Set of Recommendations to Policy Makers and Stakeholders: Executive Summary

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.

This Executive Summary is based on the Creative Little Scientists *Set of Recommendations to Policy Makers and Stakeholders (Deliverable D6.6) which can be found on www.creative-little-scientists.eu.*

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Introduction

Creative Little Scientists was a 30-month EU funded comparative study working across nine participating countries: Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania and the UK. The *Creative Little Scientists* project sought to build a picture of policy and practice in science and mathematics education for children aged 3-8 and their potential to foster creativity and inquiry learning and teaching.

The project 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. The study aimed to mainstream good practices by proposing changes in teacher education and classrooms encompassing curriculum, pedagogy and assessment.

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 within education**, demanding capable scientists and creative thinkers in an increasingly knowledge-based globalised economy, which requires certain capabilities in the classroom, including reasoning skills, innovative thinking and positive attitudes.
- **The role played by 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**.

Alongside these wider societal issues, 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.

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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 project's Conceptual Framework provided a strong theoretical framework for the study.

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 science and mathematics employed across the project and the *synergies* identified between inquiry based and creative approaches to learning and teaching, drawn from the reviews of science and mathematics education in the early years and creativity in education. The definition of creativity in early science and mathematics developed from the Conceptual Framework and subsequently refined through discussion with stakeholders is: *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 needs to be understood alongside the 'Little c creativity' definition (Craft, 2001), as in the diagram below (Figure 1) insofar as this effort toward originality and value through imaginative activity drives creativity in other domains including early mathematics and science.

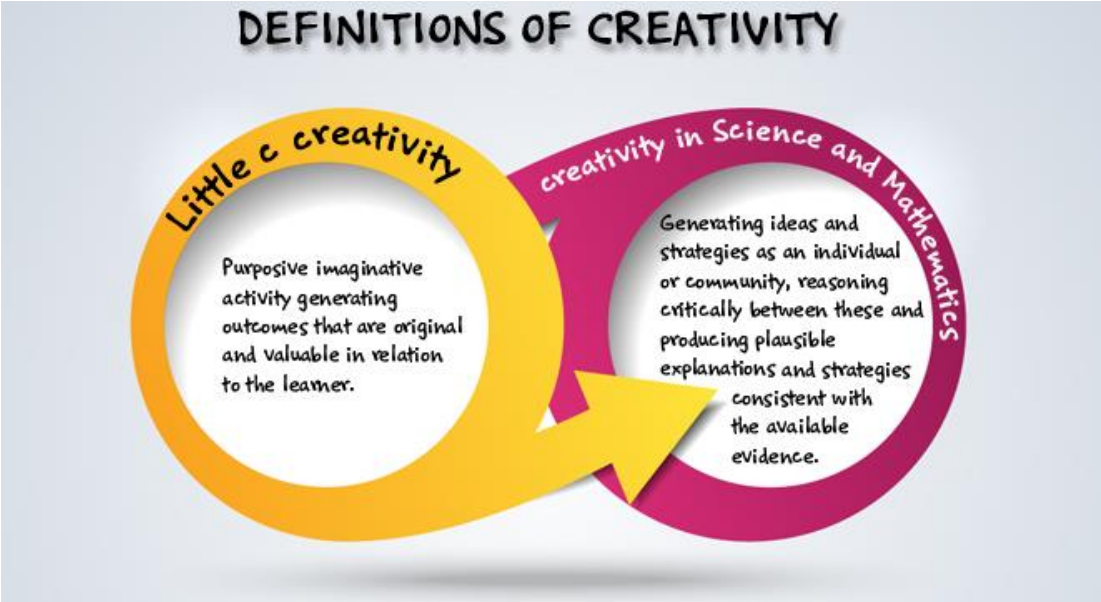

Figure 1: 'Creative Little Scientists' definition of creativity in early years science and mathematics education

The project identified *synergies and differences between inquiry based science education and creative approaches* (Figure 2). The definition of creativity as above, and the synergies between inquiry based and creative approaches, have been

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empirically tested in diverse classroom contexts across Europe throughout the project and have been found to be both appropriate and valid across geographic and age contexts (3-8). They have also proved productive and of interest more widely in the dissemination of the work of the project with varied stakeholders across and beyond Europe, including researchers, teachers and teacher educators.

