creativity in sci/math • Sufficient space • Outdoor resources; recognition of out of school learning • Informal learning resources • ICT and digital technologies; confident use of digital technology • Variety of resources • Sufficient human resources • NO reliance on textbooks or published schemes
	Location	Where are they learning?	• Outdoors/indoors/both - recognition of out of school learning • Formal/non-formal/informal learning settings/ • Small group settings
	Grouping	With whom are they learning?	• Multigrade teaching • Ability grouping • Small group settings • Number of children in class
	Time	When are children learning?	• Sufficient time for learning science and mathematics
	Content	What are children learning?	• Sci/ma as separate areas of knowledge or in broader grouping • Level of detail of curriculum content • Links with other subject areas / cross-curriculum approach; evidence of science and maths integration (planned or incidental) • Subject-specific requirements vs. broad core curriculum • Content across key areas of knowledge

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	Dimensions	Sub questions	Factors important to nurturing creativity in science and mathematics in the Early Years
Contextual factors (Teacher)	**Teacher Personal Characteristics**	Who is the teacher?	• Gender • Age
	Teacher General Education and Training		Qualifications: • Level • Focus / content • Professional
	Teacher Science and Mathematics Knowledge, Skills and Confidence		• Pedagogical competence • Scientific competence • Teachers preconceptions of science and mathematics in terms of creativity • Confidence in teaching science and mathematics – do they feel well prepared • ICT skills • Views on own ITE/CPD (what/how)
Initial Teacher Education			• entry qualifications/requirements for prospective teachers • ITE standards/competencies • ITE curriculum • level of education • length of ITE • location of ITE • ITE providers • profile/role of teacher educator • profile/role of school mentor • models of training • assessment approaches used in teacher education
Continuing Professional Development			• standards / competencies • national priorities • impact of CPD • nature of CPD • CPD providers

3.2 Mapping and comparative assessment of recorded and reported approaches

The objective of the first stage of the research was to map and comparatively assess existing approaches to science and mathematics education in preschool and first years of primary school (up to the pupil age of eight) in the nine sample countries, highlighting instances of, or recording the absence of, practices marrying science and mathematics learning, teaching and assessment with creativity. This objective was addressed via two routes:

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1. through the conduct of desk research that looked at how teaching, learning and assessment of science and mathematics in the Early Years is conceptualised in national policy documents, including curricula, reports and assessments of school practice (D3.2 Report on Mapping and Comparing Recorded Practices); and
2. a wide teacher survey aimed towards gaining insights into practicing teachers' conceptualisations of science, mathematics and creativity in Early Years education (D3.3 Report on First Survey of School Practice).

The recorded policy approaches and the classroom approaches reported by teachers in the nine partner countries were then compared to produce the Comparative Report (D3.4). These findings are summarized in Chapter 4.

Although with very different scope the two studies were similar in their comparative strategy. They used a very similar questionnaire to collect their data. Its items drew upon approaches that were identified in the Conceptual Framework (D2.2) and the List of Mapping and Comparison Factors (D3.1) as being relevant to the role of creativity in early science and mathematics and the responses used a similar 4-point Likert Scale. In the case of the policy survey, the questionnaire aimed to assess the extent to which certain approaches were emphasised in policy documents and the extent to which the role of creativity was emphasized within these approaches. In the case of the teacher survey, it aimed to assess the extent to and frequency with which teachers use certain approaches in their classroom.

They also both followed a two-layered mixed-methods comparative approach in the analysis of their data. In addition to the quantitative variable-oriented approach (Lor, 2012) indicated for the survey analysis, and adopted to help identify and reflect on similarities and differences among the recorded or reported approaches in the partner countries, both also used a more case-orientated comparative strategy (Lor, 2012). Researchers in each partner country were asked to complete a National Report where they could analyse and comment on their data and findings, drawing upon their familiarity with the national context. The National Reports therefore constituted a set of case studies providing contextual information to help interpret quantitative information from the questionnaire.

To facilitate comparisons within each study, the structure of each National Report was the same, and between the two studies very similar. In both of them the main section was for discussing under the project's curriculum dimensions (van den Akker, 2007) key themes relevant to: the main issues/tensions; the role of creativity; differences between phases; and differences between science and mathematics. Researchers were encouraged to use the National Reports as an opportunity to provide context for the responses they or the teachers had provided in the questionnaire. Finally, the structure of the end section of the National Report was also

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common in both studies and comprised summaries of the key themes and their implications for the role of creativity in early science and mathematics.

By aligning the two surveys, the aim was to facilitate subsequent comparisons of conceptions promoted in policy with those held by teachers for whom policy is largely intended (focused upon on in the subsequent D3.4).

Having talked about the methodological similarities of the two studies, there were also significant methodological challenges specific to each, dictated by their different scope and nature. These and their limitations are discussed in the following sections.

3.2.1 Study on Mapping and Comparing Recorded Practices (D3.2)

As previously mentioned, in this study first partners completed a questionnaire which asked them to rate how specific approaches were emphasised in policy guidance, and created their own National Reports on policy. These National Reports were then drawn upon in order to identify similarities and differences in approaches amongst national polices. Comparisons of ratings for each item indicated these similarities and differences, and the related comments and justifications provided by the partners about the ratings gave further insights into such similarities and differences.

Several methodological challenges were faced in the course of this process.

Nations and Educational policy

Firstly, it was important to identify what was meant by national policies. For most partners this was straightforward, as the whole country is governed by one national policy. However in the countries of the UK and Belgium there are distinct jurisdictions with completely separate educational policies, therefore separate National Reports were produced for England, Northern Ireland, Scotland, and Wales in the UK and for Flanders and Wallonia in Belgium. In the case of Germany, although each federal state has a different policy, they operate within a common framework of guidelines set at national level. Therefore one National Report was completed that identified common dimensions in policy across the country, illustrated by applications of national policy in two federal states: Hesse and North-Rhine Westphalia. The limitation of basing reports on representative regions within a country needs to be recognised. National policies also differed in terms of their educational structure, where provision and ages for ‘pre-school’ and ‘primary school’ differ. This needs to be taken into consideration when examining comparisons made of different phases between nations.

Recorded practices

There were also issues associated with the decisions of how to consider ‘recorded practices’. In this report, ‘recorded practices’ were interpreted as formal written policy documents. However, key messages about approaches are often communicated

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through other media such as webpages or textbooks. Another issue concerned what policy documents to include in analysis. Whilst guidelines were provided to researchers, messages were often spread across a range of documents that varied in their direct relevance to the particular focus of this report. Indeed, one important aspect not made explicit is the extent to which messages had to be gleaned from different documents. Another issue to consider is the status of policy documentation, as for many countries, documents were in a phase of transition, with the result that analysis may soon be outdated. Finally, it should be noted that policy documents often apply only to compulsory phases of education. Therefore in some countries there was no policy documentation for the part of the pre-school phase that is not compulsory.

Policy in relation to context

Policy cannot be considered outside the context in which it is written: historical, political, geographic or economic. A policy may be written, for example, to distinguish itself from prior governmental approaches, or to acknowledge increasing economic competition resulting from globalisation. Policy may wish to embody a particular rhetoric that has gained currency in a broader context, or attempt to address current points of contention such as teacher empowerment. Often, it is what is not said, or not emphasised in a particular document that speaks louder than what is actually said.

Understanding the intricate context of different policies is clearly complex and would require more resources than available in this project. However, it is important to recognise how national policies often need to be interpreted within a particular context, particularly when making comparative judgements.

It is also important to recognise that policies are often in a state of transition. Indeed, as illustrated later, this is the case in many of the policies of national partners. According to Rizvi and Lingard (2011), policy should be considered more as a process than a product. This is to say that the process of negotiating and renegotiating policy can often be more influential than the finished outcome. Consequently, whilst the study focused on a comparison of available documents (outcomes), attempts were made to present these within the ongoing contexts in which they arise.

Science and Mathematics

A further challenge of this study was how best to capture conceptualisations of science and mathematics in Early Years, whilst mapping approaches in way that could compare national policies. This report was able to benefit from prior work that generated a List of Mapping and Comparison Factors (D3.1) with which to map and compare approaches. However, this framework was not developed specifically for policy analysis, and hence raised questions of how easily it could be adapted. A

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further issue that arose concerned how science and mathematics are presented in curriculum documents. For many partner countries, science in the Early Years is presented within a broader area of study, with implications for how approaches to 'science' can be compared.

Subjectivity

Many of the items in the questionnaire required researchers to rate the extent to which particular approaches were emphasised: using a scale of 0-3. Rating the degree of emphasis inevitably involves a degree of subjectivity. In this regard, a significant limitation of this study is that a sole researcher, for the most part, completed the questionnaires. Validation was partly provided by checking the evidence for each response (and in some cases with local informants) but it is likely that the ratings can only be treated as broad indications of emphases in policy.

Possibly a greater challenge was how to rate the extent to which creativity was emphasised in approaches. Whilst prior work was able to identify the List of Mapping and Comparison Factors (D3.1) to draw on, characteristic of opportunities for creativity in Early Years science and mathematics, ratings were again susceptible to the particular experiences and knowledge of the different partners completing this work.

Language

Finally, there was the significant challenge of language, where translation into English may have lost important aspects of how science, mathematics and creativity are conceptualised in documentation.

With all these challenges and limitations in mind, 134 documents were analysed, comprising policy documents related to curriculum, pedagogy and assessment in science and mathematics in each partner country, documents for both preschool and primary school, and including both statutory requirements and guidance for teachers.

3.2.2 Study on Mapping and Comparing 'Reported' Practice (D3.3)

The questionnaire in this study was provided in 9 national languages versions (Greek, Dutch, English, Romanian, German, French, Finnish, Portuguese and Welsh) and administered online to teachers of preschool and early primary education in the partner countries. It included 44 questions and required on average 40 minutes to complete it.

Once again, the analysis was carried out in two stages. First, partners carried out an analysis of their country's data to produce a National Report discussing the findings and situating them within their country's educational context (Addenda to D3.3). In the second stage, the data gathered from all the partner countries were amalgamated and analysed as a whole. Statistical comparisons were performed to identify

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similarities and differences between 'reported' practices in partner countries; information provided in the National Reports was used to interpret these similarities and differences.

The analysis was conducted using SPSS and Microsoft Excel software, and was based entirely on the total valid sample of respondents from all partner countries, that is all preschool and primary school staff who taught the children age group studied by the *Creative Little Scientists* project (children from the age of 3 and up to the age of 8) during the 2011-12 school year. Additionally, respondents were divided into two sub-samples based on the level of education they teach, i.e. preschool or early primary school. The report was structured to present the findings of the study for the total sample, as well as for both sets of preschool and primary teachers. Moreover, as previously mentioned, the mapping and comparisons factors and their dimensions (D3.1) were used throughout the report to group and present these findings, in a way similar to the policy review report (D3.2), so as to allow for comparisons between policy and reported practice to take place subsequently as part of the Comparative Report (D3.4).

Several methodological challenges were faced in the course of this process.

Design of questionnaire

In designing the questionnaire the consortium was faced with a number of difficult decisions common to working with questionnaires and well documented in the literature. These were made more challenging by the necessity to construct a common questionnaire for comparison purposes, which would target teachers of different phases, backgrounds and languages in 9 different countries and 13 different educational systems. Finding the balance between having a reasonable survey length and comprehensively covering the project focus approaches, was also an important issue. To respond to these challenges, the translated versions of the questionnaire were piloted with selected groups of practicing teachers and academics – experts in the field - in all countries, who provided detailed comments and suggestions both about the questionnaire's content and structure and its use of language. Suitable adaptations were subsequently made on the original questionnaire and its translated versions.

Sample

Most of the limitations of this quantitative study are linked to the sample of teachers that completed the online survey: a total of 815 teachers from 605 schools (238 preschools and 367 primary schools) across the consortium countries. The number, although within the prescribed target in the project's description, is still quite small for very robust and statistically significant quantitative conclusions. Also, although from the outset of the project it was always the case that the national samples were

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not going to be 'representative' in a formal statistical sense of either the number of schools or teacher population in the partner countries, it is important to recognise that there were a series of biases in the sample. Some countries' or regions' samples were clearly under-represented in relation to the teacher population they correspond to, in particular Germany's, France's, Wallonia's, Wales' and Scotland's, whereas other countries' samples were overrepresented in the total sample, namely Finland's, Greece's and Romania's. Furthermore, the small number of sampled teachers in some partner countries or regions meant that it was not statistically realistic to compare their responses with others' in the rest of the partner countries. Finally, the non-representative character of the samples also signals caution in the interpretation of the similarities and differences amongst countries, which can be only understood in depth in view of the unique characteristics of the different educational systems they refer to. The value of the National Reports for this purpose is paramount.

Quantitative analysis – the value of context

The SPSS/Excel data files were used to merge all the responses gathered to produce the total sample from all countries. Although such an approach might seem as inappropriate when taking into account the differences between the consortium countries, as evident in the policy report (D3.2), and biases of the sample, as discussed above, merging the data provided the opportunity to produce an overview of the current situation across the nine partner countries. Frequency tables presented teachers' responses to questionnaire items as percentages, means and standard deviations (only for Likert scale questions). The tables grouped questionnaire items accordingly to the dimensions and approaches identified by the List of Mapping and Comparison Factors (D3.1), which enabled comparisons between countries for all the groups of factors, revealing similarities and differences among them. The National Reports provided important contextual information, for the consideration and interpretations of these comparisons.

Having discussed the limitations above, this study's findings still have a unique value as they provide a rough but rich map of an unchartered but very important area, that of the intersection between science, mathematics and creativity in the preschool and early primary education in nine European countries and 13 educational systems, through the eyes of the key players in it, the teachers, and based on a very elaborate and cutting-edge theoretical framework.

3.2.3 Comparative Report (D3.4)

The aim of the Comparative Report (D3.4) was to synthesise and compare the findings of the policy and teacher surveys and provide an answer to the project research questions RQ1 and RQ4:

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RQ1: How is the teaching, learning and assessment of Science and Maths conceptualised by teachers and in policy? What role does creativity play in these?

RQ4: How can findings emerging from analysis in relation to these questions inform the development of practice in the classroom and in teacher education (ITE and CPD)?

Findings from the studies on mapping and comparing 'recorded' and 'reported' practices (D3.2 and D3.3) alongside the corresponding National Reports compiled by each partner country, were compared and synthesised with a view to revealing any similarities and differences between policy documents and teachers' conceptualisations of teaching, learning and assessment practice of science and mathematics education in the Early Years, and the role of creativity in these. Consideration was also given to the characteristics of teacher education in Early Years mathematics and science across partner countries.

Various comparisons were made at different levels and from different perspectives:

- between the key findings of policy and teacher surveys at the European level;
- between the findings of policy and teacher surveys at the partner country level;
- of the findings of policy and teacher surveys of the partner countries, drawing similarities and differences amongst them.

and from different perspectives:

- between preschool and Early Years education;
- between science and mathematics education (when data were available)

All these comparisons were focused on the factors and approaches targeted in the project and their synthesis brought out issues and tensions in science and mathematics Early Years education, most relevant to the potential for creativity and the role of inquiry-based approaches.

The limitations involved in these comparisons are related to the limitations present in the two mapping and comparing studies discussed in the previous sections, and are not repeated here.

An overview of the findings of this Comparative Report (D3.4) is presented in Chapter 4.

3.3 Analysis of practices and implications (D4.4)

The objective of the second stage of the research was to provide a deeper analysis of the implications of the mapped and compared approaches which would reveal the

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details of current practice and provide insights into whether and how children's creativity is fostered and the emergence of appropriate learning outcomes in science and mathematics is achieved.

This part of the research was accomplished through in-depth fieldwork undertaken in each of the nine participating European countries (Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania and the UK) representing a wide spectrum of educational, economic, social and cultural contexts.

The research aimed to address research questions RQ2, RQ3 and RQ4 namely:

RQ2: What approaches are used in the teaching, learning and assessment of science and mathematics in Early Years in the partner countries; what role if any does creativity play in these?

RQ3: In what ways do these approaches seek to foster young children's learning, interest and motivation in science and mathematics? How do teachers perceive their role in doing so?

RQ4: How can findings emerging from analysis in relation to these questions inform the development of practice in the classroom and in teacher education (ITE and CPD)?

As in previous reports from the *Creative Little Scientists* project, these questions were examined in relation to a number of dimensions based on the curriculum components associated with 'the vulnerable spider web' (van den Akker, 2007, p.39), which identifies key questions about aspects of learning in schools. In addition, for this study, these dimensions were grouped to reflect the two main foci of the fieldwork, informed by the pedagogical model developed by Siraj-Blatchford et al (2002) shown in Figure 3.1, namely

- **Pedagogical interventions** (or interactions) documented by observing face to face classroom practice and listening to children's reflections on this, and
- **Pedagogical framing** documented through teacher's reflections on classroom practice and wider information concerning the teacher, school, curriculum and assessment.

The study also drew on wider contextual information concerning the teachers and schools that participated in the fieldwork, and local curriculum and assessment policy to identify any enabling factors or barriers at the contextual level that might influence opportunities for creativity and inquiry in early science and mathematics.

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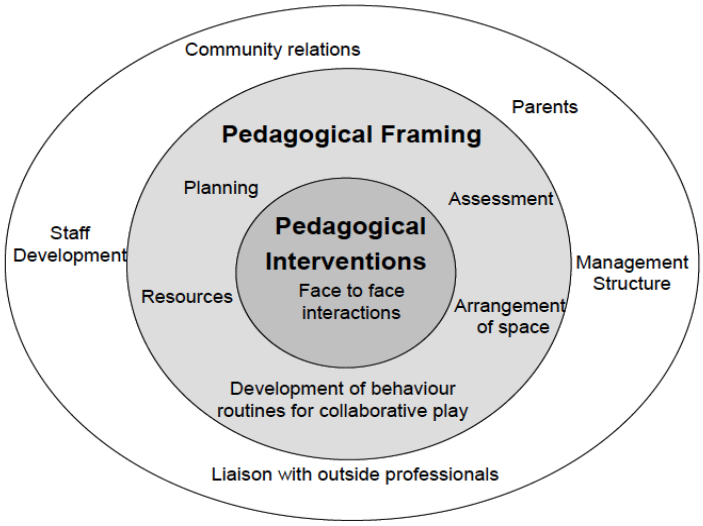

Figure 3.1: Pedagogical interventions in context (Siraj-Blatchford et al, 2002)

3.3.1 Research Instruments

The methodology for fieldwork (detailed in D4.1 Methodology of In-depth Fieldwork) set out a series of core instruments, as indicated below, to be used by all partners. In addition each partner could select from an agreed repertoire of instruments, depending on preferred approaches and existing expertise. Data was collected across the following four areas:

1. **WIDER SITE CONTEXT**: building on previous findings from the policy and teacher surveys (Deliverables D3.2, D3.3, and D3.4), information from school policies and websites, inspection reports and national and local curriculum documents.
2. **CASE PEDAGOGICAL CONTEXT**: the setting's teaching and learning policies and planning documents as appropriate, assessment records if they exist, overview of resources and a map of the space.
3. **CASE OBSERVATION OF PEDAGOGICAL INTERACTION AND OUTCOMES** (episodes of learning involving children and teachers):

   Core Instruments: Sequential digital images capturing detailed interactions, with fieldnotes supplemented by audio recording (later transcribed) and an overall timeline, enabling narrative construction.

   Possible additional repertoire instruments: teacher journals, Fibonacci style tools to support diagnostic observation (Fibonacci, 2012), Laevers Involvement Scale (Laevers, 1995), Reggio style documentation (Mercilliott Hewett, 2001), conceptual drawing, video.

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4. **CASE ORAL EVIDENCE (INTERVIEWS) - PERSPECTIVES ON PEDAGOGICAL INTERACTION AND OUTCOMES** (children and teachers)**:**

   Core Instruments: individual interviews (teachers), group interviews (children) using digital images from observations, 'learning walk' led by child, looking at children's work.

   Possible additional repertoire instruments: supplements to interviews such as conceptual drawings or teacher journals. Some oral interviews might be spoken to audio recorder.

3.3.2 Data Collection

The focus of the fieldwork in each country was on sites where there were indications that we would find 'exemplary practices' in fostering creativity and inquiry in early science and mathematics, covering all pupil age groups from age 3 up to 8 years and the range of provision of pre-primary and early primary education in the country. The characteristics of 'exemplary practices' emerged from reflection on findings of previous project deliverables: the Conceptual Framework (D2.2), the Report on Mapping and Comparing Recorded Practices (D3.2) and the Report on First Survey of School Practice (D3.3). Partners drew on a range of information in identifying possible sites for fieldwork including findings from the teacher survey (D3.3), reports of school inspections, data related to children's attainment and information from local education authorities and institutions of teacher education.

