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

D6.6 Set of Recommendations to Policy Makers and Stakeholders

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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1. Introduction

The main objective of *Creative Little Scientists* was to establish the details of the current landscape both in official policy and actual practice across the nine partner countries, and provide insights into whether and how children's creativity is fostered, identifying the emergence of appropriate learning outcomes in science and mathematics. Furthermore to make these insights easily available to educational policy makers and other stakeholders, at the European level as well as at national and institutional level.

The proposed Set of Recommendations to Policy Makers and Stakeholders has been based on the findings of the theoretical review, policy and teacher surveys, and in-depth field research that took place as part of the project. The synthesis of these findings provided an arena to make comparisons between the partner countries, but also to make comparisons between documented policies and existing practices, the former recorded by policy survey and the latter by teacher survey and fieldwork. Moreover, these comparisons of policy with practice have taken place at both European level and national level, resulting in policy recommendations also at both levels, presented separately in this document.

Finally, the proposed policy recommendations have been informed by the involvement of communities of stakeholders – teachers, student teachers, school staff members, teacher educators, researchers, out-of-the box thinkers, policy makers and experts in the fields of inquiry, creativity or science – in online and face-to-face focus groups, as well as in a discussion session set up for this purpose during the Final International Conference of *Creative Little Scientists.*

This deliverable (D6.6) should be seen as one of the major outputs of *Creative Little Scientists*, but also as complementary to the other final deliverables:

- D6.5 Final Report on Creativity and Science and Mathematics Education for Young Children
- D5.2 Guidelines and Curricula for Teacher Training
- D5.3 Exemplary Teacher Training Materials

the latter two referring more explicitly to teacher educators and teacher education institutions.

The first sections of the deliverable serve as a reminder of the project's objectives, methodology, research questions and key findings. Then the key recommendations for policy development **across Europe** in early years science and mathematics education are presented, followed by the corresponding key **national**

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recommendations for each of the partner countries[1]. The latter were prepared by each relevant partner, based on the national findings of the policy and teacher surveys, and in-depth field research conducted in the country.

[1] Exception was the partner in Romania, who contributed to the recommendations at the European level, but decided against drawing their own national recommendations.

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2. Key messages from the *Creative Little Scientists* 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.

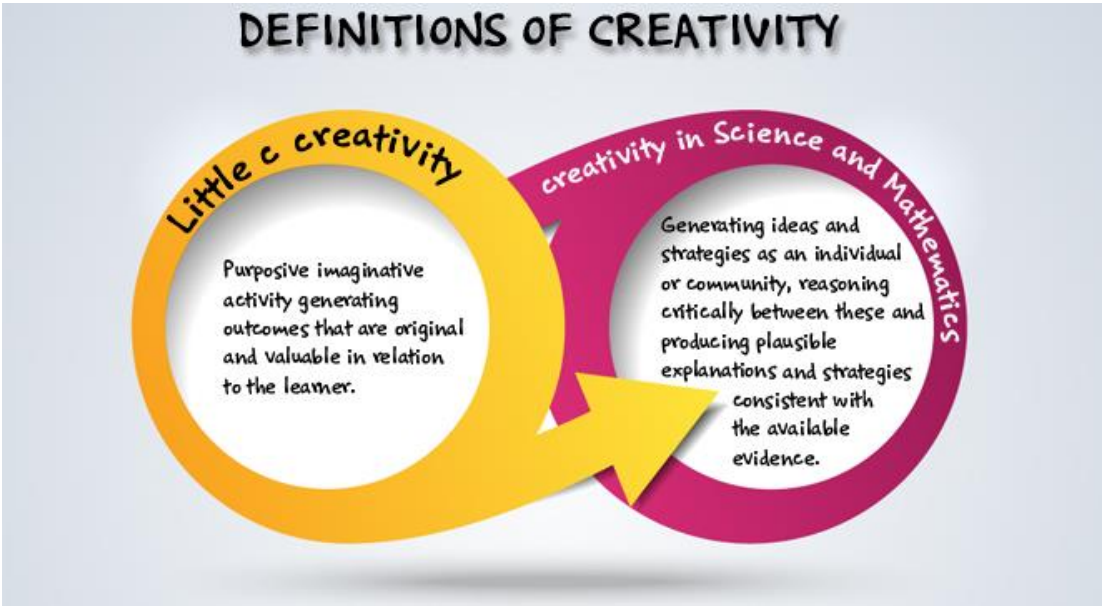

Figure 1: 'Creative Little Scientists' definition of creativity in early years science and mathematics education

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The project identified *synergies and differences between Inquiry Based Science Education (IBSE) and Creative Approaches (CA)* (Figure 2). The definition of creativity as above, and the synergies between inquiry based and creative approaches, have been 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.

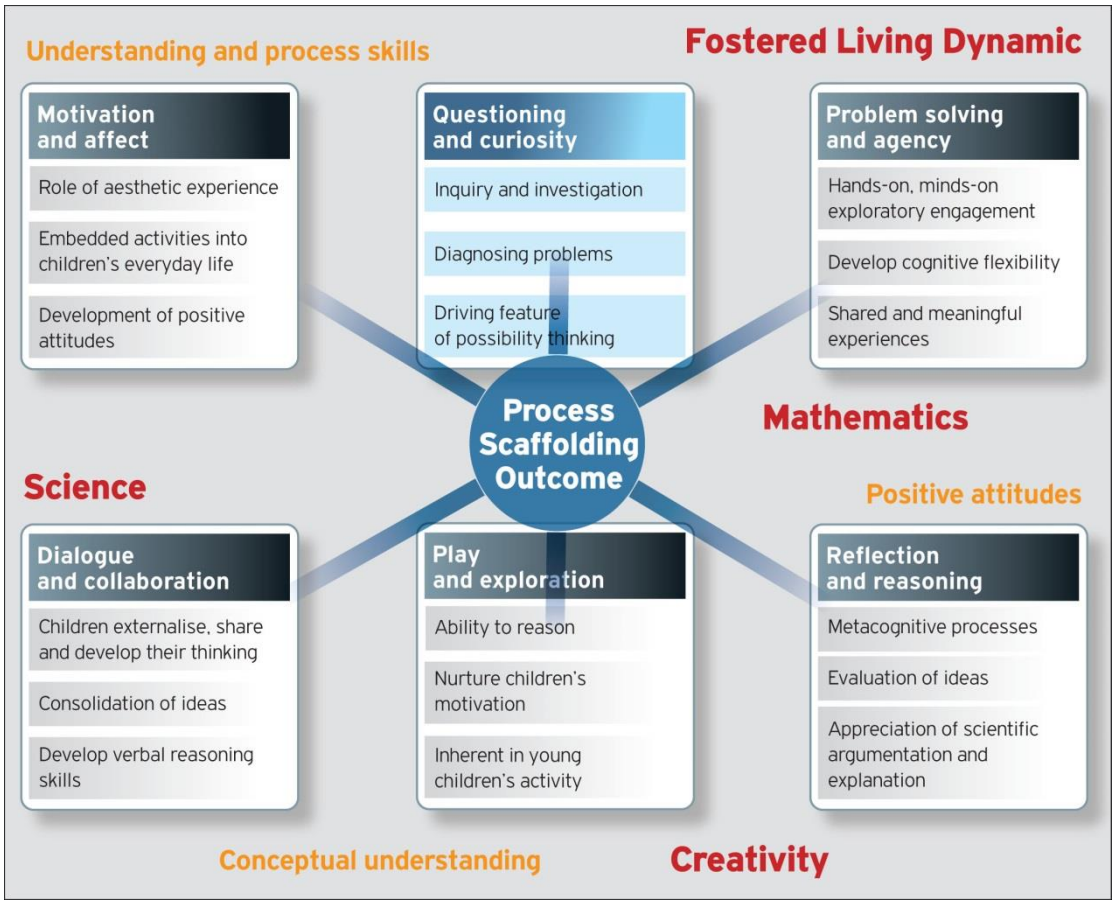

Figure 2: A diagram to represent the pedagogical synergies between creativity, science and mathematics in early years education

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*.

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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).

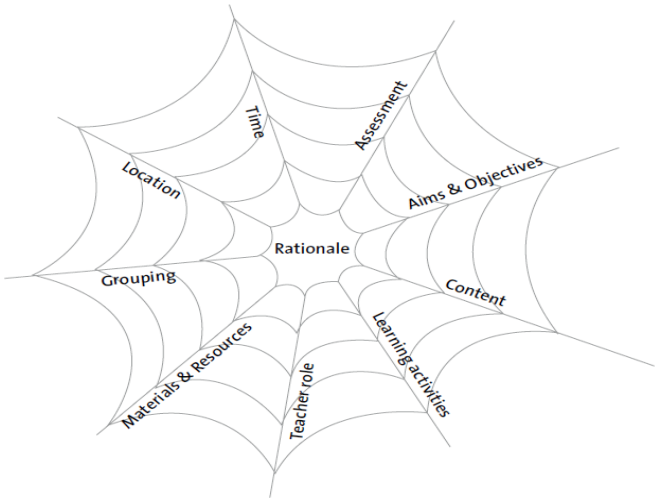

Figure 3: Curricular Spider Web (van den Akker, 2007, p. 41)

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.

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3. 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?

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.