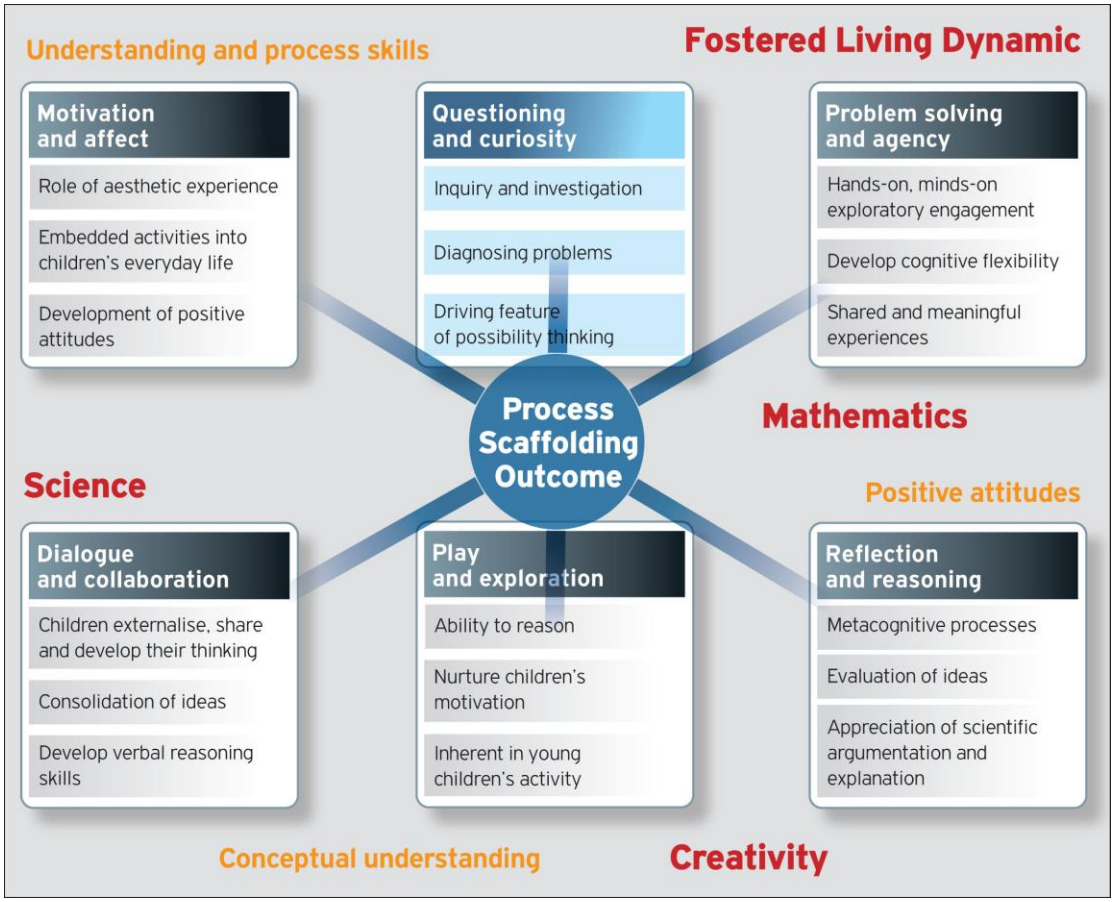

Figure 2: A diagram to represent the pedagogical synergies between creativity, science and mathematics in early years education

The *Conceptual Framework* identified three broad strands that might be addressed across the phases of the project namely: *Aims, purposes and priorities*; *Teaching, learning and assessment*; and *Contextual factors*. These were further elaborated drawing on the *curriculum dimensions* associated with the 'vulnerable spider web' (Figure 3), which identifies key questions about aspects of learning in schools (van den Akker, 2007). The rationale in the middle of the spider web refers to the central mission of the curriculum. It is the major orientation point for curriculum design, and the nine other components are ideally linked to the rationale and preferably consistent with each other. The spider web illustrates the many interactions and interdependence of the parts 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).