Each partner was required to visit a minimum of <u>four sites</u> (i.e. schools/preschools), and gather data from a minimum of <u>six cases</u> (i.e. one teacher and the children they work with) reflecting both settings (preschool and primary education). Partners were asked to aim to identify <u>three episodes</u> of activity per case (ensuring at least one each of science and mathematics) to illustrate the potential for inquiry and creativity in early science and mathematics, resulting in a total of 18 episodes to be reported per partner.

Fieldwork was conducted on 48 different sites across partner countries resulting in 71 case studies of practices in early science and mathematics. A total of 218 episodes were analysed and reported, including episodes focusing on science and mathematics and instances where science and mathematics were integrated in the episodes observed.

It should be noted that whilst empirical work was undertaken across partner countries it was not the intention to engage in a systematic comparative study in the sense of comparing 'like with like', rather to exemplify practices that foster inquiry and creativity in each national context.

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3.3.3 Ethical issues

Any fieldwork undertaken with young people carries ethical implications, both in terms of the conduct of the researcher whilst undertaking fieldwork, and in the collection and use of data following the fieldwork period. The consortium identified minimum standards and protocols that were applied by all partners in all cases concerning:

- Participation in the research on an informed voluntary basis.
- Explicit permission to take and use photographs or video recording.
- Explicit permission to interview children as part of focus groups.
- Storage of electronic data on password protected encrypted storage systems, where only authorised staff had access.
- Confidentiality and anonymity - All sites and participants were given pseudonyms to protect their identities.
- The need for partners to identify and meet ethical approval policies for their institution, school system, region and country as appropriate.

3.3.4 Data Analysis and Reporting

Analysis of data was carried out in two phases. First partners created their own *Country Reports* (D4.3). These consisted of a series of case studies, comprising background information about each case and analysis of associated classroom episodes highlighting opportunities for creativity. This was followed by a summary and discussion of findings with implications for teacher education and policy development in their national contexts.

The Report of Practices and their Implications (D4.4) was the outcome of a second phase of analysis. It drew together findings from across the D4.3 Country Reports, based on synthesis and further analysis of data from the Country Reports. Findings from this second phase of analysis were presented according to the dimensions and factors used across the *Creative Little Scientists* project in mapping and comparing practices, based on examination of the following sources of evidence: factors associated with inquiry and creativity identified in episodes across partner countries, themes and issues discussed in the Country Reports and examples of opportunities for creativity in learning and teaching illustrated in the episodes reported. This provided the basis for discussion of findings and their implications in the final sections of the report.

3.3.5 Limitations

During the in-depth fieldwork some limitations were encountered, some due to local issues, others linked to the project itself.

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The sample of sites selected for fieldwork in each country was small. It was constrained by issues of access, geographical and financial considerations and details of school timetables. It was not designed to be representative of practices across each country but rather to offer opportunities to study and exemplify good practices in fostering creativity in science and mathematics in a range of contexts. This limits the scope for generalization and comparison. However, as indicated in the research design, the intention was not to make comparisons between countries or sites but to illustrate and comment on the potential for creativity in varied contexts across the consortium.

The short time frame and available resources necessarily limited the scope of data collection. Time available for classroom observation was limited. It was only possible to gain snapshots of classroom practices that may not have been representative of everyday approaches to learning and teaching. For example teachers in some instances were keen to try out or discuss new ideas during the period of fieldwork and opportunities for outdoor learning were limited by the winter weather. (Although the weather conditions contributed to the many 'ice' episodes observed!) It was not always feasible for two researchers to be present to manage the range of fieldwork instruments or to capture the rich diversity of classroom practices, particularly in preschool settings where many varied activities were often taking place simultaneously.

Partners also reported limitations associated with schools' varied experiences of involvement in research or classroom observation. In some countries and settings this is common practice, for example associated with teacher professional development processes or inspection. In addition some partners were able to capitalize on previous relationships established with schools through research or involvement in teacher education. Such schools were used to accommodating visitors, and teachers and children felt confident to talk informally with researchers. In other settings classroom observation was much less part of school culture. In some instances this had on impact on the conduct of the fieldwork, in particular the opportunities for dialogue with teachers and children. Building on the comments above about the limitations of time, further time to develop the trust and confidence of participants might have afforded more detailed insights into their perspectives on learning and teaching.

A summary of the findings of this second stage of the research in the *Creative Little* Scientists project are presented in Chapter 5.

3.4 Directions for teacher training (D5.1 and D5.2)

In the framework of the *Creative Little Scientist*s project, a set of curriculum design principles, expressed as concrete guidelines, for European ITE and CPD programmes

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were developed with the purpose of enhancing the use of creative approaches to learning in pre-school and first years of primary school science and mathematics education. The research question addressed by this was RQ4:

RQ4: How can findings emerging from analysis in relation to these questions inform the development of practice in the classroom and in teacher education (ITE and CPD)?

To this end, the methodology of curriculum design research was used.

The curriculum design research model in Figure 3.2 (also in Deliverable D5.1 Prototypical Guidelines and Curriculum Design Principles for Teacher Training, p19) depicts the different phases – analytical, prototypical and assessment– of the design research process, as well as how the project's research work and findings have contributed to these.

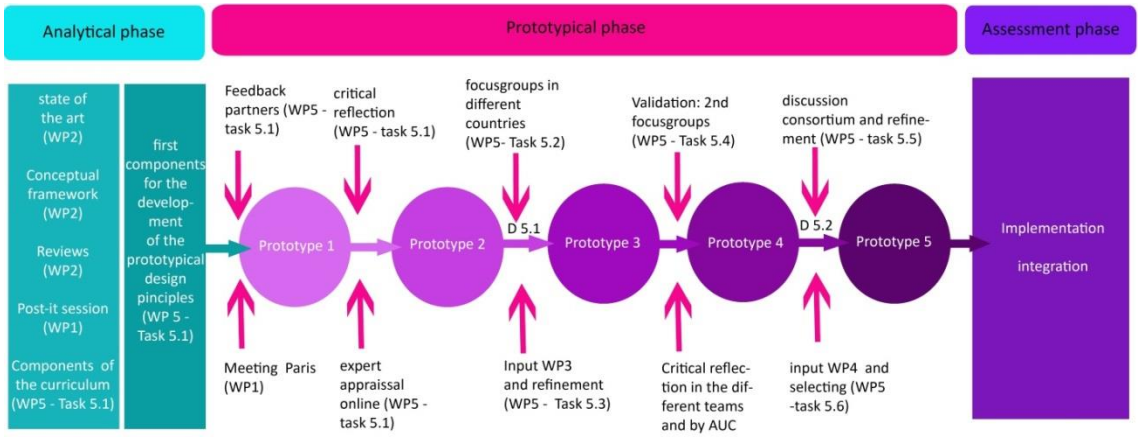

Figure 3.2: Curriculum design research model of **Creative Little Scientists**

The design principles and the successive guidelines were developed in collaboration with different relevant stakeholders in iterative cycles, represented by the gradually optimized and elaborated prototypes in Figure 3.2.

During the analytical phase, the project's conceptual framework (D2.2 Conceptual Framework) was developed, based on four literature reviews (Addenda to D2.2 Conceptual Framework), including one on teacher training for Early Years educators and primary teachers. In addition, during the same period a research of literature was undertaken with a focus on curriculum design and curriculum design research.

At the end of this phase, important issues from the Conceptual Framework and the reviews were combined with the corresponding viewpoints of the consortium partners and presented under the 10 curricular components (van den Akker, 2007), this time adapted to teacher education. Following further elaboration and feedback by the consortium partners, a draft version of the design principles (prototype 1) was prepared.

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During the next phase, the prototypical phase, this draft version of design principles was evaluated and refined through iterative cycles with a view to developing curriculum guidelines for teacher education. In the first cycle, the draft version (prototype 1) of the prototypical design curriculum principles was adjusted for the purposes of teacher education, using a web-based expert appraisal panel, consisting of the *Creative Little Scientists* consortium partners. The results of this expert panel were analysed through negotiation and synthesis, and these results guided the development of prototype 2 of curriculum design principles (see D5.1, Prototypical Guidelines and Curriculum Design Principles for Teacher Training).

In a following cycle, the draft prototypical design principles were evaluated in each of the partner countries by means of online focus groups for stakeholders. Moreover, they were analysed and further adjusted according to feedback from the partners.

During the final cycle, prototype 3 was developed into the final set of curriculum design principles for teacher education. This was achieved through the organisation of face-to-face focus groups with teacher educators. Each *Creative Little Scientists* partner provided context-specific examples of (best) practice, intended to clarify and illustrate the underlying messages of the final set of design principles. Additionally, the set of design principles was further refined based on the findings and implications from the two stages of research, described in the sections above. These findings provided the teams with insights into the main focal issues that had to be addressed by teacher education in order to foster creativity in science and mathematics education in Early Years. Based on these issues, the curriculum design principles which referred to the Content component of the teacher education curriculum were elaborated into a specific and concrete set of statements: the Teacher Outcomes. These Teacher Outcomes can be seen as important content recommendations for teacher educators to frame their courses.

The proposed Curriculum Design Principles and associated Teacher Outcomes are presented in Chapter 7.

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Chapter 4
Main Findings: Mapping and comparative assessment of recorded and reported practice

4.1 Introduction

This chapter has been informed by findings from the first research phase of the *Creative Little Scientists* project, and is concerned with the comparison between existing approaches of teaching, learning and assessment of Early Years science and mathematics and the role of creativity in these, as reflected on the one hand in public policy documents, and on the other on teachers' own perceptions of their practice, revealed through an online survey. It highlights commonalities and differences between policy guidance and reported practice amongst the nine European partner countries represented in the consortium. The comparison of conceptualisations of existing practice in particular promotes a better understanding of the global challenges and strengths of science and mathematics education in Europe.

This chapter draws out the main findings linked to the research questions to this research phase of the *Creative Little Scientists* project namely:

RQ1: How is the teaching, learning and assessment of science and mathematics conceptualised by teachers and in policy? What role does creativity play in these?

RQ4: How can findings emerging from analysis in relation to these questions inform the development of practice in the classroom and in teacher education (ITE and CPD)?

More particularly, RQ1 was operationalised in the Comparative Report (D3.4), summarised in this Chapter as:

> *What are the main similarities and differences in how the teaching, learning and assessment of science and mathematics in Early Years are conceptualised in the partner countries? What role does creativity play in these?*

The mapping and comparison focus on key aspects of learning, which have been derived from the framework of curriculum components the 'vulnerable spider web' (see van den Akker, 2007) that have also influenced other aspects of work in the *Creative Little Scientists* project (see Chapter 3). Findings in this chapter are

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therefore presented under these key aspects of learning, which are further grouped in relation to the three strands suggested by the Conceptual Framework (D2.2):

- Aims/purpose/priorities, which include the curriculum components Rationale or Vision and Aims and Objectives.
- Teaching, learning and assessment, which include the curriculum components Learning Activities, Pedagogy and Assessment;
- Contextual factors, which include Material and Resources (used or prescribed), Content, Location, Grouping, Time and institutional factors.

4.2 Aims/purpose/priorities of science and mathematics in Early Years

4.2.1 Rationale and Vision

The overall picture formed by the policy review and teacher survey in regard to the rationale or vision for science learning in the Early Years and compulsory education shows that even though policy in the partner countries tends to focus its guidance on specific drivers for science education, such as promoting positive skills and dispositions in young children, and in developing socially and environmentally aware citizens, teachers do not clearly focus on one specific rationale, but rather follow a more holistic approach considering all priorities as important.

Commentary included by partners in their National Reports provides information on the main foci for the rationale and vision presented in their policy documents. In almost all the partner countries, the purposes of education are focused on enhancing children's lives now and in the future as well as their roles as citizens, with particular emphasis on environmental awareness. The development of skills and dispositions for future learning takes on a more prominent role in Belgium, Germany, Malta and Romania, while attention to the economic benefits of developing children's basic skills and dispositions is given in France, but also in Flanders. In terms of reported practice as revealed through the teacher survey, only one purpose of compulsory science education was singled out by teachers as less important than the others, to produce future scientists and engineers, although this is still given greater emphasis than in preschool and primary policy documents. This particular rationale has the largest variance in policy evidencing the diverse focus on the economic driver of education in Early Years education settings across the partner countries, for example UK, England teachers strongly emphasised the economic imperative in the survey results whilst teachers in countries such as Belgium and Finland suggested more of an emphasis on the development of children as citizens through science.

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4.2.2 Aims and Objectives

Comparisons between the policy review and teacher survey reveal an interesting imbalance in the framing of learning outcomes linked to science in preschool and early primary education across the partner countries. The learning aims and objectives of the science curriculum in partner countries tend to focus on cognitive factors of science learning and particularly on the development of process skills associated with scientific inquiry and of knowledge and understanding of science ideas (the latter particularly in primary school). Such learning outcomes take on a dominant place in the curricula of Finland, France, Greece, Portugal, Romania and England. The findings from the teacher survey on the other hand suggest that teachers perceive the teaching of science overall as contributing primarily towards affective and social aspects of teaching and learning. Teachers view their role in the Early Years as mainly one that places at the forefront fostering positive attitudes and dispositions for science and lifelong learning and the development of children as socially and environmentally aware and responsible citizens.

Learning outcomes connected to the *cognitive dimensions* of science learning, even though used quite often by teachers, are featured less strongly in teachers' responses in comparison to outcomes linked to the *social and affective dimensions*. In contrast to responses to the teacher survey, the review of policy across partner countries showed that social and affective dimensions of learning are given more limited attention compared to cognitive dimensions. More particularly, the majority of policy documentation inspected lacked emphasis on promoting *positive attitudes to learning and interest in science* among the intended learning aims of Early Years science education. Exceptions to this are the Flemish community in Belgium, Germany and Malta where raising interest in science is seen as one of the main learning outcomes of Early Years science education. The vast majority of teachers on the other hand reported including such learning outcomes very frequently in their teaching.

In the teacher survey of practice, learning outcomes linked to the *social aspects of teaching and learning* were reported by teachers as very frequently included in their planning for learning and teaching. Here the comparison between findings of the teacher survey and policy review reveal a significant correspondence in the strong emphasis placed in both on including learning outcomes connected to fostering children's abilities to collaborate with others in science learning.

Learning outcomes related to *how science works and scientists develop knowledge* are under-emphasised in both policy and reported practice. As indicated in the Report on Mapping and Comparing Recorded Practices (D3.2) policy documents across the consortium make limited reference to knowledge and understanding of the nature of science. Items in the policy survey related to knowledge and understandings associated with the nature of science are not strongly emphasised in policy

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documents in either phase of education. Similarly, learning outcomes related to the nature of science and thus understandings about scientific inquiry (that is about how scientists develop knowledge and understanding of the surrounding world) are the least frequently pursued by teachers overall in comparison to other aims and objectives.

4.3 Teaching, learning and assessment of science and mathematics in Early Years

4.3.1 Learning Activities

The comparison of the two separate reviews, one for policy and one for reported practice, reveals interesting findings on the significance that features of inquiry-based science education play in terms of conceptions of learning activities in Early Years science education. Overall the surveys of policy and teachers' views found that features of inquiry were both promoted in curricular policies among suggested learning activities, as well as frequently included by teachers in the preschool and early primary science classroom. In particular, learning activities associated with observation, questioning, communication and the use of simple tools took a dominant place among inquiry related activities.

On the other hand the survey results indicated that inquiry skills associated with planning and conducting investigations and using data to construct explanations, that are linked to the development and use of scientific concepts and procedural knowledge, were given a less prominent place in the learning activities carried out in the classroom and in curriculum guidance. In particular, learning activities that involve children planning and designing their investigations were the least common of all the learning activities tied to scientific inquiry, despite the fact that they were thought of by many teachers as amongst the three most likely to contribute to children's creativity. The low frequency of use of these activities is consistent with the findings about teachers' inquiry-related science learning priorities. Even though no major differences were found between countries in terms of teachers' use of learning activities that promote children's observational and questioning skills, the same cannot be said for activities that involve children designing (or planning) and conducting simple investigations or projects. Finnish and Maltese teachers occupy the lower end of the spectrum in the use of these activities, while English teachers the upper end. The responses of Greek and German teachers suggested they involve children more in the conduct of investigations but less in their planning.

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4.3.2 Pedagogy

In order to bring together the results discussed in the Report on First Survey of School Practice (D3.3) and the Report on Mapping and Comparing Recorded Practices (D3.2) about policy and teachers' conceptualisations of the various learning contexts and approaches linked to pedagogy the synergies identified at the conceptual framework stage (Chapter 2) and the factors described in Chapter 3 (see Table 1) were used.

4.3.2.1 Dialogue and Collaboration

It can be ascertained that teachers overall appreciate the *role of dialogue and collaboration* in their practice, but fail to see their potential for development of creativity in children. This is consistent with policy in partner countries which puts some emphasis on the importance of dialogue and collaboration but includes very limited reference to features of creativity that might be fostered through dialogue and collaboration and very limited guidance to support teachers in enabling creativity using classroom discussions and collaborative work (even in cases where there is a strong explicit emphasis on creativity in the overall aims for education in Early Years of education).

4.3.2.2 Motivation and Affect

There is an uneven treatment in both policy and reported practice of the contexts and approaches grouped under the synergy *motivation and affect*. The contexts of 'drama' and 'using history to teach science' are used the least frequently and are least considered as 'creativity enabling'[5] by teachers while curricula also fail to promote these approaches or make reference to the potential for creativity of these two learning contexts. The approaches of *'building on children's prior experiences' and 'relating science to everyday life'* on the other hand were amongst those reported as most frequently used by teachers and referenced in policy, though still not highlighted as similarly 'creativity enabling' by both teachers and policy guidance. Finally, the teacher survey indicated that the cross-disciplinary teaching of science (*'integrating science with other curricular areas'*) is a context used frequently by both preschool and early primary school teachers, but not considered equally as 'creativity enabling' by them. Many more early primary than preschool teachers consider this context as 'creativity enabling'. Integrating science with other curricular areas in official policy is very similarly framed. It is more strongly emphasised in the preschool phase and only a few countries include commentary that suggests its potential to enable the development of children's creativity (for example preschool policy in Finland, Germany and Greece or primary policy in Finland).

[5] In the teacher survey teachers were presented with a number of approaches and contexts, identified by the project Conceptual Framework as having potential for creativity, and asked them to choose the three they thought were most 'creativity enabling'.

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4.3.2.3 Play and Exploration

There is a similarly uneven treatment of the contexts and approaches grouped under the synergy *play and exploration*. Preschool teachers use 'open/unstructured play' and 'role/pretend play' significantly more than early primary school teachers, and a greater proportion of preschool teachers also conceptualise these as 'creativity enabling'. This is also reflected in curricula across the partner countries. Policy in the majority of partner countries promotes playful exploration in preschool considerably more than in primary education, with guidance that suggests a recognition of its value in promoting creative skills and dispositions. On the other hand teachers who responded to the survey from both preschool and primary phases were in agreement in reporting frequent use of *physical exploration of materials* and identifying it as 'creative'. This agreement across phases is however not reflected in policy guidance. Even if curricula and policy guidance across the partner countries advocate children's physical exploration of materials in both phases, references to the opportunities this can provide for fostering creative skills and dispositions differs between the two phases. Here too there is more limited reference to the creative potential of this learning approach in primary policy in comparison to official guidance offered for the preschool phase of education.

4.3.2.4 Problem Solving and Agency

In terms of the synergy *problem solving and agency*, official policy across partner countries emphasises almost all relevant approaches and contexts identified by the project (such as the use of the environment as a means of scaffolding learning and encouraging children to raise their own scientific questions and ideas) across both phases of Early Years education. In the majority of partner countries, this emphasis on problem solving in policy is often also linked to suggestions about its potential to foster children's creativity, particularly in preschool. According to responses to the teacher survey, teachers use problem solving approaches quite or very frequently. A large majority of teachers across both phases of Early Years education considered almost all problem solving and agency contexts and approaches to be amongst the most 'creativity enabling' approaches to learning and teaching.

4.3.2.5 Questioning and Curiosity

Concerning the learning approaches associated with *questioning and curiosity*, these are either given various mentions or emphasised in preschool policy in the majority of partner countries. However in contrast to preschool, more limited emphasis is given to questioning in the primary phase policy.