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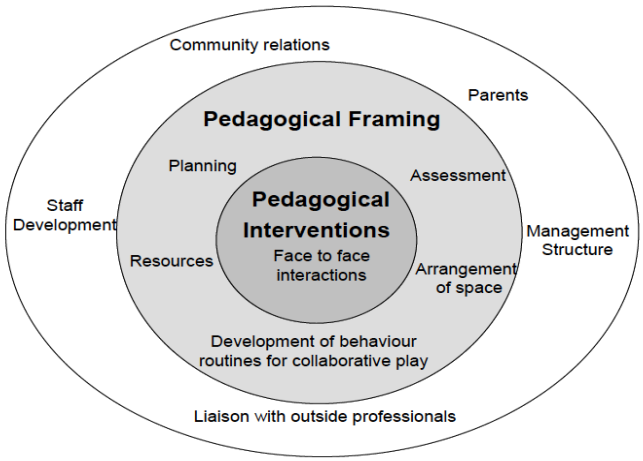

Figure 4: Pedagogical interventions in context (Siraj-Blatchford et al, 2002)

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.

The *Creative Little Scientists* project was organized into different phases, each of which produced public 'deliverables' (Figure 5), which are available on the website.

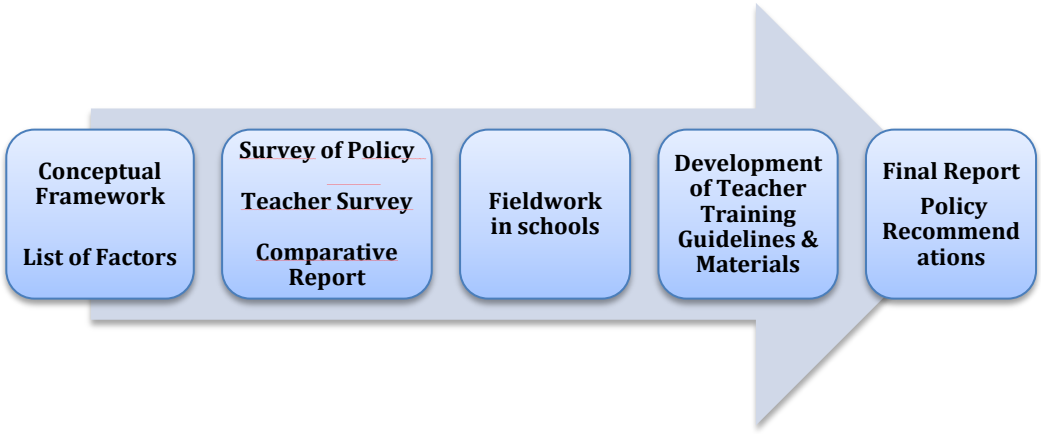

Figure 5: Key deliverables available on the website

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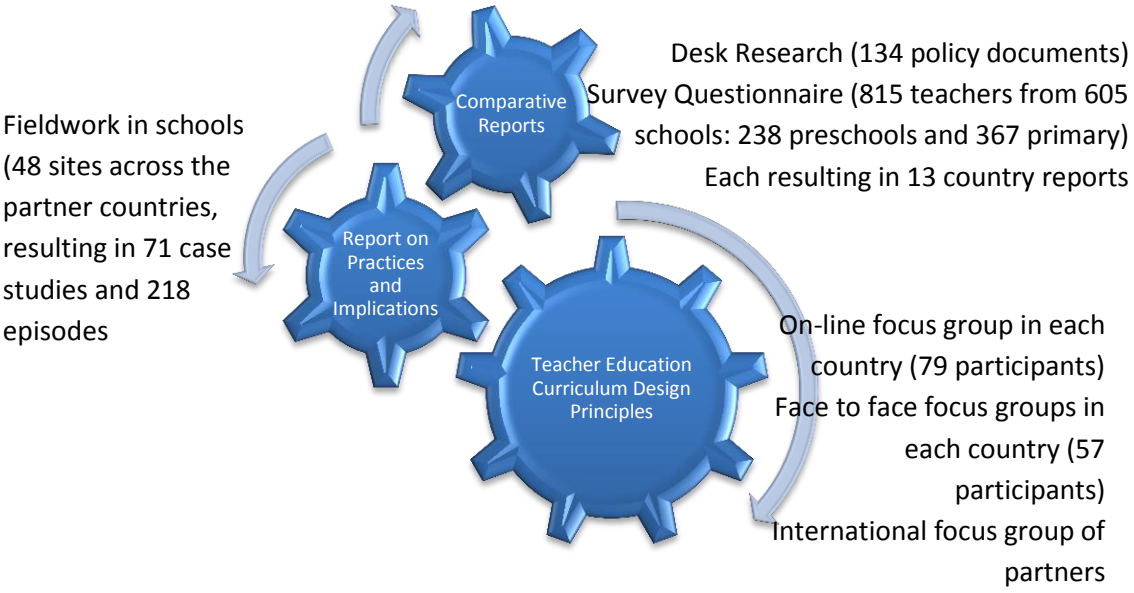

Figure 6: Interaction between the research phases

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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4. Key Findings from the *Creative Little Scientists* research

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 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

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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.

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

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

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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 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 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.

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.

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.

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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.

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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5. 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.

5.1 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 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.

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5.2 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 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

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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 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

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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 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

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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 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

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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 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.

5.3 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

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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 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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6. Key national recommendations to policy makers and stakeholders in early years science and mathematics education

6.1 BELGIUM

6.1.1 Approaches to Teacher Education

Findings from the Belgian research work suggest implications for learning and instruction in initial teacher education and continuing development. The recommendation outlines presented underneath are the most critical ones identified via the *Creative Little Scientists* project research and discussions on teacher education. They might be seen as a guide for specialist professional development routes and/or a starting point for discussions on context-specific factors supporting implementation.

✓ **A strong school philosophy in which creativity and inquiry education are fostered.**

The Decree on Quality of Education (2009) states that each school in Flanders is responsible for providing good quality education. As such, schools carry the major responsibility for the quality of education they deliver and they are controlled for in a standardized way. The choice of design and type of quality review system is up to the schools. In practice (in-depth fieldwork) we notice that schools frame their own pedagogical project, vision and quality assessment strategy, based on the national curriculum and on curricular objectives of the umbrella organisations (macro level).

However, freedom of education could also be a barrier. Based on the findings of the in-depth fieldwork we can conclude that as a school (principal and school team) you need to have a strong policy capacity, a grounded educational project and vision, especially if you want to enable creativity in a proper way and/or on a longer term through science and mathematics. A school philosophy in which the school team discusses action goals, approaches, assessment strategies and learning processes of children seems very valuable when you want to enhance children's agency, when you want to work with their experiences and prior knowledge, talents and skills (creative, problem solving, inquiry, …), when you want to come to deep level learning.

These findings suggest that it would benefit professionals and school teams to examine their own school philosophy and policy. As such, the school visions and policy from schools of the case studies could help teachers and other teams examine their own approaches concerning teaching, learning and assessment. These evidence-based viewpoints could also be used and debated in initial teacher education.

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✓ **Focus on quality control**

School evaluation (external but especially internal audits through self-assessment) which is focused on the quality of teaching in all subject areas (mathematics and science as well), can higher the quality of education and can prevent 'education to the test'. Teachers and school leaders have to be prepared for analysing data from summative and formative evaluations. They should be prepared for selecting and using the most appropriate evaluation strategies in a certain educational setting. As such, teacher education should focus on and train for improved data literacy.

'Classroom observation should play a prominent role in teacher appraisal and feedback. There is also room for teachers to more systematically seek feedback from students on their teaching. In addition, the results of teacher appraisal should be connected both to self-evaluation and the school's professional development plan. This would bring a greater sense of coherence to the process and increase the connection for teachers. **Teachers need further support both in their initial education and their ongoing professional development to develop their competencies as researchers and innovators, as well as becoming proficient users of data.** Through access to research on effective pedagogy as well as effective schooling, teachers can gain deeper understanding of what a good school is and what it means to be part of a professional learning community – a school where collaborative enquiry and use of data for whole-school improvement is the norm.' (OECD, 2011: p. 114)

Extend collegial practice both within and among schools (OECD, 2001: p. 115)

✓ **Focus should not only be on pedagogy and developmental psychology but also on creative teaching and learning in science and mathematics education, and on inquiry approaches**

Findings from the teacher survey highlight that pedagogy and developmental psychology are chiefly studied in teacher education. It are two areas of emphasis. The respondents (preschool teachers) indicate they are not aware of fashionable didactics of science education and they have lack of competence to carry out scientific inquiry approaches. Additionally, Flemish teachers are not educated and experienced with dispositions which foster children's creativity in science education. It seems that teachers recognize creative tendencies but yet do not focus them in their current teaching. Teacher education is now starting to be viewed as a platform for (student) teachers' ongoing creativity. The attitudes and beliefs underpinning this area of competence include change and development is constant in creativity and teachers need the skills to manage and respond to inquiry approaches throughout their careers.

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✓ **Power of teamwork and team teaching**

In one of the schools team teaching is tried out and is found very interesting in an experiential and inquisitive approach. One of the advantages: interests, ideas, theories, questions, special needs of children are picked up faster – necessary in promoting a child's initiative and to have an idea about the basic schemes of children – conversations and discussions with the children can become richer (if children are allowed to discuss and bring in their own opinions and ideas). Using these examples of good practice in teacher education could be encouraging for other teachers and schools to foster team teaching and teamwork.

✓ **Teachers as reflective practitioners**

Based on the research methods and instruments, the following implications for teacher education could be expressed.

Video recall is an interesting method to be used with (student) teachers, reflection of the (student) teacher is much more enhanced when he/she watches her/his own approach or interactions.

The template with factors, used to analyse video data, is an interesting instrument and/or script to analyse (student) teacher practices (we used the template with factors to start and guide the discussions and interviews with the teachers).