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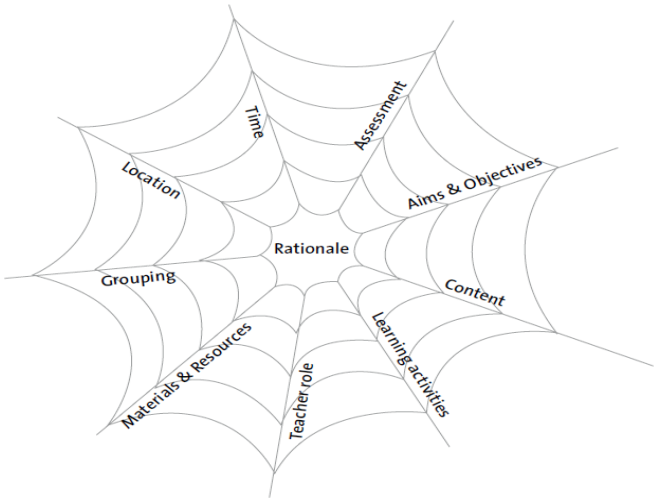

Figure 3: Curricular Spider Web (van den Akker, 2007, p. 41)

The review of research findings related to creativity in learning and teaching was used to develop a List of Factors 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 across the different phases of research in capturing an in-depth empirical picture of conceptualisations, practices and outcomes related to opportunities for creativity in early science and mathematics.

Research questions and approach

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.

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

- *capturing conceptualisations*
- *evidencing practice*
- *developing practice*

and were:

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? What role if any does creativity play in these?

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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 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 questions 1-3 inform the development of practice in the classroom and in teacher education (Initial Teacher Education (ITE) and Continuing Professional Development (CPD))?

These questions were examined in relation to the curriculum dimensions and associated List of Factors found to be associated with creativity in early science and mathematics. 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 4, 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.

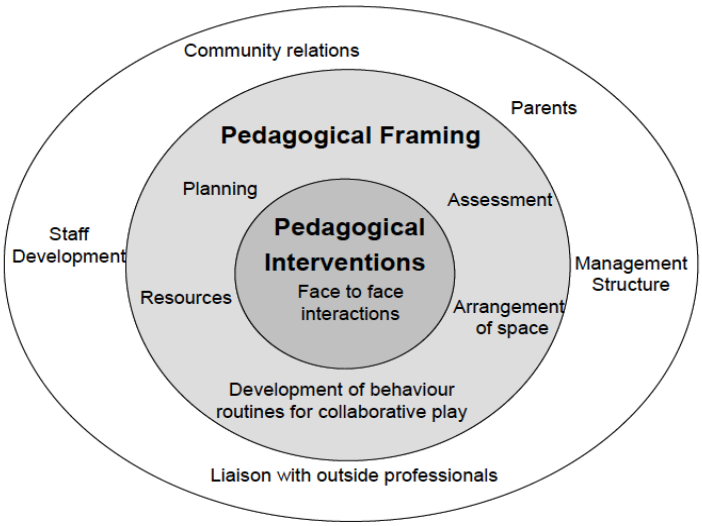

Figure 4: Pedagogical interventions in context (Siraj-Blatchford et al, 2002)

The study also drew on wider contextual information concerning the teachers and schools and early years settings 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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The *Creative Little Scientists* project was organized into different phases, each of which produced public 'deliverables' (Figure 5), which are available on the website.