In terms of teachers' reported practices, there was correspondence between teachers' use of practices that encourage children to ask questions and foster their imagination and teachers' perceptions of these practices as 'creativity enabling'. However, the

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same cannot be said for the use of questioning by teachers and their encouragement of children to record and express their ideas in different ways. Although results from the teacher survey indicated that both practices were used quite or very often by the large majority of teachers, they were not considered amongst the three most 'creativity enabling' by many of them. These findings are also reflected in policy guidance across partner countries. There is a common emphasis on children's questioning and curiosity and suggestion of their importance in fostering creativity. However the roles of teacher questioning and the value of varied approaches to children recording their ideas in supporting creative learning are given more limited recognition. Given the importance of modelling and fostering by teachers of positive attitudes of curiosity and questioning, these differences in recognition, reflected in both the teacher and policy surveys, rather point to an important gap that needs to be bridged by teacher education.

4.3.2.6 Reflection and Reasoning

The IBSE/CA synergy *reflection and reasoning* was identified by the project as emphasising the importance of metacognitive processes and reflective awareness, and showed a large variance between official policy documentation and teachers views on their practice. The synergy was represented predominantly through fostering classroom discussion and evaluation of alternative ideas, since, in the context of IBSE, participating in the process of evaluating ideas can foster an appreciation of scientific argumentation and explanation, and for creativity evaluation of ideas and reflection are considered important.

The Report on Mapping and Comparing Recorded Practices (D3.2) notes that a number of National reports stated that as children progress from preschool to school, greater attention to discussion of alternative ideas and independence might be expected. This however is not reflected in the emphases identified in policy across partner countries either in relation to the range of teaching approaches or aspects of inquiry discussed in policy. On the other hand, the Report on First Survey of School Practice (D3.3) indicates that the evaluation of alternative ideas is a teaching approach used quite and very frequently by a majority of teachers who participated in the survey.

Interestingly, even though a large majority of teachers reportedly used consideration of alternative ideas quite or very often many of the teachers did not consider this to be amongst the three most 'creativity enabling'. However, the proportion of teachers who used this practice quite or very frequently would suggest that it may contribute significantly to the development of children's creativity. The limited perceived scope for creativity of this particular learning approach is also highlighted in the review of policy as policy documents rarely indicated roles for creativity associated with discussing alternative ideas in the teaching approaches advocated.

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Due both to the elusive nature of reflection and reasoning, and to its relatively sparse representation in the list of teaching and learning contexts and approaches included in both policy and teacher survey questionnaires, a deeper examination of this particular synergy was referred to the next research phase of the project, the in-depth field study.

4.3.2.7 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. The final synergy identified by the *Creative Little Scientists*' Conceptual Framework emphasises the importance of teachers mediating the learning to meet the child's needs, rather than feel pressured to meet a given curriculum.

Teachers' responses about their self-image on their role indicate that they overwhelmingly saw themselves as facilitators of children's own inquiry, delaying instruction until the learner has had a chance to investigate and inquire on their own or with others. They were a little more reticent to allow children to find solutions on their own, but strongly reject the suggestion that they should first act as demonstrators of the correct solution before children get a chance to try out by themselves. Concerning the ways teachers perceived their role in scaffolding inquiry, more preschool teachers than primary teachers saw themselves as facilitators of children's own inquiry. Moreover, significantly more preschool teachers agreed that they should give children ample time to work out their own solutions to problems before showing them how they are solved. Similar to the previous IBSE/CA synergy (reflection and reasoning), a detailed analysis of this particular synergy was included in D4.4 Report on Practices and their Implications, summarised in Chapter 5.

4.3.3 Assessment

Assessment, especially formative assessment, was widely highlighted as a particular area for development in both policy and practice in both preschool and primary phases. A common theme to emerge across the two research surveys was lack of policy guidance in terms of both methods of assessment and criteria for assessing on-going progress, resulting in considerable variability in approaches adopted among partner countries. The findings from the policy and teacher surveys also revealed particular challenges in assessment related to inquiry and creativity, linked to a common tendency to focus on product rather than process in assessment requirements, allied with the pressures of statutory summative assessment processes in a number of partner countries.

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The policy review highlights the need for a closer match between the aims and rationale for science education and assessment priorities and approaches. For example while assessment of *science ideas* is widely emphasised in policy, more limited attention is given to assessment of *inquiry processes and procedural understanding* and even less to *social and affective dimensions of learning,* although these dimensions are often highlighted in the rationale and aims set out for early science and mathematics education. For example, while assessment of affective dimensions of learning (such as interest in science) is prioritised in curriculum policy in the Flemish community in Belgium (for both phases) and in Finland (for the primary age phase), guidance to promote assessment of affective dimensions of learning is absent from the curriculum policy in the majority of partner countries. In contrast, teachers who responded to the survey overwhelmingly gave greatest priority to the assessment of affective dimensions of learning, judging them to be more important than cognitive dimensions, such as acquiring *knowledge and understanding of science ideas and processes*. Interestingly, the cognitive dimension rated most highly among teachers was children's understanding of important science processes, as well as the assessment of inquiry competences, both given little emphasis in the policy survey. Teachers' responses to the survey regarding their priorities for science assessment were consistent with the frequency with which they indicated pursuing the corresponding aims and objectives in their science teaching. This is in contrast with the mismatch identified between rationale, aims and assessment priorities in official policy across partner countries.

While the importance of formative assessment is increasingly recognised in policy, the Report on Mapping and Comparing Recorded Practices (D3.2) indicates that further guidance would be valuable to support classroom practices in assessment. Areas highlighted in particular include: the use of multimodal forms of assessment to give young children opportunities to show best what they understand and can do; ways of involving children in peer and self-assessment to support children's reflection on inquiry processes and outcomes; and criteria to assess progression in learning, particularly in relation to inquiry and the development of dispositions associated with creativity. For example, guidance in official documentation regarding the value of children's multimodal expression for assessment purposes was identified in Romanian policy and some consideration of this particular dimension of assessment is provided in Finnish preschool policy. In the majority of partner countries however, there is very limited or no mention of the value of drawing on a variety of evidence such as pictures, graphs and relevant gestures for assessment purposes. Again here a contrast was noted between findings from the policy and teacher surveys as the teachers' responses to the relevant survey items showed that teachers' approaches to assessment tend to include evaluation of children's responses in varied modes, particularly in Greece, Romania, and in England where preschool

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teachers reported taking account of children's multimodal expressions for assessment purposes. The same cannot be said concerning teachers' employment of peer and self-assessment practices, as only about half the teachers surveyed reported that they use the formative approaches of peer or self-assessment quite or very frequently. The alignment in findings from both policy and teacher surveys concerning the limited role of peer and self-assessment suggests that the locus of the judgment in assessment in Early Years education is firmly in the hands of teachers with limited involvement of children.

In terms of the creative attributes that were identified in partner policy, such as the development of self expression through the use of language and communication, and through an inquiry based approach to learning, the assessment of thinking skills feature most strongly, especially in the early primary age phase. The other creative attributes most commonly emphasised or mentioned as being assessed include curiosity (greater emphasis in preschool), ability to work together (greater emphasis in primary) and ability to make connections with learning in other subjects. The teacher survey showed that a large majority of the sample of all teachers across the partner countries reported praising and rewarding creative dispositions in their pupils in science quite or very frequently. The dispositions most frequently rewarded were children's ability to work together and their curiosity and imagination. Some differences were noted in response across partner countries, for example it was noted that French teachers were less frequent in their praise of the eight creative dispositions when carrying out science assessment whilst, Romanian teachers, along with Greek and Maltese teachers rewarded most of these creative dispositions significantly more frequently than others.

4.4 Contextual factors

4.4.1 Content

The findings from both the policy and teacher surveys suggest a number of differences in the presentation and nature of curriculum content for science and mathematics across partner countries.

In preschool, science is generally included within broader areas of learning such as 'Discovery of the World' (France) or 'Child and the environment' (Greece) or 'Knowledge and Understanding of the World' (UK (Wales)) with the majority of official guidance advocating integrated cross-curricular approaches to learning and teaching. In addition, overall there is limited specification of subject specific content for science in this phase of education. The emphasis is rather on the development of basic skills and positive attitudes in the context of content selected to build on children's prior experiences and interests. This is the case for the Flemish community

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in Belgium, France, Finland, Germany, Malta and England. In early primary school, many national curricula such as of the Flemish community in Belgium, Finland, Germany, Greece, Northern Ireland and Wales continue to specify science within broader areas of learning. In Wallonia, France, Malta and Romania on the other hand, science is presented as a separate area of learning. In both cases, the emphasis is placed on developing specific scientific concepts associated with learning objectives for the primary age phase.

Large variation was also observed in the sections of the curriculum that present the teaching methodology to promote the specific skills and processes associated with inquiry. In some countries there are separate sections devoted to inquiry (for example UK (England) 'Scientific Enquiry' or Belgium (Flanders) 'General skills in science') or requirements may be integrated within subject content for example in Portugal 'Conducting experiments with Light' as part of the area of learning 'Discovering objects and materials'. A further approach to the inclusion of skills and processes within requirements for curriculum content is that of specifying skills and processes within cross-curricular themes and competencies (Belgium (Wallonia) or UK (Northern Ireland)) to be developed across all areas of learning.

While skills and processes related to inquiry feature strongly at both phases, in general a more specific focus on the development of concepts and on a broader range of investigative skills and processes is evident in primary curriculum content.

A greater role for creativity was generally identified as implicit in policy, indicated for example in the common presentation of the curriculum in terms of experiences, the importance given to play and exploration, building on children's interests, and the greater attention to affective and social factors within curriculum content. However, primary school curricula across the partner countries rarely offer explicit guidance on the development of social and affective dimensions. Affective dimensions of teaching and learning are given far greater attention in preschool education. Examples include references to 'aesthetic sensitivity and imagination' (Portugal) and 'motivation to learn' (Romania). Social factors are little mentioned within the content specified for particular areas of learning but often feature within generic curriculum requirements or guidance.

The policy survey indicates limited explicit references to creativity related to curriculum content. Explicit references include for example 'develop pupils' curiosity, creativity and critical thought' (France), 'develop creative approaches to problems' (Germany), 'stimulate creative potential', 'develop creativity' (Romania)or in UK (Northern Ireland) 'learning experiences that encourage creativity'. A greater role for creativity was generally identified as implicit in policy, indicated for example in the common presentation of the preschool curriculum in terms of experiences, the

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importance given to play and exploration, building on children's interests, and the greater attention to affective and social factors within curriculum content.

In comparison to science, mathematics is more commonly set out as a distinct area of learning in partner policy at both phases of education. As in science, mathematical content specified in the curriculum includes both concepts and processes with increasing focus on concepts and higher order thinking skills across the primary school. Mathematical content of the curriculum receives greater attention in preschool in comparison to science, and in mathematics reference is often made to problem solving rather than inquiry or investigation. In general there is a similar focus on affective and social factors. Mathematics in some countries is also treated as a cross-curricular dimension (UK Wales). In Romania, the application of mathematics to general science knowledge is emphasised. This is not the case in science although generic inquiry or thinking skills for example may feature in cross-curricular dimensions.

4.4.2 Location

The teacher survey indicated that collaboration amongst peers and working in small groups are approaches employed by the majority of teachers, as recommended in policy across partner countries and phases of education. With regards to the use of outdoor learning environments there is also consistency between policy and teacher surveys. Outdoor learning is mentioned in most countries' policy guidance - more strongly for preschool. Similarly, teachers in the majority of partner countries reported making use of teaching and learning opportunities linked to outdoor environments, with the exception of primary school teachers in the Flemish community in Belgium and Portugal. On the other hand, non-formal learning environments such as visits in places of interest were given limited attention in most partner countries' policy and also reported to be used rarely by most teachers across the consortium. Countries where such opportunities were particularly highlighted in policy include France, Germany and Greece.

4.4.3 Materials and resources

Materials and resources, in this context, were evaluated in relation to the frequency of use, rather than with regards to role or importance in lessons. As indicated in the Conceptual Framework (see chapter 2) provision of a wide range of materials in the classroom, including digital technologies, can be motivating and offer different ways for young children to represent ideas and express their thinking. Research in science, mathematics and creativity also highlights the importance of a rich physical environment and the use of the outdoor environment in promoting opportunities for exploration in the Early Years. The materials used in the science and mathematics classroom are therefore closely linked with the 'curriculum components' 'Learning

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Activities' and 'Pedagogy' and could equally be seen as a feature of 'Teaching, Learning and Assessment' approaches, as well one of the 'Contextual Factors' important in fostering creativity in early science and mathematics education.

The National Reports on policy indicate that limited guidance is offered about materials in the national policy of many partner countries. In the instances where guidance is provided, equipment associated with inquiry, such as materials to explore or equipment for measuring are most often mentioned, as well as digital technologies (for example Belgium (Wallonia), Finland, Germany, Greece, Romania). Teachers' responses regarding the materials used most frequently in the classroom are consistent with the guidance offered in curricula. Interestingly the vast majority of respondents reportedly used quite or very frequently equipment and materials for hands-on exploration in the classroom, such as magnets, building blocks, sorting activity games and rulers, despite the fact that only a little over 60% (for mathematics) and a little over 50% (for science) reported that their schools are fairly or well equipped in these resources. Official policy also provides information about a range of resources provided for teachers, such as textbooks (Finland and Greece) and assessment tools online (France). The reported frequency of use of audio-visual materials, relevant library materials, ICT science resources and student textbooks for science also exceeds significantly the reported availability of these resources in schools by their teachers. On the other hand, the availability of computers and other digital technologies (such as interactive whiteboards) appears to match and exceed respectively their use in schools. Teachers who responded to the teacher survey predominantly used materials prepared by themselves or downloaded from the internet for the teaching of science and mathematics.

In preschool, materials for exploration outside the classroom, and in primary school computer resources, are also given some emphasis in policy. It is notable however that there was very little emphasis on a budget for teaching or technical support for science. Comparing the science and mathematics resources of preschool and primary schools, according to the teacher survey it was found that preschool teachers used more frequently relevant library materials and resources for hands-on exploration in the classroom. However, they used student textbooks, digital technologies and ICT resources significantly less than primary teachers. These findings are consistent with the resources provided to teachers, as preschools were overall better resourced than primary schools in relevant library materials, and primary schools were overall better resourced than preschools in relation to computers and technical support personnel for both science and mathematics education.

4.4.4 Grouping

The surveys of policy and teaching practice indicate that grouping is an aspect of practice where advice in policy is limited and teachers are able to make their own

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decisions about groupings for particular purposes. There are a number of common themes in the policy guidance provided. In some countries a variety of approaches is advocated in policy, appropriate for particular tasks or learning needs (for example in Finland or UK (Scotland)). The benefits of collaborative working in pairs or groups are most commonly highlighted (for example in France, Germany, Greece, Portugal and Romania). References are also made in policy guidance to opportunities for individual work (Finland, Germany, UK (Wales)) and whole class teaching (UK (England and Scotland)).

According to the teacher survey, class groups comprised of between 20-30 children with only a few exceptions to this (either smaller or larger classroom sizes) in the partner countries. As indicated in policy documents, this makes the option of collaboration and group work possible in science and mathematics. Teachers in the survey also indicated they fostered collaborative approaches in their pedagogy. Working in small groups was an approach used quite or very frequently by the large majority of all sampled teachers, most frequently used in England and Romania and least frequently in Finland. A further issue explored was whether children are allocated to age or ability groups for learning. Just over half of the teachers in the total sample reported using assessment (quite or very often) to group children for science instruction purposes. This practice was embraced most frequently by Romanian teachers and least frequently by German teachers.

Neither policy not teacher responses revealed any significant differences in grouping between science and mathematics, or in relation to preschool and primary settings.

4.4.5 Time

In all but two of the partner countries there are no specific time requirements for either science or mathematics in preschool policy. The exceptions are in Romania where there is a requirement of 4 to 5 hours of combined mathematics and science teaching and in England and Northern Ireland, where daily mathematics teaching is advocated. As in preschool, set requirements concerning the time allocated for science and mathematics are absent from all official documentation in the majority of countries. In Germany, Finland, France and Malta there are specific time allocations for science. As in preschool, in Romania, 4 to 5 hours of combined mathematics and science teaching are required and there are more specific recommendations in relation to the time to be spent on mathematics. Seven countries recommend a specific time allocation (Finland, France, Germany, Malta, UK (England and Wales)).

Teachers' responses about the amount of time dedicated to teaching science and mathematics per week revealed that overall more time was spent teaching mathematics than science. Preschool teachers in the majority of partner countries

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reported teaching 1 to 2 hours of science and mathematics per week. Only Finnish teachers reported teaching extra hours for both subjects each week (3 to 4 hours for science and more than 4 hours for mathematics). In primary schools, there was a more varied picture for science with teachers spending 1 to 2 hours teaching per week in France, Germany, Malta and England; 3 to 4 hours in Finland and Greece, while Portuguese primary teachers spend over 4 hours per week teaching science. In regard to mathematics teaching, teachers in all sample countries reported dedicating more than 4 hours per week without any exceptions. Overall, Maltese teachers seemed to spend the fewest hours per week in the teaching of science whereas Finnish teachers spent the most time. Finnish and UK (English) teachers also spent the most hours per week for the teaching of mathematics, whereas Belgium (Flemish) teachers spent the fewest.

4.5 Conceptualisations of the teaching, learning and assessment of science and mathematics by teachers and in policy: the role of creativity

This section provides an overview of key themes emerging from the research findings of the policy and teacher surveys in relation to the research question identified for this comparative study:

> *What are the main similarities and differences in how the teaching, learning and assessment of science and mathematics in Early Years are conceptualised in the partner countries? What role does creativity play in these?*

4.5.1 Aims, purpose, priorities

4.5.1.1 Rationale for Early Years science and mathematics

Two common emphases are evident in the rationale for Early Years science education in partner policies: the need to *develop socially and environmentally aware citizens*, and the importance of *fostering skills and dispositions to support future learning*. In both instances, links to creativity were identified in the need to promote skills of inquiry and positive attitudes to science, in particular curiosity and critical evaluation. In only a small minority of countries was the need *to provide a foundational education for future scientists* or *to develop more innovative thinkers* prioritised in policy.

The results of the teacher survey showed teachers across all partner countries agreeing with the two emphases in the rationale provided for Early Years science education in policy. The view of science learning as an economic imperative reflected in very few policy documents was mirrored by teachers in the survey, suggesting that this is a view least favoured by them.

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4.5.1.2 Curriculum Aims and Content

Science is represented in different ways within the curriculum: in some countries within a broad area of learning such as 'Knowledge of the World' or 'Study of the Environment', in others as a single subject. The aims, objectives, and content of the science curriculum in partner countries emphasise the development of *process skills associated with scientific inquiry* and of *knowledge and understanding of science ideas* (the latter particularly in primary school). More limited attention is afforded to *social* and *affective* dimensions of learning and few countries highlight *understandings related to the nature of science*. A role for creativity was most strongly indicated in the focus on questioning and investigating and the importance given to curiosity. In most countries a very limited role for creativity was identified in relation to the development of science ideas.

In comparison, teachers reported pursuing most often *affective* and social dimensions of learning. More limited attention was afforded to cognitive outcomes especially by preschool teachers. Out of the inquiry-related science learning aims teachers fostered quite or very frequently the development of children's capabilities to carry out scientific inquiry, such as to ask questions, gather and communicate findings, but to a lesser degree, children's abilities to plan and conduct simple investigations. Learning aims related to understandings *about* scientific inquiry, were the least frequently pursued by teachers, echoing the emphasis put on understandings related to the nature of science in policy.

4.5.2 Approaches to teaching, learning and assessment

4.5.2.1 Learning Activities

In general, decisions about learning activities are made by teachers in the light of the rationale, learning objectives and curriculum content specified for areas of learning in the partner countries. Some form of guidance is provided about appropriate activities in all nine participating countries.

Commentary provided by partners in their National Reports for the teacher survey point to a common emphasis on hands-on approaches and activities linked to children's everyday lives in science classrooms. The learning activities which were reportedly used most commonly by the respondents were predominantly linked to children being allowed opportunities to gather evidence, ask questions and elicit their curiosity in natural phenomena. The National Reports from the review of policy, very similarly to the teacher survey results, indicate a common emphasis in policy on hands-on approaches and activities linked to children's everyday lives. Observation and communication feature strongly in learning activities recommended for both phases. Questioning is also commonly mentioned, particularly in relation to preschool. In the majority of countries conducting investigations or projects and

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using simple equipment are also included in guidance provided. There is more variation in relation to planning investigations and using data to construct reasonable explanations. These activities feature more strongly in early primary school policy.