Participation in a research project = professional development – it would be interesting to encourage (student) teachers to engage in a research or development project. Communities of practice and special interest groups (online/F2F) have been discussed and agreed upon by stakeholders involved in the *Creative Little Scientists* project.

Pedagogical Framing

✓ **The role of a rich environment inside and outside the school**

The value of resources and materials, inside and outside, are highlighted tremendously in the cases of the in-depth fieldwork. These teachers also often go outside with their children; they value the immediate environment of the school and field experiences.

Based on the observations we noticed that certain materials are particularly interesting to enhance the curiosity of the children, to encourage them in their creative ideas and to challenge them in their natural inquisitive attitude. These materials are amongst others the life-like materials or the so called 'household' materials and the unformed materials, such as sand and water. By offering a wide variety of these materials children get the opportunity to build up fundamental experiences and basic mental schemes that evolve from concrete over schematic to abstract thinking (CSA). Several of these materials can be found outside or are found

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outside by the children themselves. In the pedagogical project of 'AUC1' the necessity of life-like materials is stressed as follows '*The school prefers to work with life-like materials. As such, children can often better adjust their research question and they dare to go further in their experimenting.'*

✓ **Planning and time**

In the participating schools the teachers are used to interact with their children. They are used to make time for unexpected moments or to plan more time if activities are not finished or if individual children need to have additional time to understand a certain topic or to train a particular skill. Corner work is used frequently. Findings in the project stress on the importance of time and free play. Time is indeed an important factor in activities in which children are really engaged and; their agency and initiative are encouraged.

In teacher education curricula the value of unexpected moments have to be stressed as well as using these unexpected moments. We recommend teacher education to value flexible planning and timetabling. The areas of competence within this issue relate to differentiation and being open to and proactive to volatility.

Pedagogical Interactions

✓ **Active listening and observing**

The teachers participating in the in-depth fieldwork were all experienced in active listening to and observing of children so that they could easily respond to children's own ideas and conceptions. It would be interesting to train (student) teachers in active listening to children and broad observing of children. In order to have insights in the (pre)conceptions, the (pre)knowledge of children, teachers need to have an idea about the children's preliminary theories and ideas on science. In order to enhance deep level learning they also need to know the interests of the children, their wellbeing and their learning questions.

✓ **Teacher scaffolding and standing back**

Several of the teachers participating in the in-depth fieldwork were very good in scaffolding and standing back at the right moment. They also were used to ask open question leaving a lot of creative thinking to the children. In teacher education (student) teachers have to be trained in standing back but even then they still need to create opportunities by adding things or asking questions at the right moment, development of understanding of concepts and procedures in science and mathematics and the processes of inquiry.

The teachers searched information (use of internet, digital board, experts, …) together with the children and they discussed this information and resources with

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them, so in collaboration. Teacher education is recommended to focus on the importance of training information skills from the young ages.

✓ **Teacher questioning – focus on reflection and discussion**

Based on the findings in the in-depth field work, it would be interesting if (student) teachers are trained in reflection and discussions with children, in the domains of science and mathematics. As a consequence it is important to train teachers in asking questions related to scientific (open) inquiry; however they have to be the right questions at the right time (for example open questions if children do not have own thoughts or ideas). If not, the process could be blocked or teachers are leading the activity instead of the children.

✓ **Assessment for learning – enhancing transfer**

Findings in the in-depth study suggest to train (student) teachers in enhancing learning transfer by offering them strategies in order to do so.

6.1.2 Implications for Policy Development

✓ **Learning outcomes related to the nature of science should to be integrated in the Flemish national curriculum.**

In Flanders – in the national curriculum and in the teaching practice - there is little or no focus on learning outcomes related to the nature of science (NoS) and thus understandings about scientific inquiry, that is about how scientists develop knowledge and understanding of the surrounding world.

In the practices observed during the in-depth fieldwork the teachers showed confidence in inquiry practices as well as in reasoning and reflecting with children. However, there was no specific focus on how scientists develop knowledge. In a discussion after the in-depth fieldwork - discussing the findings - they agree that they don't have knowledge about the aspects of nature of science nor have they profound insights in different inquiry approaches. The researchers used tools such as Tricky Tracks to visualize the aspects of nature of science and to provide some deeper insights in science. Based on this interaction, the teachers asked for further guidance in order to ameliorate their own practices and to guide children in their exploration of the world and creative learning.

Integrating nature of science as an area of competence in the national curriculum would initiate an integration in practice and in teacher education.

✓ **The importance of a rich physical environment**

Governmental policy can encourage schools to use the environment as learning environment by fostering local communities to participate in school life.

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They are also suggested to make profound choices when they provide funds to schools in order to build up their accommodation. They should have criteria that take into account the school as a multi-faceted learning environment, and not only the classrooms.

In the selection of learning materials there should be enough attention for unformed materials, because of their amazing learning potential. Moreover, extended empirical evidence is recommended in order to explore the impact of architecture, interior, … on learning and instruction processes.

✓ **Tensions on text books**

There should be some quality control on the content, vision and didactics present in text books. Schools can choose to use several manuals and resources (also digital ones) as background, instead of one handbook that offers a suggested learning path. It is recommended that handbooks are not a script for teacher training content, but rather might be considered as a stimulus material for identifying relevant content, planning methods and specifying desired learning outcomes.

✓ **The importance of a grounded school philosophy when fostering creativity and inquiry education**

As noticed during the in-depth fieldwork a combination of freedom of education with a strong school philosophy based on principles of creative and inquiry education and team work can lift a school to a higher level. Vision-building sessions and collegial consult are considered as a resource and an asset to education.

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6.2 Finland

6.2.1 Implications for Policy Development

The implications of previous research are presented in this section, and based on these research results some core recommendations for future work can be suggested. These recommendations refer, among others, to policy makers such as curriculum writers or communal stakeholders, as well as developments in teacher education. The core recommendations are explained and justified from the results of Finnish data that has been collected from studies conducted on the project.

✓ **Focus on Nature of Science and Creativity**

According to the policy survey and research carried out amongst teachers, findings showed that aims and objectives are relevant for the early years, the main focus being on emotional and social factors. However, a clear link towards science literacy and issues that relate to nature or science, were not mentioned or conducted during the early years. In order to educate children towards a better understanding of science and its significance in everyday life, emotional and social factors should be explicitly linked to the nature of science content.

✓ **Fostering simple investigations and projects**

Early years teachers in Finland do not systematically conduct simple investigations and projects. Although problem based learning and the inquiry approach are considered to be significant in both policy documents and by teachers, investigative projects are rarely implemented. Defining inquiry learning and putting it into practise, is a significant question facing teacher education at different levels. Through curriculum guidance and effective, systematic teacher education, more emphasis could be placed on inquiry methods.

✓ **Increasing imaginative play pedagogy at primary school**

On the project, it became apparent that imagination is one of the core principles of creativity and play-orientated pedagogy was seen as being significant for early years learning in general (D2.2). In ECEC, Finnish early years education, although these aspects were emphasized rather systematically, at the primary level imagination and play were not frequently used. This trend was confirmed by surveys and field work research. According to knowledge relating to child development, play orientation and the role of creativity is also considered to be significant in the 7-9 age group. Finnish primary pedagogy could therefore foster children's creativity by focusing on activities that provide space for imagination and play.

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✓ **Increased focus in the early years on specific assessment criteria and methods**

Assessment priorities, their purpose and methods, were not discussed at a specific level. This caused rather large variation amongst the teachers when putting into practice aspects related to assessment. Assessment was, however, seen as a part of learning and a significant element in the quality of instruction. As such, there is a need for intense discussion that relates specifically to assessment in Finnish preschool education; assessment being a part of children's subject based learning and development. In addition, multimodal ways of assessment should be taken into account in initial teacher education, in-service teacher education and in curriculum work. Through these developments, teachers' conception of assessment could become more coherent and its role seen to be more multidimensional.

✓ **The reasonable use of ICT tools in the early years**

Creative education comprises of inquiry and problem based activities that include the use of ICT tools (Craft, 2011). ICT equipment is seen as a motivation for children to learn science (Katz, 2011). Different electronic learning equipment should therefore be used in early years learning for supporting children's skills in gathering and reporting data. According to studies on this project, ICT is not highly emphasized in policy documents and Finnish teachers very rarely use it in their pedagogy. However, teachers did use tablet computers in the fieldwork study and interactive whiteboards were available in several classrooms. To preserve high standards, early years educators should respond to the need to use ICT material in varying ways, increasing their own competence in the use of recent ICT learning materials such as tablet computers and interactive whiteboards.

✓ **Focus on timing the potential of cross-curricular projects**

The Finnish education system allows teachers widescale freedom to plan their teaching and learning activities. The hours stipulated for science and mathematics are presented in policy documents for primary school, but otherwise, teachers are able to organize their teaching as they feel appropriate. Thus it should be recommended, that teachers organize cross-curricular projects for school learning in order to foster children's scientific literacy and thinking skills. Issues in science, mathematics and the mother tongue are all closely related therefore the potential to develop projects between subjects which are interrelated, is still yet to be exploited.

✓ **Class sizes when optimizing the potential for inquiry and creative processes**

In highlighting collaborative learning approaches and pedagogy in their work, Finnish teachers very well meet the requirements of inquiry and creative processes. A close relationship between the teacher and children fosters the possibilities for

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positive feedback and child engagement. It was noticed in fieldwork research, that when teachers had the opportunity to divide the children into smaller groups during their child-centered activities, more potential was created for scientific learning. It seems that this is not always possible, thus we need competent assistant teachers or team teaching to support children's scientific learning and promote their opportunities to conduct inquiry and creative projects.