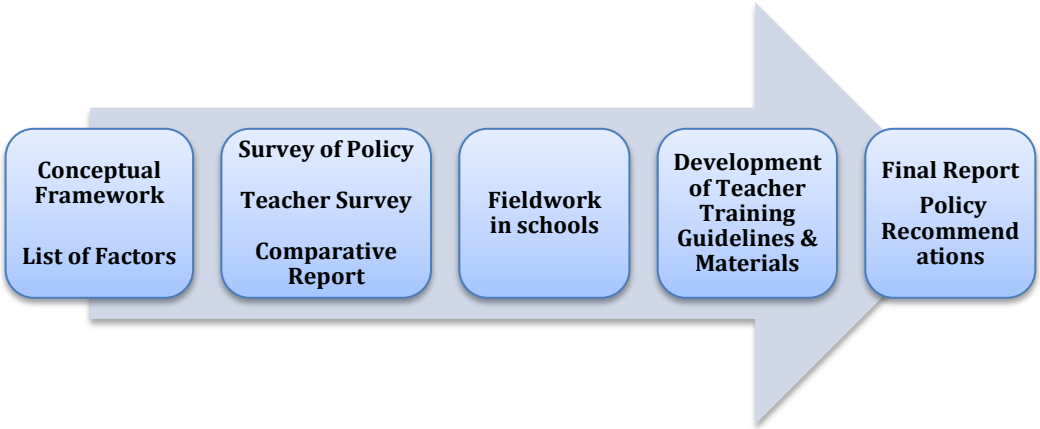

Figure 5: Key deliverables available on the website

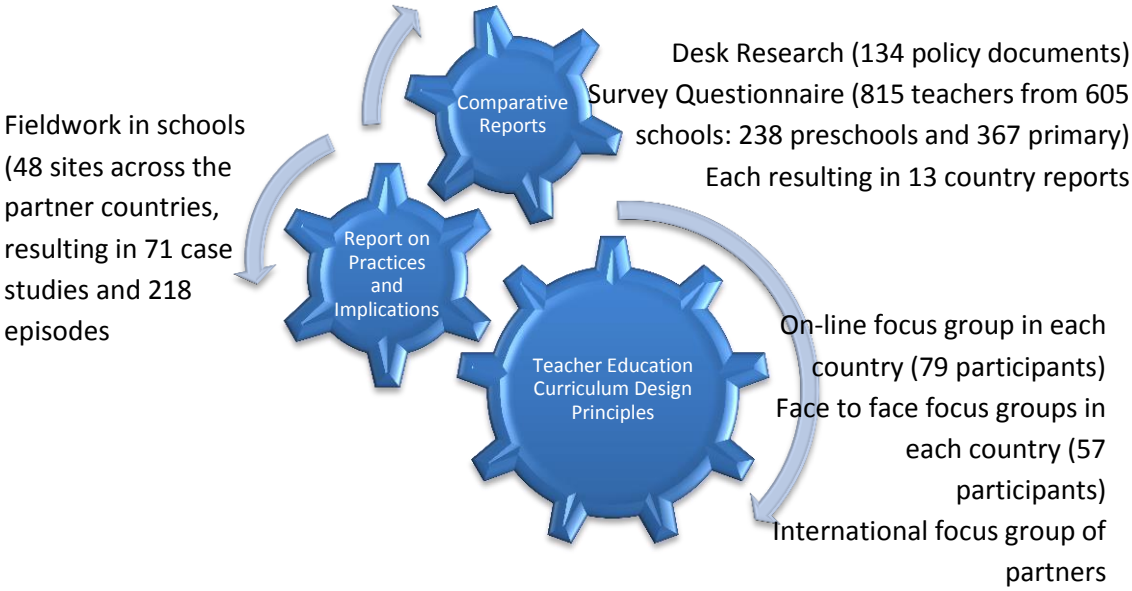

Figure 6: Interaction between the research phases

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 studies of classroom practice and iterative processes associated with teacher education curriculum design research (Figure 6). It was also recognized that policy and practice needed to be interpreted within partners' particular national contexts, especially 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 overall *Creative Little Scientists* project reports, which are available on the website.

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Key Findings

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.

Episode 'Sandbox' (3 years old) (Belgium): Making a wall

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

The activity presented the children with several problems. They were given space and time to *generate their own solutions.* There were opportunities for collaboration between children as they played and watched what each other did. They made decisions based on observations and *evaluation of evidence* of the impact of their actions demonstrating creativity in *making connections* and in their *reasoning skills.*

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 when she noticed that the sand was not mixing enough with such a large amount of water and so she poured some of the water out of her bucket. Her action suggested creativity in *modifying her approach* based on her *observations.*

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

Episode 'Building blocks' (5 years old) (Germany):
Building the "Leaning Tower of Pisa"

The teacher had observed that the class of 5-year old 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" showing creativity in their *sense of initiative* and *imagination* in *generating* plans for a new building project.