4.5.2.2 Pedagogy

As mentioned above, there is a common emphasis in policy across partner countries on hands-on approaches and activities linked to children's everyday lives. In preschool in particular providing a broad range of experience and making links across the curriculum is widely recommended. There is a considerable focus on play and fostering autonomous learning. Encouraging problem solving and children trying out their own ideas in investigations are advocated in the majority of countries. Approaches given the least attention include the use of drama, stories, history, field trips and everyday experiences as contexts for learning. Moreover, in the aspects of inquiry discussed, most limited reference is given to connecting explanations to scientific knowledge and reflection on inquiry processes and learning. It is notable that in most countries limited references are made to the role of imagination or the discussion of alternative ideas – also linked with creative approaches to learning and teaching. Some differences are evident between phases of Early Years education. In preschool, play is strongly emphasised and greater attention is given to questioning and fostering autonomous learning. In primary school greater importance is afforded to investigation and problem solving.

Considering the results from the teacher survey, there seems to be a large consensus amongst teachers – reflected in their reported practice - that the teaching of science should be building on children's prior experiences and help relate science to everyday life. Teachers consistently and uniformly across the partner countries held a great appreciation for all pedagogical contexts and approaches that promote dialogue and collaboration in science amongst children, failing however to see the potential of these approaches for creativity development in children. On the other hand, using drama or history to teach science, or fostering children's autonomy in learning are not practices very commonly used by teachers across the partner countries, nor were they considered very 'creativity enabling' by them. It should be noted that although uniformly teachers strongly endorsed affective learning outcomes in their teaching of science, the way they perceived the contexts and approaches identified in the research literature as enhancing motivation and affect in children varied significantly. The physical exploration of materials was frequently promoted by the large majority of all teachers and considered as a creative practice. Finally, all problem solving science contexts and approaches were thought of as amongst the most 'creativity enabling' by a large number of teachers, who also reported usingthem quite or very frequently.

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4.5.2.3 Assessment

Policy in relation to assessment showed the widest variation across partner countries. In many cases findings reflected the limited guidance for science assessment and inconsistencies in emphasis across different elements in curriculum policy. There is very limited evidence in policy of a role for creativity either in the priorities or methods for assessment advocated across partner countries. Greatest emphasis is given to the assessment of science ideas. Understandings and competencies in relation to scientific inquiry are emphasised in assessment policy in a minority of countries and in only a few instances are attitudes a priority for assessment in science. In general, guidance in relation to assessment methods is limited, with little attention to multimodal forms of assessment or the involvement of children in assessment processes often associated with creative approaches to learning and teaching in the Early Years.

According to the teacher survey, teachers prioritised the affective dimensions of learning in science assessment in agreement with their declared rationale, vision, aims and objectives for science education. In contrast with policy however, they did not consider the assessment of scientific ideas and processes, or scientific inquiry in Early Years science education as important.

4.5.3 Physical and social environment

In general, limited advice is given in policy in terms of the physical and social environment for learning. Where advice on materials is provided, it mostly related to the provision of equipment for inquiry and use of digital technologies. There was very little emphasis on a budget for teaching or technical support for science. In terms of forms of grouping, common themes include the recommendation of a variety of approaches to suit particular tasks and learning needs and the benefits of collaborative learning.

According to teachers in the study preschools and early primary schools are well resourced in computers and relevant library materials for science teaching, and in instructional materials, computers and equipment and materials for hands-on exploration in the classroom for mathematics teaching. Support personnel for teaching or for technical issues in both science and mathematics is overall the least available resource in schools, though more available in primary schools than in preschools.

Primary schools are overall better resourced than preschools in computers and technical support personnel. Accordingly, primary teachers overall use more frequently than preschool teachers computers and ICT resources, whereas preschool teachers overall use more frequently relevant library materials and resources for hands-on exploration in the classroom.

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Chapter 5: Main findings: Report on practices and their implications

5.1 Introduction

The focus of the fieldwork in each country was on sites where there were indications that we would find 'exemplary practices' in fostering creativity and inquiry in early science and mathematics, covering all pupil age groups from age 3 up to 8 years and the range of provision of pre-primary and early primary education in the country. Fieldwork was conducted on 48 different sites across partner countries resulting in 71 case studies of practices in early science and mathematics. A total of 218 episodes were analysed and reported, including episodes focusing on science and mathematics and instances where science and mathematics were integrated in the episodes observed.

This chapter draws out the main findings linked to the research questions to be addressed during the fieldwork phase of the *Creative Little Scientists* project namely:

- RQ2: *Probing practice*
  What approaches are used in the teaching, learning and assessment of science and mathematics in Early Years? What role if any does creativity play in these?
- RQ3: *Probing practice*
  In what ways do these approaches seek to foster young children's learning, interest and motivation in science and mathematics? How do teachers perceive their role in doing so?

5.2 Approaches used in the teaching, learning and assessment of science and mathematics in Early Years: opportunities for inquiry and creativity

As in previous sections of this report, key findings in relation to teaching, learning and assessment approaches are presented in terms of the *pedagogical interactions* observed during fieldwork alongside evidence of teachers' *pedagogical framing* of activities and wider *contextual factors* that influenced the approaches adopted. They also make reference to the dimensions and factors identified as important in nurturing creativity in science and mathematics in the Early Years (as listed in Chapter 3).

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5.2.1 Pedagogical interaction

5.2.1.1 Learning activities

Learning activities observed during fieldwork offered considerable potential for inquiry and creativity in learning through the opportunities they provided for the *generation and evaluation of ideas and strategies*.

Observing and making connections featured in most episodes. Although *questioning, planning, gathering evidence (using equipment), explaining evidence* and *communicating explanations* received more limited attention, they were still evident in more than half the episodes and were more strongly represented in primary settings. Findings indicated the important contribution of rich, motivating contexts in *generating* ideas, questions and interests, but also the need for teacher sensitivity to features of inquiry and emerging ideas implicit in young children's explorations, as well as for time and teacher flexibility to build on these.

In preschool episodes questions and ideas often emerged during play activities as shown in the examples in Figure 5.1 below.

Episode 'Sand box': Making a wall

In the sand corner the teacher had placed materials to build with including real bricks. They also had unfamiliar specialist tools to help with the building process such as plaster trowels and spirit levels, as well as the familiar buckets and spades.

First the two children worked separately to make their own walls. However after some time they started working together to build one wall, sharing the tasks required to prepare their materials.

One child was pouring out the water to mix with the sand she noticed that the sand was not mixing enough with such a great amount of water and so she poured some of the water out of her bucket.

The other child *observed* this effect and only put a little bit of water on the sand in his bucket, indicating that he had *used the evidence* from his partner's mixture to make decisions about his own mixture.

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Episode 'Building blocks': Building the 'Tower of Pisa'

The teacher had observed that children enjoyed playing with wooden building blocks. To extend their learning she gave the children a book with photographs of buildings. Inspired by these the children decided to build the "Leaning Tower of Pisa".

One child started off with a plan but the tower tumbled down. The teacher encouraged the child to *reflect* on the source of the problem and then stood back while the child worked with another child to find a solution. The children *observed*, *predicted* and *communicated* their ideas.

Episode 'Gloop': Exploring the properties of gloop, using different tools

This activity involved making and exploring 'gloop' – mixing water and corn flour in a large plastic tray that had been placed on a desk. Children were free to attend and leave the activity as they pleased. After a short time, the teaching assistant placed a number of different tools for example spatulas of varying sizes, rubber paint brushes, a funnel – into the tray to further provoke interest and exploration.

One child became immersed in this activity over a long period, *observing* the mixture, and *trying out different ways* to use the tools and their effects, for example scooping it with spatulas or drawing in it with the rubber-tipped paint-brushes.

Figure 5.1: Opportunities for generating and evaluating ideas and strategies in preschool settings

Episodes from early primary settings illustrate the value of a purpose for inquiry and opportunities for children's decision as shown in the examples in Figure 5.2 below:

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Episode 'Water Inquiry': Demonstrating that ice and steam both come from water

The teacher talked with the children about the findings of a previous lesson, acting as if she did not believe that there was a connection between water, ice and steam.

The children had to *plan and conduct experiments* by themselves, working with a partner or in small groups to prove to her there was a relationship between water, ice and steam. They were allowed to work inside or outside (in the school yard/garden) as they wished. The teacher asked the children to document their plans by writing or drawing their ideas and procedures on a prepared "Scientist's sheet".

The children *communicated and brought together many different ideas*. The teacher's real interest in their experiments encouraged them to try out new things.

Episode 'Measuring Tables': Taking measurements to give the carpenter for their new tables

The teacher asked the children to help her in giving the carpenter measurements to create new worktables for the classroom, identical to the current ones. The children worked in small groups *choosing the measuring tools* to use and *taking* and most importantly *recording measurements* in their group notebooks. They then had to *present and explain their findings to the whole class*, including the tools they used and how the measurements were made. Finally the children *discussed and reflected on the activity*: what problems they faced and how they felt about it.

Episode 'Float and Sink': How can the dove rescue the little ant who fell into the river?

The teacher told a story about an ant who fell into the river. A dove flying by wanted to help the ant. The children discussed natural materials in the forest the dove might use to help keep the ant afloat. They were given small containers with water asked to work in groups to test which materials existing in the forest could be used as little 'boats' for the ant. A variety of materials was made available, including nuts, feathers, wooden sticks, leaves, little stones, acorns, pieces of bark, fir cones. Each group predicted the materials they thought most suitable to save the ant, items they intended to test. Children shared their findings, *drawing on evidence from their observations*, to *justify conclusions* about whether this object would be appropriate to help save the ant.

Figure 5.2: Opportunities for generating and evaluating ideas in early primary sessions

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Findings indicated the key contribution of discussion and teacher questioning in fostering the social dimensions of inquiry associated with communicating and justifying explanations based on evidence, other key features of creativity in early science and mathematics related to the *evaluation* of ideas and strategies.

Partners commented on the greater scope for child-initiated activity and creative engagement in preschool settings, although this was not always recognised by teachers, and on the tendency for pressures of time and curriculum requirements to limit opportunities for children's creativity and inquiry in primary settings.

5.2.1.2 Pedagogy

The episodes reported provided many examples of each of the teaching approaches identified in the Conceptual Framework (D2.2) as associated with both creative teaching and IBSE (the synergies). With the exceptions of *play* and the promotion of *varied forms of expression* there were examples of each of the other factors in at least half of the episodes reported in both preschool and primary settings. Those that featured most strongly were *collaboration, problem solving and agency and scaffolding*.

Opportunities for children's agency varied. In preschool there was greater scope for child-initiated inquiry, but even where the teacher set the focus, as was more common in primary settings, there were opportunities for children's decision making with varied levels of guidance from the teacher. Strong examples of creative teaching were associated with experiential learning in preschool and an explicit focus on IBSE/PBL in primary school.

Reflection and reasoning was more strongly represented in the episodes than might have been anticipated from the policy and teacher surveys (D3.2 and D3.3), fostered by rich examples of *dialogue and collaboration* offered by the extensive use of group work in both phases of education. Varied forms of *teacher scaffolding* were evident in the episodes reported through the choice of materials, teacher questioning or the introduction of particular skills or equipment to enhance inquiry. The potential of sensitive responsive scaffolding to support independence and extend inquiry was underlined both in terms of when to intervene and when to stand back.

Providing motivating contexts for learning was a strong feature of many episodes, particularly in preschool, linked for example to everyday life, stories and poems or children's interests and questions. However it was noted as reflected in the teacher and policy surveys (D3.2 and D3.3) that there were very few examples of the use of drama or history to prompt inquiry or a creative response.

Play was the factor that featured least in primary settings. The value of opportunities for play and exploration in the primary age phase could be more widely appreciated, in generating ideas and questions and a feel for phenomena.

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While the episodes reported included different approaches to representing ideas in science and mathematics (as shown in Figure 5.3), findings also suggested that the roles of varied forms of representation and the *processes* of representation (not just the product) in developing children's thinking need greater recognition, including the role of ICT.

Episode: 'Counting Minibeasts': Children designing their own methods of counting

Children were asked to sort, count and record the number of plastic minibeasts in a bucket. They were able to lie out the different minibeasts in different areas of the carpet and to leave them without having to clear their working space each time they finished counting each type. This allowed children to learn from each others' approaches, and for the teacher to examine everyone's work at any point during the activity.

During *reflection* at the end of the lesson the child whose work is shown was overheard saying to his talking partner *"When you're lining them up … 'cause you know when you're lining them up, and there's only one … I don't know where to put it"*. Looking at his work he has four rows of five dragonflies (and of spiders) with two remaining dragonflies being placed on the ends of the rows.

Episode 'Sun distance': Developing understanding of the relative sizes of the Earth and Sun and the distance between them.

The teacher set the problem: *"If the Sun is represented by a ball what would the Earth's size be and what would be the distance between them?"* The children were asked to use their hands to show the diameter of the ball (the Sun) and asked how many diameters would represent the distance between the Sun and the Earth. When the children learned that it would take around a hundred, they were fascinated. The teacher then gave the children one hundred pieces of paper, each roughly the length of the diameter, to model the distance between the Sun and the Earth out in the corridor.

Through their own observations, the children noticed that the grain, which they had chosen to represent the Earth, could no longer be seen from the position of the ball, which represented the Sun. Subsequently, they concluded that the distance between the Sun and the Earth was too great and the size of the Earth too small for it to be seen from the Sun.

Figure 5.3: Representing ideas in different ways, the role in supporting reasoning

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5.2.1.3 Assessment

Findings from fieldwork confirmed the picture gained from the policy and teacher surveys (summarised in Chapter 4), that policy and practice in relation to assessment is underdeveloped. Assessment approaches were generally informal and formative based on observation and teacher questioning. Episodes provided examples of ways in which teachers built on assessment information to inform their interventions and planning for future sessions. However partners noted that in some instances potential for inquiry based on young children's interests and questions or implicit in children's actions was not recognised.

There was limited evidence of the involvement of children in assessment, although interviews with children conducted during fieldwork indicated their capabilities to reflect on their learning and gave teachers new insights into their learning processes.

There was also limited evidence of summative assessment. In primary school there was greater focus on summative assessment, particularly in mathematics, where the use of more formal approaches to assessment such as standard tasks and tests was noted.

Some differences were identified between practices in preschool and primary school settings. In preschool settings there was evidence of a more holistic approach to assessment involving cognitive, social and affective factors, drawing on varied forms of evidence such as gesture, talk, children's recording or visual images. In a number of preschool settings children's profiles provided a valuable record of progress. In some cases children actively contributed to the selection of material, offering opportunities for reflection on learning. More generous staffing levels in preschool often made this more possible than in primary settings.

5.2.1.4 Materials and resources

A common feature of the episodes recorded was the provision of a rich, motivating physical environment for exploration, making good use of everyday and household materials and natural resources.

Children's access to a variety of resources played an important role in fostering inquiry and creativity, although this was mostly implicit in teachers' planning for provision. The episodes provided limited evidence of children's use of ICT to support learning in science and mathematics.

There were also few examples of episodes involving the use of outdoor resources, however as fieldwork was conducted during the winter period, this might have been expected. Here differences were noted between preschool and primary settings. In a number of preschool settings, children had free access to outdoor areas and the overall provision of space and staffing levels were more generous. This provided

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greater scope for practical exploration, fostering children's creativity in generating and pursuing ideas for investigation.

Teachers in most settings designed their own learning experiences. Only a small proportion of episodes (although more common in mathematics) relied on textbooks or published schemes.

5.2.2 Pedagogical framing

5.2.2.1 Aims

Findings from fieldwork across both preschool and primary settings reflected a strong focus on social and affective factors of learning. Scientific and mathematical content, the development of process skills, fostering IBSE/PBL and the promotion of creative dispositions also featured in the majority of episodes. No substantial differences were noted between the aims of science and mathematics episodes.

The episodes reported also illustrated ways in which aims associated with IBSE/PBL were closely interconnected with the promotion of social and affective factors important in engaging children in inquiry and in the development of skills and understandings in early science and mathematics through their inquiry processes.

Explicit focus on the nature of science was limited, reflecting findings from the policy and teacher surveys (see Chapter 4). However opportunities for discussion of the nature of science were indicated in a number of episodes, particularly in reflecting on the outcomes of explorations or investigations in early primary episodes.

Partners noted that the aims of activities were often not made explicit and where aims were explicit they rarely featured a focus on creativity. Partners also commented on the important influence of teachers' wider perspectives on learning and teaching, and their views of the nature of science and mathematics on the aims explicit or implicit in the activities observed. They also noted that the integration of cognitive, social and affective aims common in many episodes reflected the holistic approach to Early Years education set out in policy in many partner countries.

5.2.2.2 Grouping

Class sizes varied considerably with class sizes of 20-30 being most frequent. Small group work was a common feature of practice in the episodes reported, informal child-chosen groupings was most often seen in preschool, whilst in primary schools groupings tended to be structured by the teacher. The episodes provided rich examples of the potential of small group work for fostering dialogue, collaboration and peer learning. Use was also made of whole class discussion to introduce concept and ideas, share experiences and reflect on findings from investigations.

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5.2.2.3 Location

As indicated in the discussion of teachers' provision of materials, only a small number of episodes recorded involved the use of the outdoor environment. However where examples were reported these highlighted the rich opportunities within the immediate school environment for inquiry. This could be capitalised on further. In more general terms greater attention could be paid at whole school level to provision and resources to support learning in the school environment beyond the classroom, both indoors and out. The episodes also illustrate how the organisation of staffing and equipment at whole school level can facilitate learning outdoors in all weathers. Examples are shown below (Figure 5.4).

Episode 'Measuring Outside': Trying to find something as big as the stick.

The children spent time in the forest with the teacher and observed the environment. The aim was to make comparisons for example using the concepts smaller, bigger and equal. They also measured the temperature on and inside the snow, as well as the temperature of water. The teacher assessed the children's findings, giving individual feedback and separately recognising their outcomes.

The teacher presented a problem or task for example "*try to find a plant that is smaller than yourself*" and scaffolded the children's inquiries by providing instruments and posing questions.

Episode 'Forest School': Observing changes in the natural environment over time.

Visits to a local wildlife area were planned each week to provide children with opportunities to explore the natural environment and observe change over time for example in the weather and in the life cycles of living things. Visits were also designed to encourage a range of inquiry skills in particular *observing* and exploring, *asking questions*, developing skills associated with *reasoning and making connections.*

The school organises clothing and resources carefully to enable visits in all weathers, such as mats, blankets, thermal clothing, warm drinks and snacks. A variety of equipment is taken to support activities at the site, including tarpaulin and ropes for making a shelter, magnifiers, binoculars and a camera to support observations, collecting pots, litter pickers and spades.

Figure 5.4: Inquiry in the outdoor environment

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5.2.2.4Time

The influence of school timetables and curriculum requirements on teachers' approaches was highlighted in many Country Reports.

More flexible timetabling and a more holistic approach to learning and teaching commonly associated with preschool settings allowed teacher greater flexibility to follow children's interests over time and to revisit experiences, and make provision for children to encounter ideas in a range of different contexts. The challenge here was often less one of time but of recognising and building on children's emerging interests, skills and ideas.

In primary settings, specific teaching hours and times were more likely to be laid down. This presented challenges associated with following up on children's ideas, responding to the unexpected or making connections between experiences.

The episodes provided useful examples of ways of building on children's ideas and questions over time and fostering reflection across a class project or scheme of work. These would provide useful starting points for discussing ways of making the best use of time.

As outlined in Work Package 3, a further difference noted by partners, particularly in primary settings was the greater time allocation for mathematics in comparison with science. However this was also often associated with restrictions associated with specific requirements in terms of subject content. As outlined below science was more often presented as part of wider area of learning. This offered greater scope for flexibility and making connections, but there were also dangers of neglect of science if not prioritised by schools or teachers.

5.2.2.5 Content

Fieldwork indicated varied approaches to tackling subject content in science and mathematics, influenced by school and teacher perspectives on learning and teaching as well as policy requirements and guidelines. Integrated approaches combining science and mathematics with other subjects were more common in preschool, especially in countries where the curriculum was presented in terms of broad areas of learning with an emphasis on holistic, child-centred approaches to learning. In primary school, sessions were often planned to focus separately on mathematics or science. There was some suggestion from fieldwork data that episodes integrating science and mathematics offered greater scope for inquiry and creativity. This would be a worthwhile area for further inquiry. Partners noted the effective approaches to building connections across the curriculum would be a useful focus in teacher education.

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5.2.3 Wider contextual factors

5.2.3.1 School

The cases studies illustrated ways in which factors at school level can contribute to a climate that has the potential to foster creativity in learning and teaching in early science and mathematics. They include influence of the whole school approach to learning and teaching on teachers' scope for creativity and the value of team work in giving teachers confidence and encouragement to share and try out new ideas.

The case studies also indicated ways in which school organisation of resources, space, staffing and timetabling can support, or act as a barrier, to creativity and inquiry both in teaching and learning. Findings indicated that preschool settings often had more generous space, resources and staffing with greater scope for flexibility to allow time to follow children's ideas and interests.