6.2.2 Approaches to Teacher Education

- ✓ **Focus on studies relating to inquiry and creative education in science education**

Policy documents support inquiry approaches as being relevant in science education pedagogy. In addition, teachers value inquiry dispositions and use them rather extensively, whereas, investigations and projects are seldom used. It seems apparent that teacher education needs to provide teacher students with the competence for conducting investigations and cross-curricular projects, which in turn, will foster children's scientific literacy and creativity. It was also noted in the fieldwork research that inquiry activities resembled guided experiments more than investigations in which child-initiated approaches were highlighted. Teacher education should provide more of the type of activities that demonstrate the significance of inquiry approaches in early years science education.

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6.3 France

In the French context, the next recommendations have emerged from the data collections.

6.3.1 Approaches to Teacher Education

Pedagogical Framing

Curriculum space and time

- ✓ To teach science and mathematics, teachers need contexts, which included play and exploration to arouse children's motivation and positive effects, which promotes learning.

Time and Content

- ✓ **Teachers need time (half a day per week) to make collective reflexion on their practice, to go to museums, to work in team inside and outside of the school (etc.).** Teachers found that all the propositions of the *Creative Little Scientists* project were really interesting and could occur in an ideal world. But, in a daily work, teachers do not have the time to make contacts even with colleagues from others schools in their own city. In France there is little continuous formation. When teachers can participate to continuous formation it mostly occurs during the weekend. So the main proposition of the focus group was to suggest that teacher's education asked for the institutionalization of a time (half a day per week for example) dedicated to peer-work, team's collaboration, inter and super vision, collaboration with researchers (etc.). This time should allow them to accomplish most of the propositions present in the *Creative Little Scientists* project that followed their actual preoccupations and aspirations.

Materials and resources

- ✓ Teachers asked to introduce (in initial and continuous training) videos where real teachings in science or in mathematics could be shown. Indeed, videos are attractiveness for future teachers. Moreover, as we know they offer different and sometimes much more information compared to writing texts.
- ✓ It might be important to reinforce the link between researchers and teachers.
- ✓ To feel more comfortable in teaching science and mathematics, it could be proposed to teachers to participate to collaborative projects with partners inside or outside of the school. School's projects can constitute real leverage for school team to get involved in scientific or mathematical teachings. Moreover it allows teachers who are not confident in science and mathematics to benefit from colleagues expertise.
- ✓ We need to reinforce an access for more teachers to the existing devices such as those proposed by the ASTEP, the "hands-on" or National Education.

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- ✓ Teachers in both groups (preschool and primary) require more personnel to support them in science and in mathematics. It seems to be a solution bringing into schools qualified personnel on scientific domains and on mathematics pedagogy. At the present, most of the teachers use their proper materials support enriched by Internet and library materials to do their teaching.

Pedagogical approaches in teacher training

- ✓ The more important in teacher's education is to know ''how to teach'' more than ''what to teach''. As a teacher said "*when you understand the processes used in sciences you can use them anywhere even for grammar".* So, dedicated teaching can be proposed in order that teacher feel confident in this process.
- ✓ Need to provide training and professional support to teachers to help them use Inquiry based learning in Science and mathematics in schools. This point is very important because the inquiry approach involves the active engagement of children in the learning process. As we know, one important aspect in the process of learning is to promote **motivation** and self-confidence. In this way what is important in teaching and in learning is to find situations that involve collaboration between teachers, researchers and children. In other words, create ''a real situation of research''! In this sense science provides rich contexts to foster the development of inquiry skills (asking questions, observing, collected evidence and answers questions).

6.3.2 Implications for Policy Development

CPD entitlement

- ✓ Creativity is not mentioned as a key concept in the French programs and the official texts. To promote this approach in preschool and in primary school, it could be appropriate to include the concept in the French official recommendations.

Training for science and mathematics co-ordinators

- ✓ **Preschool teachers** need additional training course in **science** (knowledge about scientific ideas and process, assessment and scientific inquiry). This lack of training for preschool teachers can be related to the time they spend to teach science (less than one hour per week).
- ✓ Concerning mathematics (didactics and pedagogy) both groups of teachers (preschool and primary) are not confident in how to teach.
- ✓ Teachers need to have formation to do sciences and mathematics in classroom and in a more general way, need to have formation in Inquiry-based learning approach.

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6.4 Germany

The German education system is complex and constantly changing. Legislation and administration in the field of education are primarily the responsibility of the 16 Federal States (*Bundesländer*). Regulative guidelines are provided by Federal Ministries or by the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany (*Ständige Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland*; *KMK*). The interpretation of these guidelines then lies in the hand of the Federal States. Therefore, school systems and teacher training requirements vary greatly. Preschool education (Kindergarten) in Germany is not part of the state-organised school system, but is assigned to Child and Youth Welfare. On the level of the Federal States, education plans specify the basic notion of education. Responsibility for actual educational work in the individual Kindergarten lies with the maintaining bodies (e.g. churches, welfare associations, local authorities, parents associations). Primary schools are run by a head teacher who is responsible for the educational and pedagogical work in the school. Together with the teaching staff, the head teacher takes decisions on instruction and education. Pedagogical concepts are laid down in individual school programs.

As a consequence, there is not *one* German educational system, and a national curriculum does not exist. Nevertheless, some common features are apparent in the early years maths and science education in Germany. The following recommendations, which are grounded on the research outcomes, refer to these common features.

6.4.1 Approaches to Teacher Education

✓ **Science knowledge and understanding about the Nature of Science**

In preschool and primary school, scientific skills (hypothesise, conduct investigations and then communicate results) are seen as vital for both science and maths education. Inquiry-based approaches are mentioned in all the German policy papers that have been considered for our research. It is emphasized that children should be able to ask relevant, scientific questions and to investigate them.

However, our research findings show that inquiry-based approaches are not very common in German early years science education. A major reason for this seems to be the teacher's lack of scientific content knowledge and knowledge about the nature of science (NOS). During initial teacher training, science education is only of minor importance in Germany: In preschool teacher education, science is introduced as a restricted learning area, focussing only on ecology and health. In primary school teacher education, science is only an optional subject. As a consequence, primary school teachers often teach the subject «Sachunterricht» (which includes topics from natural sciences as well as from social sciences and history), without having attended

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any course in natural sciences during their initial teacher training. As our research data shows, these teachers feel unsure with their own expertise on the subject matter as well as on inquiry approaches. Just as well preschool teachers often feel overburdened by teaching sciences due to their lack of science knowledge.

In order to become confident to teach science and to foster inquiry and problem-based learning, it is important that teachers acquire a good understanding of basic science ideas and processes, as well as knowledge about how science and scientists work (NOS).

✓ **Organizing and assessing group work**

Social learning and the role of collaboration are emphasized in German early years policy papers. Teachers who took part in our studies valued group work and mentioned that it often generates more ideas than individual work. Nevertheless, in German schools (at least at primary level) group work is often not used because of problems with assessment or because it is seen as less efficient.

During teacher education, assessing group work (e.g. process/product assessment, self/peer assessment) as well as organizing group work (e.g. group formation, roles, ways of sharing group results) should be trained and the role of social learning for the development of creativity should be emphasized.

✓ **Teacher's Role**

Presently, the teacher's role is changing in Germany. Many policy papers now advocate the role of the teacher as facilitator and supporter or co-constructor, dismissing her/ his former role as leader. Teachers observed in our studies had adopted this role and supported their children in discovering natural phenomena and in finding new possibilities to approach problems. They encouraged them to pose and investigate their own questions, and valued their ideas for finding solutions or explanations. Children in these classes were highly motivated and found creative ways of problem solving.

Teachers need to know different ways to scaffold autonomous learning in maths and science as well as the development of creativity, e.g. by asking questions that support inquiry and by finding the right moments to stand back and observe the children or to assist and help them.

✓ **Learning activities**

Mathematics and Sciences should be introduced in concrete situations using hands-on approaches that involve all of the children's senses. Furthermore, the observation of natural phenomena and the planning or designing of experiments are also highlighted in the policy papers as advisable activities. These kind of learning

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activities were also recommended by the teachers in our research. In addition, the huge potential of open-ended inquiry for the development of creativity and maths and science learning became evident during our classroom observations: by opening up their learning activities – instead of heading for the "one right answer" – teachers encouraged their children to try out their own ideas and new approaches to problem solving; imagination and autonomous learning were fostered.

Teacher education should involve planning and designing of learning activities that are based on the children's everyday experiences and involve hands-on approaches. Teachers should also recognise the importance of open-ended inquiry for the development of creativity and maths and science learning - instead of heading for the "one right answer".

6.4.2 Implications for Policy Development

✓ **Location**

According to German policy papers, outdoor projects and excursions should be conducted (strong focus especially in preschool), giving children the opportunity to experience nature first hand or to see how people work in mathematical or scientific domains. In preschool, the use of outdoor play areas and excursions to nearby destinations are very frequent and offer various possibilities for first hand experiences and informal learning. However, primary school teachers reported that the possibilities for outdoor learning are very much restricted by time constraints.

Outdoor learning (offering direct relation between science and maths education and everyday life situations as well as real-life encounters) should be more supported and facilitated, especially in primary schools where time restrictions are often a problem.