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 demonstrating creative dispositions such as *making connections* between observations and using *reasoning skills* in coming up with a solution

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

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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.

Episode 'Gloop' (4-5 years old) (Northern Ireland):
Exploring the properties of gloop, using different tools

In this activity children aged 4-5 years old were involved making and exploring 'gloop' – mixing water and corn flour in a large plastic tray that had been placed on a table. 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. Creativity was evident in his *curiosity* and *sense of intiative* and in the question implicit in his actions *"What can I do with this?"* This was particularly apparent when analysing Ryan's observable contemplation and subsequent use of tools in the tray. At one point, he was moving gloop across the tray with a wide spatula in his right hand, then trying to stop its return flow using a rubber paintbrush in his left hand. At another point he was scooping up the cornflour mix with the spatula and slowly dribbling it on to his forearm and hand. This *generation of alternative strategies* and ways to use the tools provided often novel and unexpected outcomes.

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.

Episode 'Forest School' (3-5 years old) (Scotland):
Observing changes in the natural environment over time

In this setting visits to a local wildlife area are 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 are also designed to foster *children's own interests and explorations* and 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.

The explorations of one child, Ian, illustrate the opportunities to foster creative dispositions in particular *motivation*, *curiosity* and *sense of initiative* in his active pursuit of his own interests and observations. First he spent a long time at the pond that was covered with ice. He noticed bubbles and began breaking up the ice *'so they (the frogs) can breathe'*. A second focus of activity was taking photographs of the different fungi on the site to add to his growing collection.

In reflecting on his visit later in the day Ian highlighted these two activities (breaking ice and photographing fungi), making connections with previous visits. *'I think I saw frogs in the summer – and before I saw frogspawn.... It was sort of jelly – and tadpoles inside the ball of jelly.... Not the kind of jelly from what you eat and got tadpoles inside it'.*

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

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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.

Episode 'Minibeasts' (6-7 years old) (Malta):
Observing and making connections to previous experience

The teacher allowed the children space and time to work freely in groups and explore their environment as they saw fit. This freedom resulted in the children engaging in discussions where they were spontaneously questioning and discussing their surroundings.

The children observed different minibeasts and were very interested, engaged and motivated to record and discuss their observations.

They demonstated creative dispositions in their *curiosity*, in raising their own questions and in *making connections* with previous experiences:

C_1: *See what this is…*

C_2: *That is a pupa…it was a caterpillar once.*

C_1: *Yes we had one in our garden…it turns into a butterfly.*

C_2: *Look how it is stuck to the tree. Will it fall?*

C_1: *How long do they take to become a butterfly?*

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

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

Episode 'Magnetic Attraction or Not' (3-4 and 5-6 year olds) (France): developing a collective conceptualization through exploration and dialogue

The children explored whether objects were attracted to a magnet or not. The objects included pairs of scissors that were made out of iron and plastic, so part of the scissors were magnetic and part of them were not magnetic. The children tested the materials and *generated their own categorisations* in small groups. They then came together to form and record *a collective categorization as a whole group*. The category in which to place the scissors posed a problem for the class as different results for the scissors had been recorded depending on which part of the scissors had been tested with the magnet. At the end of the workshop a girl showed creativity in *offering a solution* to the problem by suggesting that the scissors could be placed 'on the line' between both categories, *fostering new understanding* that an object might belong in more than one category linked to the different materials from which it is made.

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 there was considerable scope for children's decision making.

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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 in order to listen to and build upon children's creative engagement and the development of their ideas and questions.

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.

Episode 'Measuring Outside' (6 years old) (Finland):
Trying to find something a big as the stick

The children spent time in the forest with the teacher and observed the environment. The aim was to capitalise on opportunities for measuring. They measured the heights of different plants and made 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 then presented a challenge *"try to find a plant that is smaller than yourself"*. This activity provided opportunities for *problem solving and agency*, and children *generated their own creative solutions*. One child for example added some snow in order to 'make' a plant of the correct height. Children were asked to explain and justify their solutions. This provided opportunities for the creative use of *reasoning skills* in evaluation.