Finally, partners emphasised the need for schools to value the place and contribution of science in the curriculum to ensure potential for science learning is capitalised on in preschool and not neglected in primary settings.

5.2.3.2 Teacher

Findings highlighted the important influence of teachers' perspectives on learning and teaching and opportunities for professional development on the approaches adopted in the classroom and the scope afforded for creativity and inquiry.

The teachers associated with strongest episodes were often able to articulate their views of learning and teaching informed for example by child-centred, experiential perspectives, or explicit reference to inquiry based learning. However few teachers indicated they had considered the nature of creative teaching and learning or how this might be reflected in early science and mathematics.

In a number of episodes teachers indicated that they were adopting teaching approaches they had learnt about and tried out on courses of professional development. The courses had provided inspiration and confidence, for example to take on exploratory or investigative approaches or find out about children's ideas. However in other cases, while teachers were sympathetic to approaches associated with inquiry and creativity, they felt they needed further guidance on teaching strategies to foster creativity and stronger subject knowledge in science and mathematics to recognise and respond to children's ideas and thinking.

5.2.3.3 Policy

Finally findings suggested a varied picture of the influence of policy on opportunities for inquiry and creativity reflecting findings from D3.2 Report on Mapping and Comparing Recorded Practices. Policy in many of the partner countries advocates inquiry-based approaches and in a number of instances there are general references to

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the importance of creativity in learning and teaching. This provides important support for teachers and schools concerned to foster inquiry and creativity in early science and mathematics.

However, curriculum and assessment requirements, and space and time at school level can constrain teaching approaches, particularly in primary settings. The support of the whole school and teacher professional development are important, as outlined above, in enabling teachers to take advantage of the scope for inquiry and creativity in their particular policy contexts. The episodes recorded provide inspiring examples of the potential for creativity and inquiry within a range of different school and policy contexts.

5.3 Ways in which these approaches seek to foster young children's learning, interest and motivation in science and mathematics

Fieldwork provided rich evidence of the varied ways in which approaches to learning, teaching and assessment fostered skills, attitudes and understanding associated with inquiry and creativity in early mathematics and science. It also provided strong illustrations of young children's capabilities and interests in science and mathematics as discussed in D2.2 Addendum 1 'Review of science and mathematics education in preschool and Early Years of primary school'. Across the episodes there were many examples of children *observing* and *making connections* for example with prior learning or between experiences. Opportunities for children's *questioning* were also present but not always recognised or built upon.

There was greater evidence of children's engagement in the social dimensions of inquiry, *explaining evidence* and *communicating explanations* than might have been expected from the policy and teacher surveys, often prompted by dialogue with peers and adults.

Explicit examples of children's developing *understanding of the nature of science* were limited but starting points for the development of understanding of the nature of science was indicated in a number of episodes, in children's reflections on learning in classroom discussion or in interviews with researchers.

Children's inquiry skills and understandings noted in episodes were interconnected with evidence of a number of creative attributes. For example children's *motivation, curiosity* and *abilities to come up with something new* were evidenced in raising questions and in their active pursuit of explorations and investigations. The episodes reported offered many examples of children's *sense of initiative* and *growing abilities to collaborate* in deciding what to do in carrying out investigations. Children showed *imagination, ability to make connections and thinking skills* in offering explanations.

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How do teachers perceive their role in doing so?

The case studies provided in the Country Reports (D4.3) included background information about the teachers involved. They also summarised key features of the teachers' perspectives on learning and teaching gained from interviews to discuss the episodes observed. This provided some indication of teachers' views of their roles in fostering children's learning interest and motivation in science and mathematics. In a number of instances teachers indicated that this was not something that they had considered previously. Approaches they adopted had mostly been implicit and that fieldwork processes had prompted reflection on the nature of inquiry and creativity in early mathematics and science and how this might be fostered.

Teachers gave varied responses and emphasised different aspects of the role of the teacher. Connections can be identified to the features of pedagogy associated with creative and inquiry-based approaches, the synergies, outlined in the Conceptual Framework (D2.2).

Most teachers made reference to the importance of encouraging and supporting young children's engagement in Early Years science and mathematics as an important starting point for learning. No other feature of teachers' views was highlighted by a majority of teachers.

Other aspects of the role of the teacher that gained the greatest attention included an emphasis on fostering motivation and collaboration and providing a rich environment with space and time for exploration and problem-based learning, reflecting findings from the teacher survey. Another key role identified was the role of the teacher in encouraging reflection and making connections to promote children's conceptual understanding and application of ideas in varied settings. A number of teachers also underlined the important roles of careful listening and observing in supporting learning (linked to the key role of assessment). Other themes mentioned were the importance of child-initiated investigation, the key role of teacher questioning, the need for varied forms of expression and the importance of collective processes of discussion, review and evaluation linked to notions of citizenship. However limited explicit reference was made to the role of creativity or features of inquiry in science and mathematics.

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Chapter 6: Summary of findings in relation to the research questions

This chapter provides a summary of key findings from the different phases of research in relation to the research questions for the project.

RQ1. How are the teaching, learning and assessment of science and mathematics in Early Years in the partner countries **conceptualised** by teachers (and in policy) and what role if any does creativity play in these?

RQ2. 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?

RQ3. In what ways do these approaches seek to **foster young children's learning and motivation in science and mathematics**, and how do teachers perceive their role in doing so?

RQ4. 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)?

RQ1. Conceptualisations of teaching, learning and assessment of science and mathematics in Early Years by teachers (and in policy) in the partner countries. The role of creativity in these.

The explicit curriculum *rationale* for science education in nearly all partner countries was focused on children's role as citizens and highlighted science and environmental awareness as a part of their life in general; this was also reflected in what teachers said. However the research findings revealed that teachers' viewpoints regarding the rationale for science learning was in practice more holistic than what had been found in the policy documents in the partner countries. Learning *aims and objectives* were conceptualised by teachers as primarily contributing towards affective and social aspects of learning, such as increasing interest and positive attitudes towards science and science learning. These views contrasted with the emphasis in official policy documents on the development of knowledge and understanding of science and mathematics ideas and on process skills associated with scientific inquiry, especially in primary education.

In terms of *learning activities*, specific features of inquiry were conceptualised in both teachers' views and through policy guidance. Teachers in the preschool and

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early primary science and mathematics classroom made reference to inquiry based learning, a key part of the policy framing in all countries, in particularly through learning activities associated with observation, questioning, communication and the use of simple tools, which all took a dominant place among inquiry related activities. Yet, despite this general conceptualization of inquiry based learning, teachers' responses in fact rarely referred to inquiry activities related to practical investigations and using data to construct explanations.

In terms of conceptualisations about *pedagogy* teachers across the partner countries consistently and uniformly held a great appreciation for all valued pedagogical approaches that promote *dialogue and collaboration* in science amongst children, although teachers often failed to see the potential of these approaches for the development of creativity in children. This was consistent with policy which put some emphasis on their importance but included very limited reference to features of creativity that might be fostered through dialogue and collaboration and very limited guidance to support teachers in enabling creativity using classroom discussions and collaborative work.

There was an uneven treatment in both policy and reported practice of the approaches grouped in relation to the synergy *motivation and affect*. Learning approaches which are based on *building on children's prior experiences* or *relating science and mathematics to everyday life* were amongst those reported as most frequently used by teachers and referenced in policy, although these were not highlighted as 'creativity enabling' either by teachers or by policy documents. In addition, approaches making *use of drama or history to teach science and mathematics* were promoted the least frequently both by teachers and in curricula, which also failed to make reference to their potential for creativity.

There was a similarly uneven treatment of approaches with reference to the synergy *play and exploration*. Preschool teachers reported using open forms of *play* and *role play* significantly more than early primary school teachers, and a greater proportion of preschool teachers also conceptualised these as 'creativity enabling'. This was also reflected in preschool curricula across the partner countries with policy in the majority of them promoting *playful exploration* in preschool considerably more than in primary education. On the other hand teachers and policies of both phases were in agreement in fostering children's *physical exploration of materials*, an approach also conceptualised as 'creativity enabling' by teachers and in policy, and especially for primary education.

Teachers, as well as policy guidance, emphasised teaching approaches linked to *problem solving and agency* across both phases of Early Years education. These approaches were also often suggested to foster children's creativity, particularly in preschool.

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Learning approaches associated with *questioning and curiosity* and their importance in fostering creativity were similarly conceptualised by teachers and in policy guidance. Practices that encourage children to ask questions and foster their imagination were reported as frequently used by teachers, were emphasised in policy and were perceived by both as 'creativity enabling'. In contrast, the role of teacher questioning and the value of varied approaches to children recording their ideas in supporting creative learning were given more limited recognition.

Learning approaches linked to fostering *reflection and reasoning* were perceived to have limited scope in promoting children's creativity by both teachers and in policy documents, though teachers reported using them quite or very frequently.

In terms of teachers' conceptualisations about *scaffolding*, teachers saw themselves as facilitators of children's own inquiry, delaying instruction until the learner had had a chance to investigate and inquire on their own or with others. They were a little more reticent to allow children to find solutions on their own, although they strongly rejected the suggestion that they should first act as demonstrators of the correct solution before children investigate for themselves.

Assessment, especially formative assessment, was widely highlighted as an important area for development in both policy and practice in both preschool and primary phases. However, policy guidance in terms of both methods of assessment and criteria for assessing on-going progress was often found lacking which is reflected in considerable variability in assessment approaches found across partner countries.

A common tendency to focus on *product* instead of *process* in assessment, allied with the pressures of statutory summative assessment processes in a number of partner countries revealed a number of challenges related to assessment of inquiry and creativity. Whilst the *assessment* of science and mathematics was widely emphasised in policy, more limited attention was given to assessment of inquiry processes and procedural understanding, and even less to social and affective dimensions of learning across the majority of partner countries, even though these dimensions were often highlighted in the *rationale* and *aims* set out for early science and mathematics education. Teachers' responses to the survey regarding their priorities for science *assessment* on the other hand were consistent with the frequency with which they indicated pursuing the corresponding *aims and objectives* in their science teaching.

Finally, there was very limited evidence in policy of a role for creativity either in the priorities or methods for assessment advocated. In particular, little attention was paid to multimodal forms of assessment or the involvement of children in assessment processes often associated with creative approaches to learning and teaching in the Early Years. Again here a contrast was noted between findings from the policy and

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teacher surveys as teachers reported taking account of children's multimodal expressions for assessment purposes, especially in preschool.

RQ2. Approaches used in the teaching, learning and assessment of science and mathematics in Early Years: opportunities for inquiry and creativity.

Findings indicated considerable potential for inquiry and creativity in the opportunities teachers provided for the *generation and evaluation of ideas and strategies* in both preschool and primary settings. Opportunities for the generation *of ideas,* for example, were fostered by rich motivating contexts for play and exploration, whilst purposes for inquiry were linked to children's everyday experiences and scope for children's decision making.

Dialogue and collaboration, promoted by widespread use of group work and teacher questioning, played important roles in encouraging the processes of reflection and explanation associated with the *evaluation of ideas and strategies*.

The potential of sensitive and responsive teacher scaffolding both to support independence and extend inquiry was underlined, particularly in relation to when to intervene and when to stand back.

Opportunities for play were limited in primary settings. The value of play and exploration in the primary age phase could be more widely appreciated, for example in generating ideas and questions and fostering a feel for phenomena.

Findings suggested that the roles of varied forms of representation and the *processes* of representation (not just the product) in developing children's thinking needed greater recognition, this included the role of ICT, particularly in preschool settings.

Assessment approaches observed were generally informal and formative and were based on observation and teacher questioning. There was limited evidence of the involvement of children in assessment, although interviews with children during fieldwork did indicate their capabilities to reflect on their learning and gave new insights into learning processes.

There were few examples of episodes involving the use of outdoor resources or non-formal settings for learning in museums or the wider community. Here differences were noted between preschool and primary settings. In a number of preschool settings, children had free access to outdoor areas, and the overall provision of space and staffing levels were more generous providing greater scope for practical exploration.

The aims of activities were often implicit. Where aims were made explicit they rarely included an explicit focus on creativity although the promotion of creative dispositions was evident in the majority of episodes observed. In both preschool and

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primary settings there was a strong focus on social and affective factors of learning and the development of scientific and mathematical concepts and process skills was a common feature of episodes observed. Explicit focus on the nature of science was limited.

Findings underlined the important influence of teachers' wider perspectives on learning and teaching, and their views of the nature of science and mathematics on the aims and approaches explicit or implicit in the activities observed. Teachers in most settings designed their own learning experiences with only a small proportion of episodes relying on textbooks or published schemes, where this was observed it was most common in the teaching of mathematics

Partners commented on the greater scope for child-initiated activity and creative engagement in preschool settings, although this was not always recognised by teachers, and on the tendency for pressures of time and curriculum requirements to limit opportunities for children's creativity and inquiry in primary settings.

RQ3. Ways in which these approaches seek to foster young children's learning, interest and motivation in science and mathematics

Across the episodes there were many examples of children *observing* and *making connections*, for example drawing on prior learning or between experiences. Opportunities for children's *questioning* were also present but not always recognised or built upon.

There was greater evidence of children's engagement in the social dimensions of inquiry, *explaining evidence* and *communicating explanations* than might have been expected from the findings of policy and teacher surveys, this was often prompted by dialogue with peers and adults.

Explicit examples of children's developing *understanding of the nature of science* were limited however starting points for the development of understanding of the nature of science was indicated in a number of episodes, in children's reflections on learning in classroom discussion or in interviews with researchers.

Children's inquiry skills and understandings noted in episodes were interconnected with evidence of a number of creative attributes. For example children's *motivation, curiosity* and *abilities to come up with something new* were evidenced in raising questions and in their active pursuit of explorations and investigations. The episodes reported offered many examples of children's *sense of initiative* and *growing abilities to collaborate* in deciding what to do in carrying out investigations. Children showed *imagination, ability to make connections and thinking skills* in offering explanations.

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How do teachers perceive their role in doing so?

Teachers involved in the case studies often indicated that they had not previously thought about the approaches they adopted in terms of opportunities for inquiry and creativity. Fieldwork processes had prompted reflection on the nature of inquiry and creativity in early mathematics and science and how this might be fostered.

Most teachers made reference to the importance of encouraging and supporting young children's engagement in Early Years science and mathematics as an important starting point for learning. Many emphasised the need to foster motivation and collaboration and provide a rich environment with space and time for exploration and problem-based learning, underlining key roles for teachers in encouraging reflection and making connections to promote children's conceptual understanding and the application of ideas in varied settings.

In sharing their approaches limited explicit reference was made to the role of creativity or to features of inquiry in science and mathematics.

RQ4. 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)?

Findings suggested a number of areas for attention in teacher education to support inquiry and creativity in early science and mathematics education. They included:

- Perspectives on the nature of science and mathematics and the purposes of science and mathematics education in the Early Years.
- The characteristics and roles of creativity in learning and teaching in early mathematics and science.
- Use of the outdoor and wider school environment for learning in science and mathematics.
- Approaches to planning at whole school and class levels to maximize scope and flexibility to foster children's inquiries and to provide opportunities for play and exploration (across both preschool and primary phases of education).
- Ways in which everyday learning activities can be opened up to allow space for children's agency and creativity.
- The roles of questioning in supporting inquiry and creativity, different forms of teacher questioning, ways of supporting children's questioning, recognising questions implicit in children's explorations.
- Importance and roles of varied forms of representation, including the use of ICT, in supporting children's learning processes.
- Assessment strategies and forms of evidence that can be used to support learning and teaching in early science and mathematics, the roles of peer and self-assessment.

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Fieldwork provided classroom examples for use in teacher education programs to illustrate and discuss the potential for creativity and inquiry within everyday classroom practices in early science and mathematics.

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Chapter 7: Main messages: Report on directions for teacher education

7.1 Introduction

One of the key objectives of the *Creative Little Scientists* project was to propose a set of curriculum design principles as guidelines for European initial teacher education (ITE) and continuous professional development (CPD) programs that will foster creative approaches to science and mathematics learning in preschool and the first years of primary education in the frame of inquiry-based educational environments. These principles and accompanying conceptual recommendations were designed, based on the findings of the theoretical, comparative and in-depth field research in the *Creative Little Scientists* project, as well as through a process of involvement of communities of stakeholders in asynchronous and face-to-face discussion groups, implementing the methodology of curriculum design research (see Chapter 3).

The project report Guidelines and Curricula for Teacher Training (D5.2) offers teacher education policy makers and institutions a set of Curriculum Design Principles and accompanying conceptual recommendations in order to design and apply curricula that will foster creative approaches to science and mathematics learning in preschool and first years of primary education. Furthermore it offers teacher education institutions a related set of Teacher Outcomes regarding what teachers should know and be able to do in order to develop such creative approaches. These can be seen as concrete recommendations for teacher educators and teacher education institutions to frame their sessions, workshops and courses. They are directly linked to the implications for teacher training which arose from previous work (D2.2 Conceptual Framework, D3.2 Report on Mapping and Comparing Recorded Practices, D3.3 Report on First Survey of School Practice and D4.4 Report on Practices and their Implications*)* and are summarized in Chapter 6 (answer to research question RQ4).

Based on the set of Teacher Outcomes, Exemplary Teacher Training Materials (D5.3) originating from the data of the in-depth fieldwork were developed. These exemplary training materials are accompanied with advice as to how the teacher outcomes and the set of content design principles can be used to frame sessions or workshops.

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7.2 The set of design principles and recommendations to use them

7.2.1 The spider web: a framework for the set of design principles

As mentioned in Chapter 3, the curriculum spider web concept of van den Akker (2007) was also used as the basis for the set of curriculum design principles for teacher education. Figure 7.1 shows van den Akker's preferred visualization of these 10 components, as a spider web. The rationale in the middle of the spider web refers to the central mission of the curriculum. It is the major orientation point and the nine other components are ideally linked to the rationale and preferably consistent with each other. The spider web illustrates the many interactions but also the vulnerability. If you pull or pay too much attention to one of the components, the spider web breaks (van den Akker, 2007, p41).

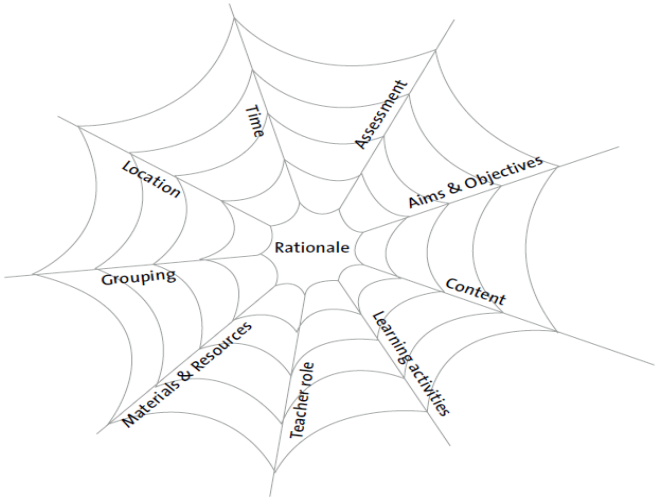

Figure 7.1: Curricular Spider Web (van den Akker, 2007: 41)

In the following section, the components (and associated questions) are presented along with the associated curriculum design principles. It is important to note that while the components and design principles are presented in a list, the components are not in any hierarchical order and should not be viewed in isolation as they are all closely interconnected and highly interdependent. All of the design principles are meant to be seen as equally important and a foundation for different curricula development routes in Europe. They also represent the starting point for discussions with various groups of stakeholders, amongst them teacher education policy makers and teacher educators in training institutions.

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7.2.2 The curriculum design principles

Rationale ***Why are teachers learning?*** **Teachers[6] should foster inquiry and creativity in science and mathematics learning in preschool and the first years of primary school.**	
Aims and Objectives *Towards which goals are teachers learning?*	**Competences for teachers** In teacher education teachers should: 1.1 Acquire secure content knowledge of science and mathematics ideas and processes, as well as the skills and competences to carry out inquiries. 1.2 Acquire the pedagogical content knowledge to foster inquiry and creativity in Early Years science and mathematics, including the use of inquiry approaches. 1.3 Become confident and develop positive attitudes towards learning and teaching science, mathematics using inquiry and creativity based approaches. 1.4 Acquire the skills to act as researchers and reflective practitioners in learning and teaching science and mathematics, and should become able to discern and reflect on innovative ideas. 1.5 Acquire the knowledge and skills to support the diverse interests and needs of young children in engaging creatively within the fields of science and mathematics. **Foci of teacher education** Teacher education should: 1.6 Emphasise the importance of science and mathematics education for personal and society development by advocating its role in the preparation of scientific and mathematic literate citizens as well as the role of creativity in these domains and in human development. 1.7 Emphasise the pedagogical synergies between IBSE and creative approaches in both science and mathematics learning and teaching. 1.8 Foster teacher learning outcomes aligned with creative science and mathematics teaching strategies and assessment methods. 1.9 Foster teachers' creativity and their potential to be creative in science and mathematics.