✓ **Materials & Resources**

Materials which could be used for teaching maths and science are not discussed in a satisfactory manner in German policy papers, leaving a lot of room for interpretations (e.g. using only paper/pencil for maths and science learning). Our research in schools has shown that everyday materials or even toys are suitable to foster the children's exploration and develop their inquiry skills. Furthermore, none of the policy papers remark upon budget for supplies, due to the fact that these factors are included in school curricula, which the schools have to write themselves and thus vary from school to school.

The important role of resources for science and maths education and creativity has to be recognised. Schools should provide varying and appealing materials to choose from, including everyday materials, offering the opportunity to get in touch with different resources or approaches.

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✓ **Time**

Kindergarten follows a holistic approach to learning/teaching and does not appropriate different units or lessons to maths or science teaching. Project work is quite frequent in Kindergarten and offers opportunities for problem solving, inquiry and creativity. Nevertheless, in our studies we observed that during inquiry activities teachers are often interrupted by day-to-day business (e.g. preparing food or changing diapers). In most German Kindergartens, there is not enough staff to concentrate on one specific activity for a longer time. Especially in mixed aged groups which include very young children – the common case in Germany – a large amount of time is needed for day-to-day routine, and only one or two teachers per group are too few to allow the support of extended inquiry learning. In primary school, time slots for maths and science teaching are scheduled, and only about 1 hour per week is planned for the subject "Sachunterricht" where natural sciences are taught together with other curricula areas. This leaves very little time for science education itself and even less for inquiry approaches. Teachers therefore report that it is very hard to organize extended inquiries (e.g. in form of longer lasting projects) which are seen as highly creative.

To allow extended inquiry learning including autonomous, experimental and child-centred learning processes, sufficient flexibility in time must be given to German teachers. In preschool, more staff is needed to deal with day-to-day routines. In primary school more hours should be allocated for science education.

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6.5 Greece

6.5.1 Approaches to Teacher Education

✓ **Teacher education should support teachers in developing a well-rounded conceptualisation of creativity**

The vagueness of creativity as a concept was a common theme found in all phases of the project. The Conceptual Framework discusses the various ways in which creativity in education is discussed. The research carried out in the project showed that the range of discourses of creativity found in the literature is significantly limited in both policy and practice. Even though creativity (or creative thinking) is prominently featured as one of the main objectives of education, it is presented in a vague and confusing way. On the other hand, the findings from the teacher survey and subsequent fieldwork in schools confirmed this rather limited view of creativity in teachers' minds as well as their practice. In order for teachers to be able to foster creativity in science and mathematics there is a need for creativity to be cleared up both as a concept and in operational terms by teachers.

A number of findings clearly point to specific issues that limit the educational value of creativity. For example, the fieldwork showed that teachers do not associate creativity with the generation of alternative ideas which according to the literature is a very important outcome of creativity in education.

✓ **Understandings about the Nature of Science should be explicitly promoted in ITE**

As indicated in the policy review, Greek curriculum documents make limited reference to knowledge and understanding of the nature of science and mathematics with no explicit indication given to how this might be reflected in practice of early years learning. This was clearly evident in the fieldwork portion of the research with no teachers referring to promoting understandings about how scientists work in their planning and their learning objectives. Teacher education should provide instruction so that early years teachers, who in their majority have not studied science during their post-secondary education, can understand the educational importance of scientific methodology. Teacher education should allow teachers to take advantage of the opportunities that arise during lessons to discuss issues linked to the nature in order to plan their teaching so that the scientific and mathematical process skills that are the focus of the curriculum can lead to procedural knowledge.

✓ **Planning learning activities**

It is suggested that teacher education should provide support to teachers in planning and designing learning activities which build on children's ideas and interests, motivate them to actively participate and at the same time, allow them the necessary

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space and resources to foster creativity, consider alternative ideas and form positive attitudes towards learning in general and learning science. Particular emphasis should be given to encouraging children to ask questions, decide on their learning path through planning their investigations and evaluating evidence. Teacher education should allow pre-service teachers to consider and evaluate learning activities through the elements of inquiry which provide a much wider scope that includes all the above mentioned points which were not commonly found in Greek policy and practice.

- ✓ **The roles of materials**

Materials and resources, as mentioned in the Conceptual Framework, are very important for teachers who plan their teaching towards fostering creativity. Teachers have to be supported in order to acknowledge the variety of opportunities offered by the thoughtful use of materials in early years science and mathematics. Careful selection of appropriate materials can support children's explorations, sustain their curiosity and serve as a significant connection between science and children's everyday life. Teacher education should be able to support teachers in realizing how materials support children's inquiries in the classroom and empowering them to search, as well as create appropriate resources for their planned learning activities.

- ✓ **Group work and collaboration**

Collaborative work is one of the most important and heavily promoted early years learning approaches found in the literature but also featured as one of the most crucial elements of the promoted pedagogy of the Greek curriculum. The findings of the teacher survey revealed that teachers overwhelmingly reported to using group work very often in science and mathematics. It is recommended that teachers are provided with guidance on the various purposes of collaborative work to be able to plan collaborative learning activities which can contribute to the pedagogy promoted in the Creative Little Scientists project.

- ✓ **Detailed guidance in assessment**

Assessment has emerged as an aspect which is significantly underdeveloped in both preschool and primary education. Teacher education should provide teachers with a framework that will allow them to evaluate children using a variety of strategies, both formative and summative, valuing diverse forms of assessment and involving children in peer/self-assessment.

- ✓ **Provide guidance on the importance of play in primary science (link to the preschool approach)**

It is suggested that providing opportunities for primary teachers to include aims that value the role of play and collaborative work which have been found to be underrepresented in primary schools should be a part of teacher education. While

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forms of playful exploration were particularly valued by preschool teachers based on the data gathered during all stages of the project, the same cannot be said for their counterparts in primary education. Playful exploration is downgraded as an important teaching context in the pedagogy of primary education, both in terms of policy and recorded teaching practice. Primary teachers tend to use more close-ended teaching contexts in their lessons compared to play, but interestingly, even when they design learning activities that include forms of play, they still rely on a strong element of completion staying away from open-ended investigations. Teachers and student teachers in primary education need to be supported to be able to recognise the potential of open-ended playful activities for learning and feel confident to allow children to make their own decisions regarding their learning path through these particular kind of activities.

- ✓ **Reflection / consideration of alternative ideas**

The teacher has a key role to play in promoting a supportive climate for debate, questioning, feedback and critical reflection. Although reflection and reasoning was highlighted in every teacher interview as an important aspect of children learning, was not evident in the majority of lessons due to the fact that teachers did not allow children ample time to reflect on the activities carried out. It is recommended that teachers are confident to allow children ample time to reflect on the activities carried out in the classroom. Children's reflection can also be promoted through teacher questioning, in order to assist in bringing out children's explanations and various forms of expression. It is recommended that teachers are supported in experiencing different types of questioning within the classroom and their effectiveness in specific classroom situations and contexts in order to foster children's reflection and reasoning.

- ✓ **Highlight the role of multimodal expression and the benefits of formative assessment as a tool to foster children's agency**

The in-field work showed that children's multimodal expression is not used by the majority of teachers in both preschool and primary education. Children were rarely encouraged to represent and express their ideas in their own ways. It is suggested that teachers and student teachers are enabled to consider the purposes of recording, selecting approaches appropriate for purpose and different ways of representing and expressing ideas in order to strengthen children's agency in early years education.

The recognition of the value of multimodal expression can be coupled with an increased appreciation of the benefits of formative assessment. It is recommended that teacher education provides opportunities for early years practitioners to examine different assessment strategies and forms of evidence in early science and mathematics in order to be supported in using assessment information to inform their

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planning and teaching. The data from the in-field work revealed that formative assessment was in large implicit in practice. An important part of this recommendation has to focus on providing a greater recognition of the importance of formative assessment in policy and the development of associated guidance for teachers. Children's engagement in peer and self-assessment will offer opportunities to consider alternative ideas, varied approaches to representation and to allow children and teachers to reflect on learning.

6.5.2 Implications for Policy Development

✓ **Ensure a smooth transition from preschool to primary education**

A recurring theme for a variety of comparison factors was the clear divide between preschool and primary education. This is reflected in both policy and practice. Even though the current curriculum preaches a common approach across all phases, this consistency is highlighted in the general statements and vision of the curriculum but it gets lost in the main part of the curriculum where the learning objectives and suggested activities are described. There is also no provision for ensuring that there is a smooth transition between the two phases in terms of pedagogy and focus. The fieldwork also showed that there is no established process to support primary teachers, the ones who take on the responsibility of this transition, either with receiving assessment data from preschools or through meetings with preschool teachers. In order to ensure children's transition effectively, there is a need for a well thought out and targeted effort to bring teachers across both phases to collaborate, exchange opinions and finally coordinate the learning path within a consistent pedagogical framework.

✓ **Promote understandings about the Nature of Science and scientific inquiry in early years education**

A common finding that has come out in each of the stages of the research was the lack of attention paid to understandings about scientific inquiry and the Nature of Science. This is particularly evident in policy, as the curriculum for both preschool and primary education provides very limited and implicit guidance regarding the promoting of understandings about the Nature of Science. Teachers' responses to the survey, as well as the data gathered during the in-field work point to the same conclusions. The survey revealed that teachers, in both preschool and primary, felt less confident about their understanding about scientific inquiry as well as their competencies necessary to carry out scientific inquiry. Furthermore, classroom observations did not provide any data to concerning understandings about the Nature of Science as none of the teachers in both levels mentioned the term in their interviews or devoted portions of their lessons to fostering understandings about how scientists develop knowledge and understanding of the surrounding world.