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

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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 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.

Episode 'Making Musical Instruments' (4-5 years old) (Wales): Resources that support children's inquiry

The children were provided with a variety of resources to make instruments. The activity fostered creative dispositions in a number of ways. For example children were motivated to make musical instruments in a *different* ways. They showed *curiosity* in exploring the sounds made by their instruments and how they could be changed, *making connections* between the sounds made and their actions. For example one girl developed her own systematic investigation. She calmly, carefully and in a very considered way put dried peas one by one into her pot. Every time she added a pea she shook the pot, considered the noise and added one more. She continued for some time. Implicit in her actions was the question '*what happens* to the sound *if* I add another pea?', and an exploration of *relationships* between the number of peas and the sound produced.

Findings underlined the important influence of teachers' wider perspectives on learning and teaching, and their views of the nature of science and mathematics and understanding of creativity 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.

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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.

Episode 'Sun distance' (5 years old) (Portugal):
Developing understanding of the relative sizes of the Earth and Sun and the distance between them

The teacher planned a range of creative activities to foster children's understanding of the relative sizes of the Sun and the Earth and the distances between them, *providing a variety of materials* to represent the Sun and the Earth and the distance between them, giving them *time* to *raise questions* and *offer ideas and explanations*. For example 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 showed imagination in suggesting that the Earth could be represented by a grain and that 'people would be the size of microbes' *making connections* with prior knowledge.

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 *reasoned* 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. Children's *curiosity* was stimulated, they brought books about the theme, they talked with their parents and *raised more questions*. For example they brought in drawings where they tried to answer their own question *"How did Copernicus find out that the Earth that moves around the Sun?"*

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.

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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.

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.

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- 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.

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.

Key recommendations for policy development across Europe in early years science and mathematics education

The recommendations for policy development are drawn from key findings from across the different phases of fieldwork summarised in the previous section. They are presented in relation to the key strands of importance in relation to opportunities afforded for inquiry, problem solving and creativity in early years mathematics and science: aims, teaching learning and assessment and contextual factors.

Aims

The aims of the curriculum should

- ✓ Give greater recognition to young children's capabilities to engage with processes associated with **evaluation as well as the generation of ideas** in science and mathematics.

One of the four key common drivers for an increased research focus on science and mathematics education and creativity in the early years classroom identified by the *Creative Little Scientists* Conceptual Framework calls for growing recognition of young children's capabilities and the importance of early years education in building on children's early experiences and promoting positive skills and dispositions. The review of relevant literature revealed an increasing recognition of children's capacities to take ownership of their own learning and take part in decision making in

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matters that affect their lives in the present. The review of policy notes a lack of coherence in policy in this aspect, for example a mismatch between rationale or aims that might emphasise the promotion of inquiry skills and creative dispositions, and assessment methods and criteria that allow limited opportunities for children to show their capabilities. Having said this, teachers need help to recognise more fully young children's capabilities to engage with processes associated with the evaluation as well as generation of ideas in science and mathematics.

- ✓ Foster the role of **social and affective dimensions of learning** and their connection with cognitive dimensions of learning such as engagement, evaluation skills and understandings related to the nature of science.

The aims, objectives, and content of the science curriculum in partner countries give considerable emphasis to the development of knowledge and understanding of science ideas and process skills associated with scientific inquiry than to social and affective factors of science learning. 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 early years science education.

Teaching, learning and assessment

Curriculum content and policy guidance should

- ✓ Emphasise the important **roles of play-based approaches**, child–initiated activity and practical investigation in both preschool and early primary school.

The *Creative Little Scientists* Conceptual Framework considers playful experimentation and exploration is inherent in all young children's activity; such exploration is at the core of IBSE and CA in early years settings. The significance of play in early learning is widely recognised in the literature but also represents the focus of considerable research within both IBSE and CA. 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. This different pedagogical approach between the two stages was apparent in the classroom observations of the in-field research. Preschool teachers use open forms of play and role play significantly more than early primary school teachers, and a greater proportion of preschool teachers also conceptualise these as 'creativity enabling'. 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

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phenomena. Findings from across the partnership reveal 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.