[6] In describing the curriculum design principles and training materials, the term 'teacher' is used to include both pre-service and in-service teachers, also Early Years practitioners who are not qualified teachers but who work closely with young children. Where a distinction is required this is made clear.

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Rationale ***Why are teachers learning?*** **Teachers[6] should foster inquiry and creativity in science and mathematics learning in preschool and the first years of primary school.**	
Role of teacher educator *How is the teacher educator facilitating learning?*	**Teacher educator profile** Teacher educators of science and mathematics education should: 2.1 Combine content knowledge, pedagogical content knowledge, and teaching practice of science and mathematics. 2.2 Be reflective practitioners who promote creative approaches in their practice, including inquiry and problem solving. 2.3 Be willing to try new things and be open to taking risks in their practice, so they can bring in (new) effective pedagogy and approaches in the fields of science and mathematics. 2.4 Have the skills to build partnerships (e.g. communities) with different science and mathematics education stakeholders such as schools, science research centers, science museums, scientific and mathematics associations at national and local level, etc. 2.5 Be encouraged to be actively involved in research and discussion networks about science and mathematics education pedagogy. **Teacher educator role** Teacher educators should: 2.6 Take into consideration teachers' prior knowledge, skills, attitudes, beliefs, fears, preconceptions (incl. stereotypical images), learning styles and experiences associated with learning and teaching science, mathematics, and creativity, and organize appropriate learning activities. 2.7 Make explicit connections among content knowledge, pedagogical content knowledge and teaching practice of science and mathematics, as well as between these and the development of creativity. 2.8 Practically demonstrate a variety of roles in their interactions with teachers e.g. facilitator, supporter, coordinator, leader, motivator, role model. 2.9 Model inquiry- and creativity-based learning, teaching and assessment practices, by for example encouraging teachers' decision making during inquiry processes, and sharing, evaluating and reflecting on outcomes. 2.10 Model how teachers should select science and mathematics materials and resources for fostering creativity in mathematics and science.

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Rationale ***Why are teachers learning?*** **Teachers[6] should foster inquiry and creativity in science and mathematics learning in preschool and the first years of primary school.**	
Learning activities *How are teachers learning?*	Teacher education should provide learning activities in science and mathematics which: 3.1 Are inquiry-based, addressing all essential features of inquiry (questioning, designing or planning investigations, gathering evidence, making connections, explaining evidence, communicating and reflecting on explanations), and their various purposes and degrees of structure and guidance (including open, guided and structured inquiries). 3.2 Bring out the synergies between inquiry-based science and mathematics and approaches directed at developing learner creativity. 3.3 Are interactive, within a rich, motivating context, and should encompass a range of formal and informal learning approaches and strategies. Examples of such activities include lesson planning, discussions focused on fostering creativity; demonstrations of good practice; outdoor learning; field trips; project work. 3.4 Integrate science and mathematics learning, making use of real life, meaningful and interactive contexts, and illustrating the potential of such interdisciplinary approaches for inquiry and creativity. 3.5 Provide teachers with opportunities to recognize and better understand both young children's learning of science and mathematics and the role of creativity within this, through for example classroom observations, collection and analysis of evidence, talking to children. 3.6 Attend to teachers' different approaches to their own learning and encourage their expression and representation of scientific and mathematics ideas in various modes. 3.7 Help teachers reflect on their own prior knowledge, (mis)conceptions (incl. stereotypical images) beliefs and attitudes about science, mathematics and creativity, using a variety of approaches, such as microteaching, peer-observations, learning journals. 3.8 Support teachers' learning, by providing them with illustrative examples of diverse practices for them to critically examine opportunities for creativity and inquiry in learning, teaching and assessment. 3.9 Are a variety of individual and collaborative to promote teachers' creative thinking skills and dispositions.

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Rationale ***Why are teachers learning?*** **Teachers[6] should foster inquiry and creativity in science and mathematics learning in preschool and the first years of primary school.**	
Assessment *How to measure how far teachers' learning has progressed? How is assessment information used to inform planning and develop practice?*	**Focus of assessment** In teacher education: 4.1 Teachers' acquisition and development of science/mathematics content and pedagogical content knowledge, skills and attitudes should be assessed. 4.2 The development of teachers' inquiry and creativity-based teaching and assessment approaches should be assessed. 4.3 Teachers' acquisition and development of understanding about what it is to foster children's creativity in science and mathematics should be assessed. 4.4 The development of teachers' abilities to plan for, foster, reflect upon and assess children's creativity in science and mathematics education should be assessed. **Process of assessment** Teacher education should: 4.5 Promote teachers' independence and responsibility in identifying their own progress and areas for development both in the fields of science and mathematics education and in the fostering of creativity within these fields. 4.6 Use different assessment strategies in order to assess holistically cognitive, social and affective aspects of science and mathematics learning, as well as tap into the potential for peer and self-assessment. 4.7 Use different forms of evidence (e.g. portfolios, teacher diary, observation lists, tests, essays, project work, teaching practice) for assessment purposes.

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Rationale ***Why are teachers learning?*** **Teachers should foster inquiry and creativity in science and mathematics learning in preschool and the first years of primary school.**	
Content *What are teachers learning?*	Teacher education should: 5.1 Provide content knowledge about science and mathematics, including interesting and current topics, to be used in activities linked with everyday life. 5.2 Provide teachers with skills and competences to carry out practical investigations of science and mathematics in the classroom. 5.3 Advance teachers' understandings about the nature of science and how scientists work, confronting stereotypical images of science and scientists. 5.4 Promote understandings about the nature and framings of creativity, characteristics of creative teaching and learning, and how creativity is manifest in Early Years science and mathematics. 5.5 Provide knowledge about how children's creativity development could be enhanced and assessed within science and mathematics education. 5.6 Provide pedagogical content knowledge to stimulate inquiry and problem solving in science and mathematics education. 5.7 Familiarise teachers with a range of formal and informal inquiry- and creativity-based learning, teaching and assessment approaches and strategies and their use in relation to authentic problems within the areas of science and mathematics. 5.8 Enable teachers to design and assess creativity-enabling inquiry-based activities which are child-friendly and include both guided and open inquiries. 5.9 Enable teachers to make best use of and assess the various modes of expression and representation of science and mathematics learning to support inquiry and the development of creativity. 5.10 Enable teachers to recognize and build on children's questionings, ideas, theories and interests for the teaching of science and mathematics. 5.11 Enable teachers to use questioning effectively and encourage children's questions in order to foster creativity and inquiry. 5.12 Provide knowledge about early child development, the purposes and aims of science and mathematics education, and their place in the Early Years curriculum.

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Rationale ***Why are teachers learning?*** **Teachers (incl. pre-service teachers) should foster inquiry and creativity in science and mathematics learning in preschool and the first years of primary school.**	
Content (cont.) *What are teachers learning?*	5.13 Provide teachers with knowledge about the relevant education policy guidelines and documents for science, and mathematics education (and the role of creativity in them) at national level, as well as about the corresponding policy trends at European level. 5.14 Equip teachers with knowledge and skills to use a range of formal, non-formal and informal learning environments, including the outdoor environment, both the school grounds and the wider environment beyond the school, in their teaching of science and mathematics. 5.15 Promote teachers' use of group work to support children's inquiry processes and creative learning. 5.16 Provide teachers with knowledge of approaches to timetabling and organizing cross-curricular project work. 5.17 Address with teachers issues in ensuring rich provision, planning and use of resources (including digital resources) in and out of the classroom to support children's inquiry and creativity. 5.18 Encourage and assess the development of teachers' literacy, numeracy and digital literacy skills through science and mathematics.
Materials and resources *With what are teachers learning?*	Teacher education should: 6.1 Provide ICT infrastructure and logistical support to teachers to access diverse learning materials and resources, which may include web-based resources, social media, videogames, online academic journals and databases, as well as other digital technologies, such as cameras, tablets, and other digital devices. 6.2 Facilitate and promote access to a variety of Early Years science and mathematics curriculum materials and resources fostering inquiry and creativity. These should be both for indoor and outdoor use and include everyday materials, picture and story books, building blocks, equipment for hands-on exploration. 6.3 Facilitate and promote access to materials and resources (including everyday materials) fostering inquiry and creativity in Early Years science and mathematics.

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Rationale ***Why are teachers learning?*** **Teachers (incl. pre-service teachers) should foster inquiry and creativity in science and mathematics learning in preschool and the first years of primary school.**	
Grouping *With whom are teachers learning? How are they allocated to various learning trajectories? Are they learning individually, in small groups, or whole-class?*	Teacher education should: 7.1 Provide a range of learning trajectories to teachers to choose from according to their needs and preferences. 7.2 Promote collaborative learning practices, including peer learning, in science and mathematics education in order to foster creativity and inquiry. 7.3 Promote team teaching and working in the fields of science and mathematics education. 7.4 Support teacher collaboration, including at a distance through digital media and other ICT tools that make this possible. 7.5 Provide interaction and interdisciplinary collaboration opportunities amongst student teachers, in-service teachers, science experts, research scientists, teacher educators, children, and educational establishments and organizations.
Location *Where are teachers learning? Are they learning in class, in the library, at home or elsewhere? What are the social/physical characteristics of the learning environment?*	Teacher education should: 8.1 Take place in a variety of learning environments (formal, non-formal and informal, indoor and outdoor), including e.g. science museums, science research centers, natural habitats, etc., modelling their subsequent use for inquiry and creativity in the classroom. 8.2 Facilitate access to industries and research centres of science and mathematics to promote collaboration, sharing, visiting, and networking of teachers. 8.3 Provide opportunities for place-independent and collaborative learning, i.e. flexibility and variety of teaching locations.

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Rationale *Why are teachers learning?* **Teachers (incl. pre-service teachers) should foster inquiry and creativity in science and mathematics learning in preschool and the first years of primary school.**	
Time *When are teachers learning? How much time is available for various subject matter domains? How much time can be spent on specific learning tasks?*	Teacher education should: 9.1 Provide time for teachers to interact with colleagues: e.g. collegial consultation/reflection, teamwork, mind mapping, vision-building. 9.2 Allow sufficient time for teachers to explore opportunities for creativity in learning and teaching in early science and mathematics and to gain confidence through the process. 9.3 Provide opportunities for time-independent (distance) learning. 9.4 Model different approaches to timetabling science and mathematics education, encouraging interdisciplinary and project work.

7.2.3 Recommendations for teacher education policy makers and institutions to apply the set of curriculum design principles

The final set of curriculum design principles presents a set of guidelines that could be a stimulus for debate and a means to promote creativity developments in science and mathematics education for young children. It is intended for policy makers and practitioners to modify as needed in order to meet a wide range of purposes and audiences.

However, in order to use the set of design principles in an appropriate way, some specific aspects have to be taken in consideration by a teacher educator, a team of teacher educators or teacher education institutions. These are:

- The concept of the spider web and its components
- The starting situation of the teacher
- Differences between initial teacher education and professional development

The concept of the spider web and its components

In designing a curriculum van den Akker argues that it is wise to pay explicit attention to several elements or components of it (see Figure 7.1). The middle of the spider web refers to the central mission of the plan (curriculum or programme) and should not, he asserts, be viewed in isolation from its multiple interconnected and highly interdependent components. For example, if the designers of a teacher education curriculum focus only on promoting inquiry approaches through learning

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activities, and pay no attention to the related time and materials, it will be hard to achieve the desired aim that teachers: *"[…] acquire profound content knowledge of science/mathematics ideas and processes, as well as the skills and competences to carry out inquiries"* (Curriculum Design Principle 1.1). According to Thijs and van den Akker, curriculum design or innovation can start with any component on the spider web, but most often starts with the learning content (2009; pp. 12-13).

As discussed, when building a programme for teacher education it is necessary to take into account all the curriculum components together with the accompanying design principles. There are differences between ITE programs and CPD programs. In CPD programs it is possible to focus on a specific teacher outcome while in ITE it is necessary to focus on all the important outcomes in order to prepare student teachers to foster creative approaches in science and mathematics education in Early Years.

The starting situation of the teacher (pre-service and in-service)

The starting situation – competences, expectations, beliefs, attitudes towards science and mathematics, prior experiences and prior knowledge – of the student teacher and the in-service teacher - are important factors to be taken into account when designing a curriculum. Consequently, it is necessary to identify these starting points which will also be influenced by cultural and gender issues. For example, in a CPD context, teachers who experienced inquiry-focused science education in their ITE will have different needs to those who simply had basic training in science principles.

Differences between initial teacher education (ITE) and continuous professional development (CPD)

In initial teacher education student teachers are educated and enabled to work as teachers of the future. Based on this and on discussions in the different focus groups it became clear that ITE curricula should encompass all the curriculum design principles and related teacher outcomes.

As such, CPD differs from ITE. In initial teacher programmes sufficient attention has to be paid to all content issues, whereas in CPD gaps have to be bridged based on a climate for generating ongoing improvement, interaction, and sharing. At this moment, based on findings in the *Creative Little Scientist* project, it is clear that teachers in Europe could benefit from professional development opportunities which for example demonstrate the potential of outdoor learning activities, which focus on the evaluation and generation of ideas of young children in science and mathematics, which demonstrate the creativity potential of questioning as a teaching tool, which train in the use and potential of digital technologies and ICT resources for creativity development in science and mathematics.

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7.3 Teacher outcomes: a framework for teacher training materials

7.3.1 Teacher outcomes as a concrete and specific set of statements

The comparative research (policy review and teacher survey) and in particular the in-depth fieldwork of *Creative Little Scientists* provided insights into a number of issues that need to be tackled in teacher education in order to foster creativity in science and mathematics education in the Early Years. Based on these, the Content curriculum design principles were elaborated into concrete and specific teacher learning outcomes.

This set of Teacher Outcomes can be seen by teacher educators as more concrete guidelines to frame the content of their workshops, sessions and/or courses.

Curriculum Design Principles about Content and linked Teacher Outcomes
5.1. Teacher education should provide content knowledge about science and mathematics, including interesting and current topics, to be used in activities linked with everyday life.
5.1.1 Teachers should be able to pursue the social and affective objectives of children's science and mathematics learning, in synergy with the corresponding cognitive ones.
5.1.2 Teachers should be able to make children aware of connections between science and mathematics learning and their everyday lives, in order to engage their motivation, interest and enjoyment in science and mathematics and foster curiosity and creativity.
5.2. Teacher education should provide teachers with skills and competences to carry out practical investigations of science and mathematics in the classroom.
5.2.1 Teachers should be able to instigate and involve children in the design and conduct of practical investigations of science and mathematics in the classroom, as such activities can contribute to the development of children's creativity.
5.2.2 Teachers should have a more detailed knowledge about the nature of inquiry and investigations in Early Years science and mathematics in order to be able to recognise the opportunities they offer both for creative learning and developing children's creativity.
5.3. Teacher education should advance teachers' understandings about the nature of science and how scientists work, confronting stereotypical images of science and scientists.
5.3.1 Teachers should be able to advance children's understanding about the nature of science and how scientists work, confronting stereotypical images of science and scientists.
5.3.2 Teachers should be able to recognize young children's capabilities to engage with processes associated with the evaluation as well as generation of ideas in science and mathematics, since these processes are also important for the development of learner creativity.
5.3.3 Teachers should be able to use foster the processes of imagination, reflection and consideration of alternative ideas in supporting children's understanding of scientific ideas and procedures and development of creativity.

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5.4. Teacher education should promote understandings about the nature and framings of creativity, characteristics of creative teaching and learning, and how creativity is manifest in Early Years science and mathematics.

5.4.1 Teachers should be able to recognize how creativity is manifest in Early Years science and mathematics and have knowledge of distinctions between features of creative teaching and creative learning.

5.5. Teacher education should provide knowledge about how children's creativity development could be enhanced and assessed within science and mathematics education.

5.5.1 Teachers should have detailed knowledge about the synergies between inquiry and creativity, such as play and exploration, motivation and affect, dialogue and collaboration, problem solving and agency, questioning and curiosity, reflection and reasoning; and teacher scaffolding and involvement, to support children's creative learning and advance their creativity within science and mathematics education

5.6 Teacher education should provide pedagogical content knowledge to stimulate inquiry and problem solving in science and mathematics education.

5.6.1 *Teachers should have knowledge of all essential features of inquiry and problem solving (questioning, designing or planning investigations, gathering evidence, making connections, explaining evidence, communicating and reflecting on explanations), their different purposes, degrees of structure and guidance (including open, guided and structured inquiries), and varied opportunities they offer for creativity.*

5.6.2 Teachers should be able to open up everyday learning activities to allow greater opportunities for inquiry, problem solving and scope for creativity.

5.6.3 Teachers should be able to recognise the key roles of children's questioning and existing ideas (both implicit and explicit) of science and mathematics.

5.6.4 Teachers should be able to use a variety of strategies for eliciting and building on children's questions and ideas during inquiry processes (before, during and after explorations and investigations).

5.6.5 Teachers should be able to foster opportunities for children's agency and creativity in learning in inquiry and problem solving – in particular the importance of children making their own decisions during inquiry processes, making their own connections between questions, planning and evaluating evidence, and reflecting on outcomes.

5.7. Teacher education should familiarise teachers with a range of formal and informal inquiry- and creativity-based learning, teaching and assessment approaches and strategies and their use in relation to authentic problems within the areas of science and mathematics.

5.7.1 Teachers should have knowledge of a range of formal, non-formal and informal learning, teaching and assessment approaches and strategies to promote creativity in their Early Years science and mathematics classroom.

5.7.2 Teacher should be able to use a range of strategies both formal and informal for supporting children's extended engagement with an area of study and progression in learning in science and mathematics.

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5.7.3 Teachers should be able to recognize and exploit the value of play and exploration in science and mathematics for fostering and extending inquiry and creativity, by for example prompting questions, eliciting ideas, providing opportunities for consideration of alternative strategies during children's familiarisation with phenomena and events.

5.7.4 Teacher should be able both to build in new and to make the most of existing opportunities for child-initiated play, recognising and capitalising on the potential of children's explorations beyond the teacher's original intentions.

5.7.5 Teachers should be able to use a range of creative contexts and approaches for provoking children's interest, motivation and enjoyment in science and mathematics, such as stories, poems, songs, drama, puppets, games.

5.7.6 Teachers should be able to use strategies for making and building on science and mathematics real life connections and applications for engaging creatively young children in science and mathematics learning.

5.7.7 Teachers should be able to assume a variety of roles in their interactions with the children e.g. allower, leader, afforder, coordinator, supporter, tutor, motivator and facilitator, to support children's creativity and inquiry in science and mathematics.

5.7.8 Teacher should be able to use a variety of scaffolding techniques to promote creativity in science and mathematics, from standing back in order to observe, listen and build from the children's interests, to intervening with appropriate questioning to support and extend inquiries.

5.7.9 Teachers should be able to use different assessment approaches and strategies and in particular those that involve children in the assessment processes, such as peer and self assessment, dialogue and feedback on progress, in the Early Years science and mathematics classroom.

5.7.10 Teachers should value and be able to make use of varied forms of assessment evidence (including children's portfolios, individual or group records of activities), both to promote creative learning, through reflection and discussion in science and mathematics, and explicitly to inform teaching and longer term planning.

5.8. Teacher education should enable teachers to design and assess creativity-enabling inquiry-based activities which are child-friendly and include both guided and open inquiries.

5.8.1 Teachers should be able to design and assess open-ended learning activities.

5.9. Teacher education should enable teachers to make best use of and assess the various modes of expression and representation of science and mathematics learning to support inquiry and the development of creativity.

5.9.1 Teachers should be able to recognize and value children's various forms of expression and representation of their ideas and learning in science and mathematics.

5.9.2 Teachers should be able to make best use of children's preferred forms of expression and representation of their science and mathematics ideas to support inquiry and their creativity development.

5.9.3 Teachers should be able to select and use different approaches for and forms of recording

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children's ideas and learning in science and mathematics at different stages of the learning process and for various purposes, including to support children's reflection and reasoning processes.

5.9.4 Teachers should be able to use the various modes of children's expression and representation of science and mathematics ideas (e.g. pictures, graphs, gestures, physical activities) for assessment purposes.

5.10. Teacher education should enable teachers to recognize and build on children's ideas, theories and interests for the teaching of science and mathematics.

5.10.1 Teachers should be able to use a range of strategies for picking up on children's ideas, theories and interests.

5.10.2 Teachers should be able to build flexibility into planning to take advantage of unexpected events, children's interests and questions.