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Teacher education should support teachers and student teachers in conceptualising the concept of the Nature of Science, by bringing them in contact with the science education literature as well provide them with opportunities to experience and study exemplary lessons that will allow them to clarify the concept and be able to define, frame and recognize what is required of the learner.

- ✓ **Allow flexibility to practitioners (time management, curriculum requirements, example of flexible zone)**

A very common complaint echoed in the policy review and fieldwork is the very limited autonomy allowed to practitioners by the Greek educational system in terms of both curriculum content and time management. The teachers who participated in the fieldwork and several others who responded in the survey reported to feeling severely limited within the constrictions of the curriculum. Teachers complained that in order to cover the required curriculum content they have to make a number of concessions in their preferred pedagogy, cutting activities short or failing to provide the necessary space and time to children to reflect on the learning activities. It has to be noted that the majority of lessons observed in primary schools were part of the "Flexible Zone" which is the only portion of the school week that allows some autonomy to teachers and children to select topics and activities collaboratively. There is a need for policy to move past allowing flexibility regarding time and space to teachers but also to motivate and empower them to teach within an entirely different framework, one that places the responsibility of planning on the teacher making him accountable for his choices.

- ✓ **Develop a consistent and appropriately realised CPD initiative for early years practitioners (Contribute towards building and sustaining communities of practice)**

The findings which have come out of the research carried out by the project in Greece clearly highlights an urgent need for CPD that addresses the fostering of creativity in early science and mathematics. However, the failure of the Major Professional Development Programme initiative proved that a top-down, nationwide approach to CPD is very problematic in terms of implementation, but more importantly in terms of its failure to prompt significant change to practitioners. It is recommended that CPD initiatives, although needed to be run through official channels and authorities such as the Ministry of Education, should aim at not only motivating practitioners to invite professional development opportunities but empower them to create additional opportunities through collaborations with other practitioners (through forming communities of practice), researchers and stakeholders. There is a need for teachers to be allowed time and space in order to take control of their professional development, similar to what is required in order to

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foster creativity in early years science and mathematics according to the findings of the research.

- ✓ **Strengthen the role of non-formal and informal learning**

The role of informal and non-formal learning is downplayed in both policy and practice in both phases. The in-field research portion of the project provided some indications of opportunities for informal learning in science and mathematics for example within day to day routines or outdoor play areas. There is a need for policy in Greece to recognise and take advantage of opportunities for informal learning within the school environment and out of it.

- ✓ **Organise widespread initiatives to raise the profile of science (such as competitions, awards and collaborations)**

National initiatives, such as competitions and awards held in a number of countries, have been proven to succeed in raising the profile of science and mathematics. The findings from the research carried out in the UK, where such initiatives have been realised, support the value of such initiatives and recommend a wider recognition in official policy. Practitioners' involvement in competitions or awards could motivate teachers to enhance their teaching by providing them with opportunities to get in contact with a variety of different sources for ideas, tools and learning activities, as well as getting them to reflect on their teaching.

One type of such actions that can be organised is a widespread initiative to bring together practitioners and researchers. This recommendation stems from the research portion of the Creative Little Scientists project. The vast majority of teachers initiated informal conversations with the researchers about their teaching and asked for comments and notes from the researchers. In general, teachers seemed eager to take part in conversations concerning their practice, stating that an outside observer's feedback (who can also be considered as an expert) is absent from their practice. A number of teachers mentioned that participation in the research was very helpful to their practice and declared their availability to participate in future projects. A well-thought widespread initiative has the potential to forge strong long lasting partnerships between researchers and practitioners which would significantly contribute to teachers' professional development.

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6.6 Malta

6.6.1 Approaches to Teacher Education

The following recommendations concern initial teacher training and continuous professional development.

✓ **Whole school approach to creativity resulting in a common understanding of creativity**

Even though a whole-school approach is encouraged in several policy documents, it is not clearly reflected in preschool and primary teachers' conceptualization of innovative thinking and creativity. Therefore, teachers need to be supported in recognizing that creativity goes beyond learning areas, such as expressive arts. By exposing teachers to the local and international examples captured in this study, they could be helped to consider creativity differently as something, which can be promoted through pedagogical approaches used in the teaching of mathematics and science. There is need for support to teachers to create a common understanding of creativity as a common theme cutting across different learning areas. We also recommend that teachers are introduced to ways to engage and introduce children to lateral thinking, problem-solving, questioning and critical thinking through initial and continuous training through activities which they organise. This should also be accompanied by fostering the importance of promoting autonomy for both children and teachers to facilitate these creative skills. At a school level the school management committees need to support the teachers in this new direction by allowing time to teach for creativity and provide adequate training to instil this new objective in their teaching staff.

✓ **Teaching for creativity**

As the survey responses indicate teachers do acknowledge the presence of creativity and express that they highly praise these instances in their classrooms. However, even when collecting episodes of good practice in Maltese schools, which involved observing teachers that intentionally incorporate creativity in their class, there was a greater emphasis on the teachers' own creativity rather than the children's creativity. Therefore, it is recommended that teachers are exposed to the examples collected in this study that depict teaching for creativity in science and mathematics where teachers promote children's autonomy, create spaces of freedom within their teaching to give the opportunity for the children to experience creativity but also incorporate children's creativity as part of the lesson. As seen, even though creative resources are important in this process, teachers need to be supported to recognize that children should use these resources without restrictions. These examples can also demonstrate how teachers can use different group work activities to provide space for children to work in an environment that supports creativity.

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✓ **Assessing for creativity**

Even though assessment is an important form of evaluation tool and considered important by many teachers completing the survey and observed in the field, assessment of creativity is missing. We recommend the introduction of a new way of assessing where the process is more important than the product. By being exposed to the exemplary teaching materials where other Maltese teachers use assessment, which does not rely on providing the expected answer, but appreciates and gives credit to the uniqueness of putting forward original responses, teachers can be inspired to follow suit. This new conceptualization of assessment reflects better learning that takes place during inquiry based learning, where the process and the skill of investigation carry more value than the answer. Inquiry should also be included and used as an assessment tool to promote as well as document students' development of investigative skills such as observation and reasoning skills along with assessing for creativity.

✓ **Shared understanding of inquiry based learning and scientific inquiry**

Most of the inquiry captured in the practice episodes collected from local school promote a highly structured and guided type of inquiry. Even though this approach has its own benefits that enhance both students' interest and learning, the opportunity to teach for creativity that inquiry activities can provide is often overlooked. This was also reflected in the survey responses as teachers ranked guided inquiry as occurring most frequently in their classrooms. Their responses also hinted that even though inquiry has become a familiar concepts its meaning is still blurry. Therefore, there is a need to clarify the meaning of inquiry by emphasizing all its different aspects including; engaging in scientifically oriented questions, giving priority to evidence in responding to questions, formulating explanations from evidence, connecting explanations to scientific or mathematical knowledge, and communicating and justifying explanations. The exemplary teacher training material can assist teacher educators in this task as they can illustrate these different aspects as they occur in different international practice. Furthermore, teacher educators should present how to use these tools by providing first hand experiences of open inquiry and student-initiated activities, so as for the teachers to be well equipped with the necessary pedagogical skills to conduct child-initiated activities in future practice. This training should be also continued within continuous professional development with regards to planning open-ended investigations leading to children being creative as they inquire.

✓ **Addressing teachers' confidence**

The teachers in the survey indicated a low level of confidence with regards to conducting inquiry. This was accompanied by similar low confidence (41.7% - low;

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13.7% - very low) in understanding important scientific processes. Additionally, the teachers identified that certain competencies and experiences needed for the teaching of science and mathematics were missing in their teacher education. A percentage of teachers (16.5%) claimed that their education did not involve mathematics content; whilst 17.5% of teacher expressed that their education did not involve science content. These declarations of lack of competence and confidence become visible obstacles to the pedagogy promoted in this project, raising questions of how possible it is for inquiry to become an integral part of classroom activities. The survey responses highlight a national need to adequately prepare student teachers during initial teacher training and a need to continuously guide practicing teachers through continuous professional development with regards to content and subject knowledge of both mathematics and science along with process skills required to conduct simple inquiry. These needs should be considered alongside adopting an inquiry based learning and creative approaches since they all serve as a foundation to these promoted pedagogies. These obstacles could be overcome through exposing teachers to the exemplary teaching training materials gathered as a result of this project, in order for teachers to encounter examples of inquiry activities that will help them increase their familiarity with scientific and mathematical processes and inquiry. By re-enacting these activities during teacher training, teachers have the opportunity to increase their first hand experiences of these inquiry processes whilst increasing their confidence.

- ✓ **Inquiry as a pedagogical tool to tap into the elements of creativity**

Although investigations, explorations and inquiry are ranked high in both the teachers' and policy's agenda, its link to creativity is still to be consolidated. The teaching examples captured in this study could help demonstrate how allocating space and time for the children to express their ideas and try them out triggers scientific learning, mathematical learning, and creativity. These examples illustrate how open-ended inquiry, which gives added freedom to the students, allows them to put forward original and creative responses. They also illustrate a new form of appreciation for uniqueness that is a common and important element in both inquiry based learning and creative pedagogical approach. Therefore, exposure to these training materials will better establish how inquiry based learning facilitates teaching for creativity.