- ✓ Give detailed attention to **key features of problem solving and inquiry based learning and teaching** particularly with regards to providing sufficient space and time in the curriculum for problem solving and inquiry to study areas in depth. Emphasise also the need for **space and time for teachers** to develop inquiry approaches and explore opportunities for creativity in learning and teaching in early science and mathematics.

Curriculum and assessment requirements, and space and time at school level can constrain teaching approaches, particularly in primary settings. Findings from the in-field research reveal pressures of time and curriculum requirements that drastically limit opportunities for children's creativity and inquiry in both settings. This tendency is observed consistently in both preschool and primary education, although feature more strongly in primary education. Most teachers emphasised the need to 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. The case studies 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 more flexible timetabling and the more holistic approaches to learning and teaching commonly associated with preschool settings allowed teachers greater flexibility to follow children's interests over time and to revisit experiences, making provision for children to encounter ideas in a range of contexts. The challenge here was often less one of time but of recognising and building on children's emerging interests, skills and creative ideas.

- ✓ Include more explicit and detailed focus on the **role of creativity in early science and mathematics**. Provide explanation and illustration of the nature of creativity in learning and teaching in early years science and mathematics.

Findings from all research phases of the project suggest that a more *explicit* and detailed focus in policy on the role of creativity in early science and mathematics would be helpful. Where explicit references are made to creativity in policy they are often in very general terms without provision of guidance about what this might mean in the context of early science and mathematics. The review of policy across partner

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countries identified *implicit* connections to creativity in policy for early years science and mathematics, but these need to be drawn out and exemplified to support teachers in translating policy priorities concerning creativity into specific classroom practices. Furthermore, while certain teaching approaches are often signaled as associated with creativity, such as problem solving and the use of digital technologies, there is limited indication in policy of how such approaches might be used to foster creativity or inquiry in early science and mathematics.

- ✓ Promote the role of inquiry activities in supporting the children's **understanding of science ideas and nature of science**. Give more attention to reflection, consideration of alternative ideas building on the social and collaborative features of learning and inquiry.

Approaches to teaching and learning associated with inquiry and creativity are widely included in policy guidance in partner countries. In preschool, priority is given to play and fostering autonomy, while greater importance is afforded to investigation and problem solving in primary education. It was notable however that in most countries, references to the role of discussion of alternative ideas and understandings related to the nature of science were rarely made in official guidance. Similarly, official guidance rarely indicated roles for creativity associated with the development of science ideas, reflected in limited attention given to fostering imagination or discussing alternative ideas in the teaching approaches advocated. In more general terms, connections to creativity in policy were largely associated with the generation, rather than the evaluation of ideas. In seeking to foster opportunities for inquiry and a role for creativity, greater recognition could be given in policy to the roles of imagination, reflection and consideration of alternative ideas in supporting children's understanding of scientific ideas and procedures. Consideration of alternative ideas is also connected to social factors in learning and the provision of opportunities for development of understandings associated with the nature of science. Explicit focus on the nature of science was limited, as evident by the findings from the policy and teacher surveys and the in-field research conducted by *Creative Little Scientists*.

- ✓ Recognise the importance and roles of **varied forms of representation**, including the use of ICT, in supporting children's learning processes.

The research indicates that the role of varied forms of representation in learning could be more widely recognised. 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. These may take many forms: children's talk, gestures, drawing, their writing and text-making questioning assumptions, redefining problems and considering what else might be

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possible, and may involve the use of digital technologies. Children's creativity is revealed through these means as well as their understandings. 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, helping them to make the implicit more explicit. While there were examples of children's employment of diverse forms of expression across the episodes, this was another factor where partners suggested that the range of approaches might be extended, in particular to incorporate children's greater use of ICT. Fieldwork indicated the value of dialogue with children about their recordings, and the potential of representation and expression, not just for recording outcomes, but for fostering reflection and reasoning processes.