5.11. Teacher education should enable teachers to use questioning effectively and encourage children's questions in order to foster creativity and inquiry

5.11.1 Teacher should be able to use different forms of questioning at appropriate points to scaffold creative learning outcomes in science and mathematics, and in particular to encourage children's reflections and explanations, foster their independence and extend their inquiry.

5.11.2 Teachers should value and be able to build on the potential of children's own questions to foster their curiosity in science and mathematics, and support their generation and follow up, including those that are investigable.

5.12. Teacher education should provide knowledge about early child development, the purposes and aims of science and mathematics education, and their place in the Early Years curriculum.

5.12.1 Teachers should have knowledge of the various purposes and aims of science and mathematics education in compulsory schooling.

5.12.2 Teachers should have knowledge of the prevailing academic rationale for the place of science and mathematics in the Early Years curriculum.

5.12.3 Teachers should have knowledge of the role of creativity in child development and in the fields of science and mathematics.

5.12.4 Teachers should be able to contribute towards the goal of preparing creative citizens, who have scientific and mathematic literacy.

5.12.5 Teacher should be able to align the aims and rationale for Early Years science and mathematics education with their teaching and assessment approaches and priorities.

5.12.6 Teachers should be able to support the diverse interests and needs of young children in engaging creatively within the fields of science and mathematics.

5.13. Teacher education should provide teachers with knowledge about the relevant education policy guidelines and documents for science, and mathematics education (and the role of creativity in them) at national level, as well as about the corresponding policy trends at European level.

13.1 Teachers should have knowledge about the relevant education policy guidelines and

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documents for science, and mathematics education (and the role of creativity in them) at national level, as well as about the corresponding policy trends at European level.

5.14. Teacher education should equip teachers with knowledge and skills to use a range of formal, non-formal and informal learning environments, including the outdoor environment, both the school grounds and the wider environment beyond the school, in their teaching of science and mathematics.

5.14.1 Teachers should be able to make use of varied settings for science and mathematics learning, including flexible use of the environment both indoors and out.

5.14.2 Teachers should be able to recognise and build on opportunities for informal learning in science and mathematics within the school environment, for example within day to day routines or child-initiated games and other activities in school classrooms or outdoor play areas.

5.14.3 Teachers should be able to elicit and build on children's informal learning of science and mathematics outside school, at home or in the wider environment.

5.14.4 Teachers should be able to manage visits with children to the outdoor and wider environment beyond the school, addressing issues of health and safety, liaison with parents, building progression in experience inside the classroom.

5.15. Teacher education should promote teachers' use of group work to support children's inquiry processes and creative learning.

5.15.1 Teachers should have knowledge of the value of collaboration for inquiry and creative thinking and learning.

5.15.2 Teachers should be able to purposefully use a variety of patterns of collaboration, shifting between individual and collaborative activity over time, to support children's inquiry processes and creative learning.

5.15.3 Teachers should be able to organize group work, aligning ways of grouping children, task design, teaching and assessment strategies in different ways to promote collaboration amongst children in science and mathematics.

5.15.4 Teachers should be able to use resources and teacher intervention appropriately to foster collaboration in science and mathematics.

5.15.5 Teachers should be able to assess group work.

5.15.6 Teachers should be able to use effective strategies for sharing ideas and discussions from different groups.

5.16. Teacher education should provide teachers with knowledge of approaches to timetabling and organizing cross-curricular project work.

5.16.1 Teacher should be able to use approaches to cross- thematic, cross-curricular and project work to promote creativity in science and mathematics.

5.16.2 Teachers should be able to use a variety of approaches to timetabling, within the existing curriculum and policy expectations to allow space for cross-curricula project work and child-

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initiated exploration and inquiry.

5.16.3 Teachers should be able to build connections across the curriculum of various kinds and with potential to contribute to children's inquiry and creativity.

5.17. Teacher education should address with teachers issues in ensuring rich provision, planning and use of resources (including digital resources) in and out of the classroom to support children's inquiry and creativity.

5.17.1 Teachers should be able to organise and use materials (including everyday materials), resources (including ICT and natural resources) and equipment (including digital equipment and simple laboratory instruments) in the classroom, school and wider environment, both indoors and out, to support independent inquiry and creativity.

5.17.2 Teachers should be able to recognize the nature and potential of different materials and resources both to constrain and extend children's explorations.

5.17.3 Teachers should be able to evaluate and select creativity enabling ICT resources for children to use in their inquiry.

5.17.4 Teachers should be able to evaluate provision for free flow play in their school settings.

5.17.5 Teachers should be able to develop and extend their own classroom resources to foster creativity in the Early Years science and mathematics classroom.

5.17.6 Teachers should be able to gain insights into children's developing explorations and creativity based on their use of resources.

5.17.7 Teachers should be able to develop the school grounds and the outdoor classroom for use in science and mathematics education.

5.18. Teacher education should encourage and assess the development of teachers' literacy, numeracy and digital literacy skills through science and mathematics.

18.1 Teachers should develop their literacy, numeracy and digital literacy skills through science and mathematics.

7.4 Exemplary teacher training materials

Based on the above set of teacher outcomes exemplary teacher training materials originating from the data - images, classroom extracts and interviews – of in-depth fieldwork were developed. More concretely, the partners were asked to review their data of the in-depth fieldwork (images, interviews and classroom extracts) and to select those images, interviews or classroom extracts which were linked to one or more of the Teacher Outcomes and which could stand on their own. A grid was provided to guide this selection. Templates were then used to structure the materials. An example of a template is provided in the section below.

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In total about 169 exemplary teacher training materials or templates are available (see Figure 7.2 below). These are all structured in an Excel-file (see Table 7.1 below) which can be found on the website www.creative-little-scientists.eu.

Table 7.1: Excel file showing all the Teacher Training Materials

Teacher Training Materials	Content Design Principle	Type of Material	Country	Case	Selected Episodes	Age Group (in Years)
BE_Class_TheHail_SocialAffectAims	TE: SocialAffectAims	classroom	Belgium	BE case 6	no	7-8
FI_Class_Volcano_SocialAffectAims	TE: SocialAffectAims	classroom	Finland	FI case 3	no	3-6
GE_Int_Materials_SocialAffectAims	TE: SocialAffectAims	interview	Germany	GE case 3	no	6
GR_Int_MeasuringTables_SocialAffectAims	TE: SocialAffectAims	interview	Greece	GR case 1	yes	5-6
UKNI_Img_Gloop_SocialAffectAims	TE: SocialAffectAims	image	UK	UKNI case 14	yes	3-4
UKNI_Int_Gloop_SocialAffectAims	TE: SocialAffectAims	interview	UK	UKNI case 14	yes	3-4
UKEN_Class_Ice_SocialAffectAims	TE: SocialAffectAims	classroom	UK	UKEN case 1	no	4-6
UKEN_Int_Ice_SocialAffectAims	TE: SocialAffectAims	interview	UK	UKEN case 1	no	4 -6
UKSC_Class_Baking_SocialAffectAims	TE: SocialAffectAims	classroom	UK	UKSC case 20	no	3-5
BE_Class_TheWind_PractInvest	TE: PractInvest	classroom	Belgium	BE case 4	no	5-6
GE_Img_WaterInquiry_PractInvest	TE: PractInvest	image	Germany	GE case 5	yes	6
UKEN_Class_Bubbles_PractInvest	TE: PractInvest	classroom	UK	UKEN case 3	no	3-4
UKEN_Class_CountingMinibeasts_PractInvest	TE: PractInvest	classroom	UK	UKEN case 12	yes	4-5
UKNI_Img_FlowerDye_PractInvest	TE: PractInvest	image	UK	UKNI case 17	no	6-7
UKWA_Class_Jelly_PractInvest	TE: PractInvest	classroom	UK	UKWA case 22	no	3-4
BE_Class_TheWaterfall_NoS	TE: NoS	classroom	Belgium	BE cases 1&2	no	4-6
FI_Class_AnimalFences_NoS	TE: NoS	classroom	Finland	FI case 6	no	6-9
FRA_Class_MagnetAttractionOrNot_NoS	TE: NoS	classroom	France	FRA case 1	yes	3-5
GR_Class_IceBalloons_NoS	TE: NoS	classroom	Greece	GR case 4	yes	5-6
GR_Class_MeasuringTables_NoS	TE: NoS	classroom	Greece	GR case 1	yes	5-6
MA_Class_Capacity_NoS	TE: NoS	classroom	Malta	MA case 5	no	7-8
MA_Class_Drums_NoS	TE: NoS	classroom	Malta	MA case 3	no	5-6
MA_Class_Waterproofing_NoS	TE: NoS	classroom	Malta	MA case 5	no	7-8
PT_Class_WolfSheepCabbage_NoS_1	TE: NoS	classroom	Portugal	PT case 3	yes	8
PT_Class_WolfSheepCabbage_NoS_2	TE: NoS	classroom	Portugal	PT case 3	yes	8
RO_Img_FloatSink_NoS	TE: NoS	image	Romania	RO case 1	yes	5-6
UKEN_Class_MothersDay_NoS	TE: NoS	classroom	UK	UKEN case 2	no	7-8
UKEN_Int_Doubling_NoS	TE: NoS	interview	UK	UKEN case 11	no	5-6

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FI_Class_MeasuringOutside_IBSE	TE: IBSE	classroom	Finland	FI case 2	no	6
FI_Img_SmeltingSnow_IBSE	TE: IBSE	image	Finland	FI case 1	yes	6
FRA_Class_IceCreamSticks_IBSE	TE: IBSE	classroom	France	FRA case 4	yes	7-8
FRA_Class_MagnetDiscovery_IBSE	TE: IBSE	classroom	France	FRA case 1	yes	3-5
GR_Class_IceBalloons_IBSE	TE: IBSE	classroom	Greece	GR case 4	yes	5-6
MA_Class_Minibeasts_IBSE	TE: IBSE	classroom	Malta	MA case 2	yes	6-7
MA_Class_ShootingBalloons_IBSE	TE: IBSE	classroom	Malta	MA case 2	no	6-7
PT_Img_WolfSheepCabbage_IBSE	TE: IBSE	image	Portugal	PT case 3	yes	8
PT_Class_SwinggameRope_IBSE	TE: IBSE	classroom	Portugal	PT case 4	yes	5
PT_Class_SunDistance_IBSE	TE: IBSE	classroom	Portugal	PT case 2	yes	5
RO_Class_FloatSink_IBSE	TE: IBSE	classroom	Romania	RO case 1	yes	5-6
RO_Class_Magic_Water_IBSE	TE: IBSE	classroom	Romania	RO case 1	no	5-6
UKEN_Class_Cars_and_Ramps_IBSE	TE: IBSE	classroom	UK	UKEN case 10	no	3-4
UKEN_Class_Cars_IBSE	TE: IBSE	classroom	UK	UKEN case 1	no	4 -6
UKEN_Class_Sound_IBSE	TE: IBSE	classroom	UK	UKEN case 2	yes	7-9
UKEN_Class_StartingPoint_IBSE	TE: IBSE	classroom	UK	UKEN case 6	yes	6-7
UKEN_Img_Syrup_IBSE	TE: IBSE	image	UK	UKEN case 9	no	3-4
UKNI_Img_GingerbreadMan_IBSE	TE: IBSE	image	UK	UKNI case 16	no	5-6
UKNI_Img_Shapes_IBSE	TE: IBSE	image	UK	UKNI case 15	yes	3-4
BE_Class_TheGiant_CreatInqPed_1	TE: CreatInqPed	classroom	Belgium	BE cases 1&2	no	4-6
BE_Class_TheGiant_CreatInqPed_2	TE: CreatInqPed	classroom	Belgium	BE cases 1&2	no	4-6
BE_Class_TheTipi_CreatInqPed	TE: CreatInqPed	classroom	Belgium	BE case 4	no	5-6
BE_Img_TheCircle_CreatInqPed	TE: CreatInqPed	image	Belgium	BE case 6	no	7-8
FI_Img_Burr_Burr_CreatInqPed	TE: CreatInqPed	image	Finland	FI case 3	no	5-6
FRA_Class_IceCreamSticks_CreatInqPed	TE: CreatInqPed	classroom	France	FRA case 4	yes	7-8
GE_Class_BuildingBlocks_CreatInqPed	TE: CreatInqPed	classroom	Germany	GE case 1	yes	5
GR_Class_Building_MrZip_CreatInqPed	TE: CreatInqPed	classroom	Greece	GR case 4	no	5-6
GR_Class_LittlePrince_CreatInqPed	TE: CreatInqPed	classroom	Greece	GR case 3	no	6-7
GR_Class_Pansies_CreatInqPed	TE: CreatInqPed	classroom	Greece	GR case 6	no	4-5
MA_Class_CountingCaterpillar_CreatInqPed	TE: CreatInqPed	classroom	Malta	MA case 6	yes	7-8
MA_Class_Feet2_CreatInqPed	TE: CreatInqPed	classroom	Malta	MA case 1	yes	3-4
MA_Class_Fruit_CreatInqPed	TE: CreatInqPed	classroom	Malta	MA case 6	no	7-8
MA_Class_MeasuringRobots_CreatIngPed	TE: CreatInqPed	classroom	Malta	MA case 1	no	3-4
PT_Img_WolfSheepCabbage_CreatInqPed	TE: CreatInqPed	image	Portugal	PT case 3	yes	8
RO_Class_Natural_phenomena_CreatInqPed	TE: CreatInqPed	classroom	Romania	RO case 5	no	7-8
RO_Img_FloatSink_CreatInqPed	TE: CreatInqPed	image	Romania	RO case 1	yes	5-6

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UKEN_Class_Habitat_CreatInqPed	TE: CreatInqPed	classroom	UK	UKEN case 13	yes	6-7
UKEN_Class_Pulleys_CreatInqPed	TE: CreatInqPed	classroom	UK	UKEN case 3	no	3-4
UKEN_Class_Ramps_CreatInqPed	TE: CreatInqPed	classroom	UK	UKEN case 4	no	3-4
UKEN_Class_Sound_Multimodal_CreatInqPed	TE: CreatInqPed	classroom	UK	UKEN case 2	yes	7-9
UKEN_Class_Waterproof_Materials_CreatInqPed	TE: CreatInqPed	classroom	UK	UKEN case 11	no	5-6
UKEN_Img_CaseJennie_CreatInqPed	TE: CreatInqPed	image	UK	UKEN case 10	no	3-4
UKNI_Class_Gloop_CreatInqPed	TE: CreatInqPed	classroom	UK	UKNI case 9	yes	3-4
UKNI_Img_GingerbreadMan_CreatInqPed	TE: CreatInqPed	image	UK	UKNI case 16	no	5-6
UKNI_Class_OutdoorSand_CreatInqPed	TE: CreatInqPed	classroom	UK	UKNI case 15	no	3-5
UKSC_Class_DayandNight_CreatInqPed	TE: CreatInqPed	classroom	UK	UKSC case 19	yes	5-6
UKSC_Class_MeltingandFreezing_CreatInqPed	TE: CreatInqPed	classroom	UK	UKSC case 18	no	3-4
UKSC_Class_WaterPlay_CreatInqPed	TE: CreatInqPed	classroom	UK	UKSC case 18	no	3-4
UKSC_Img_CaseSarah_CreatInqPed	TE: CreatInqPed	image	UK	UKSC case 20	no	3-4
UKSC_Int_CountingMoney_CreatInqPed	TE: CreatInqPed	interview	UK	UKSC case 19	no	5-6
BE_Class_TheBags_CreatinqLA	TE: CreatInqLA	classroom	Belgium	BE case 3	no	2.5-3
GE_Class_Fermi1_CreatInqLA	TE: CreatInqLA	classroom	Germany	GE case 4	yes	7
GR_Class_Game_of_swallows_CreatInqLA	TE: CreatInqLA	classroom	Greece	GR case 4	no	5-6
MA_Class_Minibeasts_CreatIngLA	TE: CreatInqLA	classroom	Malta	MA case 2	yes	6-7
PT_Class_SwinggameRope_CreatInqLA	TE: CreatInqLA	classroom	Portugal	PT case 4	yes	5
UKEN_Class_Art_CreatInqLA	TE: CreatInqLA	classroom	UK	UKEN case 2	no	7-8
UKEN_Class_Ice_CreatInqLA	TE: CreatInqLA	classroom	UK	UKEN case 4	no	3-4
UKNI_Int_Foam_CreatInqLA	TE: CreatInqLA	interview	UK	UKNI case 14	no	3-4
UKNI_Img_Foam_CreatInqLA	TE: CreatInqLA	image	UK	UKNI case 14	no	3-4
BE_Class_TheCircleandtheOval_MultiModal	TE: Multimodal	classroom	Belgium	BE case 6	no	6-7
FI_Class_Multiplicationstories_Multimodal	TE: Multimodal	classroom	Finland	FI case 6	yes	6-9
FI_Image_Floorplan_Multimodal	TE: Multimodal	image	Finland	FI case 6	no	6-9
GR_Class_Plants_Multimodal	TE: Multimodal	classroom	Greece	GR case 5	no	7-8
MA_Class_Fruit_Multimodal	TE: Multimodal	classroom	Malta	MA case 6	no	7-8
MA_Class_Numbers_Multimodal	TE: Multimodal	classroom	Malta	MA case 4	no	5-6
MA_Class_Totals_Multimodal	TE: Multimodal	classroom	Malta	MA case 3	no	5-6
UKEN_Class_Volcano_Multimodal	TE: Multimodal	classroom	UK	UKEN case 10	no	3-4
UKEN_Img_CattBoots_Multimodal	TE: Multimodal	image	UK	UKEN case 7	no	6-7
UKEN_Class_Sound_CreatInqPed_Multimodal	TE: Multimodal	classroom	UK	UKEN case 2	yes	7-9

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UKSC_Class_DayandNight_Multimodal	TE: Multimodal	classroom	UK	UKSC case 19	yes	5-6
FI_Class_WaystoCount_ChildIdeas	TE: ChildIdeas	classroom	Finland	FI case 5	yes	6-9
GR_Class_MeasuringTables_ChildIdeas	TE: ChildIdeas	classroom	Greece	GR case 1	yes	5-6
GR_Int_IceBalloons_ChildIdeas	TE: ChildIdeas	interview	Greece	GR case 4	yes	5-6
UKSC_Class_ForestSchool_ChildIdeas	TE: ChildIdeas	classroom	UK	UKSC case 20	yes	3-5
BE_Class_SandBox_Question	TE: Question	classroom	Belgium	BE case 3	yes	3
BE_Class_TheMask_Question	TE: Question	classroom	Belgium	BE cases 1&2	no	4-6
FI_Class_PairtoTen_Question	TE: Question	classroom	Finland	FI case 1	no	6
GR_Class_Game_of_swallows_Question	TE: Question	classroom	Greece	GR case 4	no	5-6
GR_Class_MagicFlute_Question	TE: Question	classroom	Greece	GR case 3	no	6-7
GR_Class_ShapeTrees_Question	TE: Question	classroom	Greece	GR case 1	no	5-6
MA_Class_Drums_Question	TE: Question	classroom	Malta	MA case 3	no	5-6
MA_Class_ShootingBalloons_Question	TE: Question	classroom	Malta	MA case 2	no	6-7
RO_Class_Measuring_volumes_non_standardized_units_Question	TE: Question	classroom	Romania	RO case 4	yes	5-6
UKEN_Class_Beebot_Question	TE: Question	classroom	UK	UKEN case 10	no	3-4
UKEN_Class_Classifying_Question	TE: Question	classroom	UK	UKEN case 6	no	5-6
UKWA_Class_Flapjack_Question	TE: Question	classroom	UK	UKWA case 22	no	5-6
BE_Class_Parallellines_EYSciMaths	TE: EYSciMaths	classroom	Belgium	BE case 5	no	6-7
RO_Img_Colouredfingersstamps_EYSciMaths	TE: EYSciMaths	image	Romania	RO case 3	no	3-4
UKEN_Class_Buttons_EYSCiMaths	TE: EYSciMaths	classroom	UK	UKEN case 4	yes	3-4
BE_Int_Case4Lies_LEnvironm	TE: LEnvironm	interview	Belgium	BE case 4	no	5-6
BE_Class_ModelingWax_LEnvironm	TE: LEnvironm	classroom	Belgium	BE case 3	no	3
FI_Img_MeasuringOutside_LEnvironm	TE: LEnvironm	image	Finland	FI case 2	no	6
FI_Class_MeasuringOutside_LEnvironm	TE: LEnvironm	classroom	Finland	FI case 2	no	6
FI_Img_SmeltingSnow_LEnvironm	TE: LEnvironm	image	Finland	FI case 1	yes	6
GR_Img_Baking_Cheese_Pies_LEnvironm	TE: LEnvironm	classroom	Greece	GR case 2	no	6-7
MA_Class_Minibeasts_LEnvironm	TE: LEnvironm	classroom	Malta	MA case 2	yes	6-7
PT_Img_SunDistance_LEnvironm	TE: LEnvironm	image	Portugal	PT case 2	yes	5
UKEN_Class_Ice_LEnvironm	TE: LEnvironm	classroom	UK	UKEN case 1	no	4-6
UKEN_Class_Cafe_LEnvironm	TE: LEnvironm	classroom	UK	UKEN case 1	yes	4-6
UKNI_Img_Bubbles_Lenvironm	TE: LEnvironm	image	UK	UKNI case 14	no	3-4
UKSC_Class_ScoutCamp_LEnvironm_	TE: LEnvironm	classroom	UK	UKSC case 20	no	3-5
BE_Class_ColouringWater_Gwork	TE: Gwork	classroom	Belgium	BE case 4	yes	5-6