- ✓ **Increasing the importance of science in primary education**

Even though a great policy effort to promote science as a core subject is underway, science is still underrepresented in practice as 35.25% of teachers completing the survey declare that they spend less than an hour per week on science, whilst 46.76% dedicate less than two hours. Teacher educators can make use of exemplary teaching training materials to discuss time management skills in order to manage to dedicate a

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designated time to science to reflect the timetabling of the Junior cycle in the National Framework Curriculum that declares that mathematics and science should be given 15% of the curricular time each. This opportunity might instil the responsibility of primary class teachers to teach science in the early years classes. This might be accompanied by efforts from school management committees to hold class teachers accountable for teaching science even though there is no official assessment. Furthermore, the social and affective dimensions of science learning should be considered important and therefore increase the importance of teaching science in the early years.

✓ **Provide meaningful CPD**

The teacher responding to the survey identified networking as the most significant CPD opportunity with the greatest perceived impact on their practice. Therefore, the last recommendation regarding training involves increasing the opportunity of networking with other teachers during CPD. The exemplary teaching training materials from a CPD perspective can be seen as a form of networking as the work of different Maltese and other international teachers share their ideas and practice. These materials can be used in networking CPD events to promote discussions, inspire teachers and invite them to reflect about other teachers' practice as well as their own.

6.6.2 Implications for Policy Development

At policy level certain changes are also deemed important in order to establish continuity between changes in initial teacher training and continuous professional development that entail:

✓ **Creating a greater emphasis on child's creativity**

The lack of emphasis on children's creativity in practice is mirrored in policy as even though documents promote creativity through a whole school approach it falls short of providing the instruments to do so. Therefore, policy should, in promoting creativity through science and mathematics education, provide practical examples on how to foster creativity through the inquiry-based approach. The exemplary teacher training material produced in this project can provide an opportunity for students and practising teachers to be exposed to this "how" element of creativity. This exposure can also illustrate how young children have the ability to participate in inquiry based learning if given time, skills needed and freedom, which most likely results in their own creative engagement. It is also very important to go beyond just committing to creativity and innovation in policy, but to go also highlight the need for teachers to be responsible for promoting creativity as well as the pedagogies that encourage it.

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✓ **Policy effort to link mathematics to inquiry**

Recent PISA and TIMSS results have put in motion an action plan to promote science. This effort has resulted in the development of policy documents such as the Vision for Science Education, which reflects a commitment to inquiry-based learning as an integral part of science education. This inquiry-based approach has also been included as a whole school approach in the new curriculum framework. However, the contribution of the inquiry approach to mathematics is still implicit. Therefore, a similar effort needs to be made to promote inquiry as an effective pedagogy also in mathematics teaching. The exemplary teacher training materials collected in this project provide a way to connect inquiry to both science and mathematics as they give teachers access to a variety of examples where other teachers have used inquiry in mathematics education, and which illustrate how to use different aspects of inquiry to foster learning and creativity.

✓ **Importance to dedicating time to science by class teachers**

An issue of time management has been identified in both practice and policy level. It has to be said that the amount of science that is actually done in primary schools in Malta is limited. This is not because official curricular documents do not acknowledge the need to include science in the curriculum, but since there is no formal assessment of science at primary level, it ends up being the first subject, which is neglected when there are time constraints in the school day. In addition, there is little official accountability on teachers to cover the whole curriculum besides through summative assessment. This is particularly so in the case of state schools. The resulting situation is that in State primary schools, science is mainly done only when the science peripatetic teachers are in schools. This means that children at most participate in one science activity once a fortnight. In the case of Church and Independent schools, this depends very much on the school's outlook towards science. The result is that in Church schools there tends to be a science curriculum and textbook, and in some cases a special science teacher is present. However, the science may be traditional in approach and the inquiry approach still needs to be promoted. Independent schools tend to provide greater space for children to have science lessons regularly. However, as in the case of Church schools, this does not necessarily mean that children are engaged regularly in inquiry-based learning. The situation is not the same in the case of mathematics, as this is assessed formally as from the age of 9. Therefore, teachers dedicate more of their class time and energy to the learning of mathematical concepts and strategies. There are thus regular mathematics lessons in the primary schools. As discussed before the exemplary training materials can foster a sense of responsibility in the student and practising teachers. However, this effort needs to be supported by policy that makes the class teacher responsible for providing science education.

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✓ **Science and creativity**

One of the main recommendations for policy relates to promoting creativity through science education. It appears that while the National Curriculum Framework documents have identified creativity and innovation as a cross-curricular theme, this is not discussed in any direct way in the document; Vision for Science Education, and that possibly, should be included in the finalised version of the document. Again, the exemplary teacher training materials are a resource, which can be used to demonstrate how inquiry, and unrestricted investigations and children's agency serve as tools to promote creativity through science.

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6.7 Portugal

Upon our observations and the case studies presented in the Portuguese D4.3 Country Reports – Report 7 of 9: Country Report on in-depth field work in Portugal accessible in the CLS website, we would like to address some key points that may summarize our findings and shed some light on teacher training issues, based on a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis. Bullet point recommendations are drawn at the end of this chapter.

STRENGTHS

- We have found teachers who were highly motivated to participate in this research by providing us the observation of teaching moments without any prior input from us.
- They did not fear to be under observation.
- They dare to face new challenges outside their comfort zone.
- The children were easily engaged in the activities, encouraged to share their thoughts and suggestions, showing confidence, creativity and participated with enthusiasm, feeling at home. This denotes a good relationship between teacher and students, which is fundamental for these actions to have success.

WEAKNESSES

- The sample reported in this document although significant is not representative of the average of our country. The cases were chosen after our previous knowledge that school teachers and students they would be interested in cooperating with this research.
- Generally speaking during their graduation the teacher' training in sciences and mathematics is weak and superficial. Creativity is not, or at most it is only marginally, explored or even mentioned.
- The teachers feel the need to have training in sciences and mathematics in the framework of their mandatory **continuous professional training,** and yet the offering of those kind of trainings is scarce.
- There is a lack of interaction among teachers to share expertise and to reflect on their practices.

OPPORTUNITIES

- The results presented show that teachers and children are easily engaged in sciences and mathematics activities beyond the curriculum, giving them the chance to discover new subjects of interest and through which imagination and creativity are put to work.

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- This research endeavored the cases under study the opportunity to get away from their usual territories with pleasant results.

There is an urgent need to create and to offer training workshops for the early years of education, not only for updating scientific knowledge, but also for different and effective teaching techniques and strategies.

In one of our cases, it can be seen that starting with a simple string it is possible to draw an extraordinary session of science learning with imagination and creativity of the children guiding the process. It is not a matter of money, but will and creativity of both teachers and institutions.

THREATS

- The political, economic and social context of Portugal is a major constraint for the implementation and development of new ways to promote science and mathematics in early years of school.
- The teachers are under an extreme stress and menace, as their binding to the educational system was drastically weakened, which compromises their best wishes to participate in improving the system.
- Increasing academic qualifications is no more rewarding for teachers: they may spend a lot of money and time to make a masters or a PhD, but in the end they are not promoted and their improved knowledge and skills are not an asset to the system, so they feel.
- The fear to interact, to share knowledge and skills, to assess and to be assessed by peers is not a habit in the Portuguese culture.

Upon our observations and the case studies presented in the Portuguese D4.3 Country Reports – Report 7 of 9: Country Report on in-depth field work in Portugal accessible in the CLS website, a final meeting with stakeholders, and from the arguments presented in chapters 3 to 4 in this report, we would like to enhance some key points and to point some recommendations.

In preschool, teachers have more freedom to work with diverse topics and interesting students, depending on their interests. There are many subjects in primary education, because the curriculum is very wide-ranging, and teacher doesn't have the need to comply it. Moreover, it is necessary to prepare students for the final exams at the end of primary education. Teachers in pre-school education are therefore always more open to new experiences and new approaches to exploit with their students.

Greater emphasis on math for results at the national level, and mathematical challenges help students to achieve patience, to reflect, to not give up, helps concentration, and any other areas do this often, almost like a moral lesson that take

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into your life, so there are no relevant differences observed between science and mathematics.

As stated in part 3.1 – Rationale or Vision – of this report, creativity is not mentioned as a purpose in the curriculum of "Environmental Studies" of the 1st cycle of Basic Education or in the curriculum guidelines for pre-school education, although the Basic Law of the Portuguese Education System, in its Article 5, point 1.f, aims at "to develop the child's capacities of expression and communication, as well as their creative imagination [...]".

The theme of creativity is a "relatively recent trend" and very often teachers do not have the necessary tools and training to foster creativity. It is required more and better preparation by teachers as they have to be prepared for students' questions and comments and guide them to reach the intended goals without defraud their expectations.

6.7.1 Initial teacher education

Initial teacher education is carried out in higher education institutions with the Master's degree being the minimum academic qualification for the teaching profession, according to the changes introduced by the Bologna Process.

The teacher training during their graduation should include more and deeper learning in sciences and mathematics. The teachers themselves recognise their poor proficiency in these matters and are willing to access opportunities to improve their scientific knowledge and related didactical and pedagogical skills. The peer interaction and the sharing of knowledge and skills, assess and be assessed by peers is not a habit in Portuguese culture, neither the teacher training suppresses this gap.

6.7.2 Continuous Professional Development (CPD)

Increasing academic qualifications is no more rewarding for teachers: they may spend a lot of money and time to make a masters or a PhD, but in the end they are not promoted and their improved knowledge and skills are not an asset to the system.

There is an urgent need to create and to offer training workshops for the early years of education, not only for updating scientific knowledge, but also for different and effective teaching techniques and strategies. It is recognized by the teachers their lack of initial and further training on sciences and mathematics but not of motivation to undergo CPD on these areas. CPD of teachers should be reinforced in the areas of science and mathematics in early years of education, which lack diversity and extensive territorial range. Namely, at pre-school level, the opportunities for this kind of CPD is scarce and in many regions is absent.