- ✓ Encourage **meaningful and authentic contexts** for inquiry, linked for example, to: events and experiences in everyday life; children's interests and concerns; questions emerging from cross-curricular projects or explorations; and issues in the wider environment beyond school.

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. Findings from the review of policy suggest that limited attention is given in policy to contexts for learning such as drama, stories, historical projects or everyday experiences in the environment. Exemplification would be valuable of the kinds of contexts teachers can provide, and ways of capitalising upon them to foster inquiry and creativity. The results of the in-field research 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.

- ✓ Create **coherence in assessment** between the aims and objectives of learning and priorities in assessment. More attention should be given to social and affective and inquiry related issues in assessment guidelines.

A common theme to emerge across the research carried out by the project 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 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. For example while

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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 learning aims set out for early science and mathematics education. This mismatch identified between rationale/aims of science education and guidance provided for assessment in official policy across partner countries however is not apparent in teachers' views, where a consistency on valuing social and affective dimensions of teaching and learning is evident throughout the spider-web curriculum dimensions and assessment in particular.

- ✓ Foster the development of **on-going assessment strategies and criteria for assessment** to better reflect the emphasis on inquiry and creativity in the aims for science and mathematics in the early years.

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 in the majority of countries across the *Creative Little Scientists* consortium.

- ✓ Provide further guidance on **formative assessment approaches** to support classroom practices**. Assessment methods** should be clearly linked to the multimodal approaches used in classroom practices. Policy statements should foster the use of **children's involvement in assessment** and provide increased opportunities to mirror the children's various strengths and opportunities in their learning.

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. In the majority of partner countries there is very limited or no mention of

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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 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 used these 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.

Contextual factors

Findings from across the project also identified a number of contextual factors of importance in fostering creativity and inquiry in early science and mathematics. Findings from the teacher survey and fieldwork in schools indicate there is a need to:

- ✓ Ensure **sufficient resources and facilities** in schools to support practical inquiry and problem solving in early science and mathematics.

Across the Country Reports (D4.3) partners identified the influence of resources on the opportunities provided for inquiry and creativity in early science and mathematics. In some Country Reports lack of resources was identified as presenting a challenge in implementing inquiry and problem-based approaches to learning and teaching. Partners identified the need in particular for further funding to support the *use of ICT* to support and extend children's problem solving and inquiry processes and the development of the whole school environment, in particular *the outdoor environment* to support learning.

- ✓ Extend opportunities for **ongoing professional development** in early science and mathematics.

The importance of on-going opportunities for and entitlement to teacher professional development was emphasised in Country Reports. At present access to Continuing Professional Development (CPD) is very varied across the partnership. Further recognition is needed of the value and importance of continued training and qualifications. The Country Reports identified key priorities for teacher education to support inquiry and creativity in early science and mathematics. The importance of space and time for teachers to practise inquiry approaches, to explore opportunities for creativity in learning and teaching in early science and mathematics and to gain

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confidence were emphasised. Reports highlighted the need for knowledge and understanding of child development and early learning in science and mathematics to be included in teacher education programmes to support teachers in recognising and building on children's interests, ideas and explorations. Finally the need for further training for teachers was identified in the use of the environment to support learning and teaching in science and mathematics, both the school environment indoors and out and the wider environment and community beyond the school.

- ✓ Encourage **dialogue with parents and the wider community** concerning the aims of science and mathematics education in the early years including the development of skills, processes and *attitudes* associated with inquiry and their roles in developing not just factual knowledge but long term understanding of concepts.

The different phases of the project associated with the policy and teacher surveys and the fieldwork in schools have indicated opportunities provided in policy for promoting inquiry and creativity in early science and mathematics. For example the aims for science and mathematics education indicated in both policy and practice across partner countries reflected a common emphasis on fostering young children's curiosity and motivation and the importance of young children's explorations and investigations. However common challenges have also been identified associated with the demands of curriculum content and a focus on summative assessment in primary schools. Both can result in a focus on factual knowledge rather than deeper understanding and attention to outcomes at the expense of the development of skills, attitudes and processes associated with inquiry and creativity. During fieldwork processes a number of teachers across partner countries commented on the pressures they felt from parents to focus on factual knowledge and grades.

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