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BE_Class_MeasuringandEstimating_GWork	TE: Gwork	classroom	Belgium	BE case 5	no	6-7
BE_Class_SandBox_Gwork	TE: Gwork	classroom	Belgium	BE case 3	yes	3
BE_Class_TheCarpenterCorner_Gwork	TE: Gwork	classroom	Belgium	BE case 1&2	yes	4-6
FRA_Class_Collaboration_Gwork	TE: Gwork	classroom	France	FR case 5	no	3-4
FRA_Class_IceCreamSticks_Gwork	TE: Gwork	classroom	France	FR case 4	yes	7-8
FRA_Class_Share_Gwork	TE: Gwork	classroom	France	FR case 6	yes	4-5
GE_Int_Materials_Gwork	TE: Gwork	interview	Germany	GE case 3	no	6
GR_Class_BeeBot_Gwork	TE: Gwork	classroom	Greece	GR case 5	yes	7-8
GR_Class_ShapeTrees_GWork	TE: Gwork	classroom	Greece	GR case 1	no	5-6
MA_Class_Minibeasts_Gwork	TE: Gwork	classroom	Malta	MA case 2	yes	6-7
MA_Class_Money_GWork	TE: Gwork	classroom	Malta	MA case 2	no	6-7
MA_Class_Senses_GWork	TE: Gwork	classroom	Malta	MA case 3	no	5-6
UKEN_Class_BalancingPens_GWork	TE: Gwork	classroom	UK	UKEN case 11	yes	5-6
UKEN_Class_MothersDay_Gwork	TE: Gwork	classroom	UK	UKEN case 2	no	7-8
BE_Class_TheCarpenterCorner_CrossCur	TE: CrossCurr	classroom	Belgium	BE cases 1&2	yes	4-6
BE_Class_TheMask_CrossCurr	TE: CrossCurr	classroom	Belgium	BE cases 1&2	no	4-6
BE_Class_ThePirates_CrossCurr	TE: CrossCurr	classroom	Belgium	BE case 1&2	no	4-6
GR_Class_MagicFlute_CrossCurr	TE: CrossCurr	classroom	Greece	GR case 3	no	6-7
MA_Class_Money_CrossCurr	TE: CrossCurr	classroom	Malta	MA case 2	no	6-7
UKEN_Class_SoftPlay_CrossCurr	TE: CrossCurr	classroom	UK	UKEN case 5	no	3-4
UKEN_Int_EggCarrier_CrossCurr	TE: CrossCurr	interview	UK	UKEN case 13	no	6-7
BE_Class_ThePizza_Resources	TE: Resources	classroom	Belgium	BE cases 1&2	no	4-6
BE_Img_ColouringWater_Resources	TE: Resources	image	Belgium	BE case 4	yes	5-6
BE_Img_TheCarpenterCorner_Resources	TE: Resources	image	Belgium	BE cases 1&2	yes	4-6
FI_Class_MapSymbols_Resources	TE: Resources	classroom	Finland	FI case 5	no	6-9
GR_Class_IceBalloons_Resources	TE: Resources	classroom	Greece	GR case 4	yes	5-6
GR_Class_Playing_with_the_microscope_Resources	TE: Resources	classroom	Greece	GR case 2	no	6-7
GR_Img_BranchesLeavesPineconeS_Resources	TE: Resources	image	Greece	GR case 6	no	4-5
MA_Class_Senses_Resources	TE: Resources	classroom	Malta	MA case 3	no	5-6
MA_Class_Totals_Resources	TE: Resources	classroom	Malta	MA case 3	no	5-6
MA_Class_Fruit_Resources	TE: Resources	classroom	Malta	MA case 6	no	7-8
PT_Img_WolfSheepCabbage_Resources	TE: Resources	image	Portugal	PT case 3	yes	8
RO_Img_Coloured lights_Resources	TE: Resources	image	Romania	RO case 3	no	3-4
RO_Img_Seasons_Resources	TE: Resources	image	Romania	RO case 5	no	7-8
RO_Img_PartsofaPlant_Resources	TE: Resources	image	Romania	RO case 6	no	6-7
UKEN_Img_CaseJennie_Resources	TE: Resources	image	UK	UKEN case 10	no	3-4

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UKEN_Class_Digiblue_Resources	TE: Resources	classroom	UK	UKEN case 5	no	3-4
UKNI_Img_OutdoorMeasuring_Resources	TE: Resources	image	UK	UKNI case 17	no	6-7
UKNI_Img_OutdoorSounds_Resources	TE: Resources	image	UK	UKNI case 3.8	no	5-6
UKSC_Img_CaseSarah_Resources	TE: Resources	image	UK	UKSC case 20	no	3-4
UKWA_Class_Makingmusicalinstrument_Resources	TE: Resources	classroom	UK	UKWA case 24	no	4-5

These teacher training materials or templates contain examples of practices from pre- and primary schools. and consequently should be seen as interesting materials to open debate and discussion in teacher education about pre- and primary school practices and curricula (components in the curricula) in order to foster creativity in science and mathematics education in Early Years.

In order to use this amount of teacher training materials some guidelines for usage are provided as well as 10 suggestions. They provide information of how the teacher training materials might be used in teacher education.

- Suggestion 1: Use of questions and ideas by children and teachers
- Suggestion 2: Resources and learning environment as essential context factors for Creativity and Inquiry
- Suggestion 3: Focus on the nature of science – a link with creativity
- Suggestion 4: Focus on Inquiry Based Science Education – link with creativity
- Suggestion 5: Focus on Practical Investigations which foster creativity
- Suggestion 6: Collaboration/group work in Inquiry and Creativity approaches
- Suggestion 7: The role of play in Inquiry and Creativity approaches in Early Years
- Suggestion 8: The use of the various modes of expression and representation of science and mathematics learning to support inquiry and the development of creativity – link with assessment
- Suggestion 9: The role of the teacher in Inquiry and Creativity approaches.
- Suggestion 10: Cross curriculum work in order to foster inquiry and creativity

These examples are presented in the project report Exemplary Teacher Training Materials (D5.3).

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GE_Img_WaterInquiry_PractInvest

Teacher Education Design Principle + code:	2. Teacher education should provide teachers with skills and competences to carry out practical investigations of science and mathematics in the classroom. **TE: PractInvest**
Specific Teacher Outcome(s):	2.1 Teachers should be able to investigate and involve children in the design and conduct of practical investigations of science and mathematics in the classroom, as such activities can contribute to the development of children's creativity.
Factors linked with:	**LA: Plan**
Type of material (image – interview (int) – classroom extract (class):	Images
Originating from:	
Country report :	D4.3
Case:	5
Episode:	Ice & Water
Teacher:	Nadja
Age Group:	6
Selected episode present in D 4.4 Appendix	Yes
Linked with	DP 6: IBSE

Children plan and conduct their own investigations to prove that ice and steam both come from water

The children were asked to plan and conduct their own experiments to investigate the changing states of water. They were allowed to use any of the equipment in the room (school lab) and to go outside as well. Before the children could start their experiments, they had to document their plan by writing down or drawing their ideas and procedures on a prepared „Scientist's sheet".

Children draw their plans and assumption on their "Scientist Sheets":
1. How does ice become water?

Figure 7.2 An example of a template

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Chapter 8
Reflections on research into enabling creativity through science and mathematics in Early Years education: issues and directions for future research and development

8.1 Introduction

As indicated in the introduction to this Final Report the project sought to build a picture of policy and practice in Early Years science and mathematics education and the potential offered for creativity and inquiry in learning and teaching.

It aimed to add to previous EU reports in science and mathematics education in its focus on the nature of science and mathematics education in the *Early Years* and in seeking to characterise and investigate opportunities for *creativity in learning and teaching* within the specific contexts of science and mathematics. A significant strand of the project was also the development of guidelines for policy and teacher education building on findings from the different phases of the study and ongoing collaboration and dialogue with participants and other stakeholders.

This chapter reflects on what has been gained from the research undertaken across the different phases of the *Creative Little Scientists* project, in relation to both research outcomes and processes and identifies emerging issues and possible directions for future research.

It outlines:

- Key features and significance of the conceptual framework for the *Creative Little Scientists* project
- Methodological challenges associated with the scope of the project related to the need to build common understanding across a diverse partnership and the range of data collection within a short timescale.
- Implications and directions for future research.

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8.2 Contribution of the Conceptual framework

In drawing together a review of policy-related and research-related literature covering fields including science and mathematics education in the Early Years, creativity in education, creativity as a lifelong skill, teaching and teacher training approaches, as well as cognitive psychology and comparative education, the Conceptual Framework provided a strong theoretical framework for the project. The processes involved in the literature review were also critical in building relationships, collaboration and shared understandings across the partnership. All partners were involved in a search of literature in the field drawing on their varied interests and expertise and in an initial examination of policy in their own national contexts. (The significance of this is underlined further in the following section).

Two particular features of the conceptual framework played key roles in fostering coherence and consistency in approach across the project and in themselves have the potential to contribute to future work in the field, the *definition of creativity* in early mathematics and science employed across the project and the *synergies* identified between inquiry based and creative approaches to learning and teaching. An important task of the project was to draw together the reviews of science and mathematics education in the Early Years and creativity in education to develop a *shared definition of creativity* in science and mathematics that could be used across the project. The project also set out to explore *synergies and differences between inquiry based science education and creative approaches*, expanding the literature in relation to both these dimensions. The definition of creativity and the synergies between inquiry based and creative approaches as described in detail in Chapter 2 have been empirically tested in diverse classroom contexts across Europe throughout the project and have been found to be both appropriate and valid. They have also proved productive and of interest more widely in the dissemination of the work of the project with varied stakeholders, including researchers, teachers and teacher educators.

Further features of the conceptual framework were also critical in decisions concerning research methodology (as outlined in Chapter 3). The Conceptual Framework identified three broad strands that might be addressed across the phases of the project namely: *Aims, purposes priorities*; *Teaching learning and assessment* and *Contextual factors*. These were further elaborated drawing on the *curriculum dimensions* associated with the 'vulnerable spider web' (van den Akker, 2007). The review of research findings related to creativity in learning and teaching was used to develop the List of Mapping and Comparison Factors (D3.1) linked to these different dimensions that had been found to be associated with creativity in early science and mathematics. The curriculum dimensions and associated List of Factors provided an essential common framework for partners across the different phases of research in

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capturing an in-depth picture of conceptualisations, practices and outcomes related to opportunities for creativity in early science and mathematics.

8.3 Methodological issues and challenges

There were a number of methodological challenges and issues associated with collaboration across such a diverse partnership, the collection of a wide range of data to address the project objectives and research questions, and production of project reports within a very tight time frame.

As indicated in Chapter 3, from the outset language was a key challenge, common in comparative policy studies across countries. Terms, such as 'Inquiry' or 'Creativity' did not translate easily between countries. It was also important to recognise that even if terms appear comparable, they may differ in the meaning attributed. Therefore, making comparisons by measuring the use, or absence, of particular terms is problematic. Furthermore, it is very possible that educational policy or practice in a country embodies much of what is signified by a word without using this word explicitly. This is highly relevant for examining the term 'creativity', where its role may not be reflected by explicit use of the term. It was therefore important to give attention to implicit as well as explicit references to creativity drawing on definitions from the Conceptual Framework. It was also recognized that policy and practice needed to be interpreted within their particular contexts, particularly when making comparative judgments. As a result all phases of research were undertaken by local researchers and reported in separate National Reports. These were then synthesized to form *Creative Little Scientists* project reports.

Developing shared understandings and ways of working and fostering ownership and involvement of partners were important and challenging priorities at each stage in a complex project. To facilitate this, project meetings with all partners were planned to precede each new phase in the project and all partners contributed to each phase of research, including the reviews of literature that provided the foundation for the Conceptual Framework. Regular Skype meetings and other forms of electronic communication provided opportunities to review progress. Across the project the team extended opportunities for mutual support and advice, for example through working in sub-teams, sharing of exemplars of analysis or moderation of reports. Partners were invited to review all project reports and all reports were in addition subject to formal internal review by a range of partners. A great deal has been learned from this experience to inform future international projects.

There were also particular challenges associated with each phase of research. To meet the project's objectives and research questions, mixed methods were employed combining quantitative approaches used in the surveys of policy and of teachers' views based on a list of factors, alongside qualitative approaches employed in the case

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studies of classroom practice and iterative processes associated with curriculum design research. Brief indications of particular issues faced are shown below.

In relation to the policy survey an initial issue was to identify what was meant by national policies. It was important first to clarify the different jurisdictions across the partnership. Then given the wide range of policy documentation and varied degrees of regulation, partners needed to make judgments about the documents that best captured curriculum, assessment and pedagogy in early science and mathematics. This could include for example generic or phase specific policies alongside subject specific documentation. Policy in a number of countries was in transition and it was necessary to review previous or future policy documents that would be in operation during fieldwork. Coding and rating the documents according to the survey tool based on the List of Factors was also not straightforward, particularly in relation to rating the emphasis on creativity. Here the Conceptual Framework and dialogue between partners provided vital support. Partners were asked to provide policy references and comments to support their ratings. In relation to the teacher survey, motivating teachers to participate proved difficult in some partner countries. Partners indicated a number of factors that may have contributed to this, including the timing of the survey in the school term, attitudes to research participation and pressures on teachers in particular policy contexts and the extent of partners' networks and previous contacts with schools.

The fieldwork phase of the project was in some respects the most challenging in undertaking case studies in diverse contexts within a very tight time frame. However it was also very rewarding. Gaining and then arranging access to sites to conduct fieldwork took time given the very busy lives of teachers and schools and the many demands made upon them. A vital element in negotiation with potential schools was the discussion of ethical issues. The project adopted a common framework of ethical requirements including informed consent (staff, parents and children), confidentiality and anonymity, and protocols concerning data protection, storage and publication. Use of photographs was particularly sensitive in some contexts and in a number of settings it was not possible to use video recording. Partners also needed to gain approval from their own institutions and in some cases from local education authorities that in some instances delayed the start of fieldwork.

The fieldwork was ambitious in seeking to gain insights into school and classroom contexts, learning and teaching processes in classrooms and the perspectives of children and teachers. Core instruments to be employed by all partners (outlined in Chapter 3) needed to be practical in all national contexts, in particular a key concern was to devise ways in which to gain insights into young children's capabilities and thinking that could be employed across all settings. A further vital consideration was the need to develop a consistent approach to recording, analysis and reporting of

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results so that findings could be combined in the final project report of fieldwork. In recognition of partners' varied expertise and experience in fieldwork of this kind a *Training Workshop* was organized to introduce and trial methods and approaches to analysis accompanied by a detailed fieldwork manual with background information about each of the fieldwork techniques to be employed. In this phase of the project partners met in subgroups to share experiences, discuss the content and reporting of episodes and issues involved in producing national reports. This made an important contribution to the success of this phase of research in terms of the number, range and quality of case studies and episodes reported in a very short period of time.

However limitations were encountered during the in-depth fieldwork, some due to local issues, others linked to the project itself. The sample of sites selected for fieldwork in each country was small. The short time frame and available resources necessarily limited the scope of data collection. As previously stated in Chapter 3 it was not always feasible for two researchers to be present in one setting at one time which would have allowed for a wider to range of fieldwork instruments to be utilized and a richer diversity classroom practices to be captured, this would have been particularly desirable in preschool settings where many varied activities were often taking place simultaneously. Partners also reported limitations associated with schools' varied experiences of involvement in research or classroom observation. Some schools were used to accommodating visitors, and teachers and children felt confident to talk informally with researchers, however, in other settings classroom observation was much less part of school culture. In some instances this had on impact on the conduct of the fieldwork, in particular the opportunities for dialogue with teachers and children.

There were a number of important areas of learning from fieldwork processes that have the potential for application in future international studies. They include:

- The possibilities of fieldwork at scale.
- Ways of developing common approaches across a diverse partnership.
- The vital role of the conceptual framework in supporting data collection, analysis and reporting.
- The value of a sequence of photographs and a timeline in capturing features of learning and teaching.
- Approaches to gaining the perspectives of young children and insights into their capabilities.

As outlined in Chapter 3, findings from fieldwork in classrooms informed the development of the *Curriculum Design Principles* and *Teacher Outcomes* as outlined in Chapter 7. Selected data and analysis from fieldwork also provided the basis for the Exemplary Teacher Training Materials (D5.3). As discussed in Chapter 7 researchers selected specific episodes which could be used as stand-alone materials in the

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development of ITE or CPD programs. One of the biggest challenges in this respect was in ensuring that episodes could be understood out of the context of the setting in which it took place. Additionally, the remit for ITE and CPD is somewhat different, and it was important that the Exemplary Teacher Training Materials could effectively be utilized for both purposes.

8.4 Implications and directions for future research

Findings from the project contribute new insights into the opportunities for inquiry and creativity in policy and practice in Early Years science and mathematics education.

The policy and teacher surveys conducted across the varied contexts in the partnership, indicate potential for inquiry and creativity, shown for example in common emphases on the importance of play, exploration and investigation and the promotion of curiosity or thinking skills in policy and in the priority given by teachers to the importance of social and affective factors in learning. However whilst policy in many of the partner countries advocates inquiry-based approaches, there are relatively few explicit references to creativity in learning within policy documentation. Though creative dispositions (e.g. curiosity or thinking skills) are mentioned, these are not framed within overt aims to foster creativity in teaching and learning. In addition although in some instances general references to creativity and inquiry are expressed in policy, these are often not reflected in specific curriculum or assessment requirements. This provides arguably conflicting and incoherent support for teachers and schools. Furthermore the emphasis is generally on the *generation* of ideas with more limited indications of scope for creativity in the *evaluation* and development of ideas and strategies or of ways in which children's involvement in assessment might contribute to these processes of evaluation.

The episodes reported in the Country Reports (D4.3) of fieldwork provide rich evidence of children's capacities for inquiry and creativity. They illustrate features of pedagogy related to the *synergies* between inquiry-based and creative approaches identified in the Conceptual Framework, for example through an emphasis on motivation and affect, reflection and reasoning, opportunities for problem solving and agency and the encouragement of dialogue and collaboration. Episodes also indicate the potential for sensitive scaffolding through teachers standing back to watch and listen attentively as well as to intervene to extend children's understanding in diverse ways. However findings from across the partnership suggest areas for further development and examination for example in relation to the more limited opportunities for play and for questioning reported in primary settings. It would be valuable to exemplify ways of creating such opportunities in the primary age phase within the greater constraints of time and curriculum requirements. Finally experiences during fieldwork in a number of settings highlighted the value of sharing

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fieldwork processes and outcomes with participants and the potential for the use of project findings to enhance recognition of opportunities for inquiry and creativity. This provided important feedback to inform development of the teacher training materials.

Findings suggest a number of implications for future research, particularly in relation to factors that were not strongly represented in the data such as:

- Opportunities for outdoor learning in the wider school environment.
- The potential of children's use of ICT to enhance inquiry and creativity.
- Role of representation in varied modes in fostering young children's reflection and reasoning.
- Opportunities for exploring the nature of science with young children.

In addition there were aspects of practice that it was more difficult to observe with the limitations of staffing and time including:

- Role of free flow play in fostering inquiry and creativity over time.
- Contribution of informal and non-formal approaches to young children's learning in science and mathematics.
- The contribution of peer and self-assessment to the development of creative dispositions in early science and mathematics.

Creative Little Scientists has, then, generated a range of findings in relation to its research questions regarding the fostering of creativity and creative pedagogy in early science and mathematics in nine European countries. Whilst the fostering of all three areas is highly valued in European educational policy and indeed in many other parts of the world, the integration of the three is under-researched at this level of the education system. The project's findings and recommendations seek to nurture teacher education in this area in both initial and in-service education, and to make a substantial contribution to knowledge and practice in nurturing creative little scientists.

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