In the Portuguese educational system CPD is mandatory, and yet it is possible a teacher to complete a full teaching career without making any CPD in sciences and

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mathematics. Therefore, it would be very much welcome the obligation for every teacher to make a CPD in these areas from time to time.

6.7.3 Main recommendations:

- ✓ Educational policies should be set to last at least for one generation (ideally for several generations on its main guidelines) with only minor adjustments to be made according to the evolution of the societies.
- ✓ Educational policies should be sound carefully designed and validated as extensively as possible taking into account the most update well established knowledge in science and math education in particular, in this context, at pre-primary and primary school level. Policy makers should refrain to impose their own personal, not widely validated by teachers and researchers in the field, believes seeking the advice of the widest range of recognised specialists, the schools teachers and parents and civil society bodies.
- ✓ Initial teacher training at higher education institutions should be reformulated with major efforts being made on the implementation of active hands-on learning teaching/learning student (future teacher and educator) centred.
- ✓ Increased attention should, on the initial teacher training, be paid and a clear focus be given to the training on scientific and technical knowledge and competencies on science and maths subject in order to guarantee to future teachers and educators a strong scientific literacy in all fields of science that will allow them to address these issues at different levels of complexity at the different pre-school and primary school level.
- ✓ Increased attention should, on the initial teacher training, be paid to the training on creativity and practical learning on strategies of promotion of creativity and on the benefits of its use in the development of the young students. As well IBSE and new trends on early year and primary school educational strategies should be widely and carefully addressed.
- ✓ The three last recommendations should apply also to in-service teacher training. That should be generalised increasing the training offer as well and the training opportunities giving teachers and educator practical condition to pursue this training in an effective (and not just apparent as currently most frequently it happens).
- ✓ Continuous in-service teacher training should be performed or validated by the active intervention of higher education specialists in the field. The contribution as advisors and or trainers of school teachers and educator should be considered of utmost importance.

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- ✓ The recognition of the social importance of the teacher and educators should be clearly and effectively made by policy makers and stakeholders.
- ✓ Peer support is fundamental to the success of the teaching/learning process and pre-primary and primary education.
- ✓ Each teacher/educator should have in her/his classroom the support of a specialist or preferentially another teacher on the first year of her/his professional life.
- ✓ The number of students per classroom and teacher should be limited in order to allow teachers and educators to give the proper individual and special support to each student in the different stages of their intellectual development.
- ✓ The curricula goals and main implementation strategies should be clearly stated but its design and implementation should be flexible and responsibility of the teacher and school.

6.7.4 Concluding remarks

At the present time, the political, economic and social context of Portugal is a major constraint for the implementation and development of new ways to promote science and mathematics in early years of school. The teachers are under an extreme stress and menace, as their binding to the educational system was drastically weakened. The constrictions hitting the teachers such as income reduction, increasing the number of students per class, increase of bureaucratic work, no career progression, constant changes in curricular design (contents, goals, etc.), and others, compromise their best wishes to participate in improving the system.

However, children are easily engaged in activities of science and mathematics. They respond positively to creative approaches and exhibit their own imagination and creativity. They share their thoughts and suggestions, showing confidence, participating with enthusiasm, and feeling at home if there is a good relationship between teacher and students.

To promote creativity and imagination in early years of school, preserving the freshness and intellectual curiosity of children and fostering higher levels of performance in later years is not only a matter of money, but will and creativity of both teachers and institutions, as long as educational political makers fully accomplish their mission.

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6.8 UK

6.8.1 Approaches to Teacher Education

Findings from the UK based work suggest implications for work in initial teacher education and continuing professional development. In particular, vignettes from the case studies could play a very useful role in supporting such development work with both teacher training groups, and in enhancing professional recognition of young children's capabilities in the early years.

✓ **Professional conceptions of inquiry, problem solving and creativity in mathematics and science**

It is clear it would benefit professionals to examine the aims of science and mathematics education, with a particular focus on the roles and nature of inquiry, problem solving and creativity in these areas and why they matter. It is suggested that the use of examples from the study could help teachers observe classroom practice in order to identify and discuss evidence of creativity in learning and teaching. In turn, this could support the explicit planning for IBSE and creativity that was rarely seen in schools.

✓ **Whole school approaches.**

It is recommended that consideration is given to whole school curriculum planning for creative teaching and learning and inquiry based approaches in mathematics and science and to whole school planning and infrastructures that maximise opportunities for such learning in the school grounds and wider environment. Additionally, approaches to timetabling and planning need to be reviewed in order to ensure there is time for extended inquiries that build on children's ideas and questions. Student teachers, practitioners and schools also need to be more aware of organisations and networks within the science/mathematics/creativity communities that might provide support.

Pedagogical Framing

✓ **The roles of materials.**

Resources were seen to be critical to fostering creativity in early mathematics and science. Teachers and student teachers need to be supported to recognise the potential in everyday materials and the importance of observing children's use of resources to gain insights into their developing explorations and thinking. Additionally, they need to examine the ways in which the organisation and nature of resources can both constrain and extend children's explorations and inquiries. The examples from the study could inform a more explicit approach to the provision and planning of resources including information and communications technology.

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✓ **Grouping practices.**

Varied forms of grouping were seen for different purposes. It is recommended that teachers and student teachers are enabled to explore the ways in which tasks can be designed with appropriate resources to support collaboration and how they can help children to collaborate effectively, encouraging them to articulate their ideas and exchange and evaluate these.

✓ **Planning.**

Professionals planned for extended engagement and progression over time, this included building seriously on children's ideas and interests. It is suggested that consideration is given to time for immersion, play and exploration as the critical context and of motivating starting points and child initiation of inquiry. Additionally attention needs to be paid to being flexible with the timetable to allow extended inquiry and follow through and being flexible with the available space and resources to nurture creativity and help children make connections across experiences and links to everyday life. Recognising the role of motivation and affect is also recommended.

Pedagogical Interactions

✓ **Teacher scaffolding.**

Teachers showed varied awareness of their roles in scaffolding children's curiosity and creativity. It is recommended that teachers and student teachers are enabled to consider ways in which they can scaffold learning in mathematics and science that support the development of creativity. They need to appreciate the value of establishing open-ended learning activities and to recognise the moment to intervene with appropriate questioning to support inquiry, and when to stand back in order to observe, listen and build from the children's interests.

✓ **Designing learning activities.**

Widespread opportunities for observing, communicating and making connections, associated with the generation of ideas were noted, but less attention was given to children's own questions, planning of investigations or the evaluation of evidence. It is thus suggested that teachers and student-teachers are supported to consider the different purposes of inquiry and the ways in which everyday learning activities can be opened up to allow greater opportunities for inquiry, problem solving and creativity. Additionally, children's roles, questioning, planning and evaluating evidence in inquiry and the connections between these deserve attention, as do the connections between the development of understanding of concepts and procedures in science and mathematics and the processes of inquiry.

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✓ **Teacher questioning.**

The importance of teacher questioning in scaffolding children's inquiries, was recognised across all four stages of the work, in particular in relation to eliciting and fostering reflection and reasoning –which the fieldwork found was rarely unprompted. It is important not to underestimate this role. The fieldwork also highlighted the complexity of when to intervene with questions and which might be the most productive in fostering children's independence and extending thinking. Thus teachers and student teachers need to be enabled to consider different forms of questioning and their productivity in different contexts, as well as ways of encouraging children's questions, particularly their scientific and mathematical questions which have the potential to be generative and/or evaluative and thus support their creativity. In addition they need to examine strategies for building on children's questions and the significance of providing time for children to formulate their responses.

✓ **The use of ICT.**

This was rarely employed except on the part of the teachers and thus comprises an area for development for teachers and student teachers. This could include the roles of ICT in enhancing observations, making measurements, collecting data; recording, presenting and analysing data; modelling ideas; searching for information; controlling models; and communicating findings in a variety of ways. Management issues and those relating to support of ICT in classrooms may also need to be conjointly considered.

✓ **Forms of representation and expression.**

The practice of children being enabled to represent and express their ideas in their own ways was not widespread, these lessened opportunities for exploration, reflection and dialogue about learning, yet where teachers left open how ideas might be recorded this helped to free children's imaginative responses. It is suggested that teachers and student teachers are enabled to consider the purposes of recording, selecting approaches appropriate for purpose and different ways of representing and expressing ideas, as well as recording as a process, to support thinking, reflection and dialogue.

✓ **Assessment for learning**

Assessment has emerged as a key area for development throughout the project. It is clear there is a vitally important role for teachers with regard to listening, observing patterns in action and in identifying children's questions, as the direction of the children's inquiries were often implicit and needed close attention to be noted. It is therefore highly recommended that teachers and student teachers are enabled to

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examine different assessment strategies and forms of evidence in early science and mathematics and are helped to use assessment information to inform planning and teaching. In addition they need help to integrate peer and self-assessment into teaching and learning processes and understand the role of children's profiles and class floor books in encouraging revisiting and reflection on learning.

✓ **Classroom research as a tool to develop practice**

Teachers involved in this study valued the opportunity to reflect on and examine their own practices. This has implications for teachers and teacher education with regard to integrating professional enquiry as a mode of learning.

6.8.2 Implications for Policy Development

The case study findings have implications for policy across the United Kingdom, policy that would help enable teachers to foster creativity in early science and mathematics. The key policy implications are outlined below.

✓ **CPD entitlement**

There is a need for CPD that addresses the fostering of creativity in early science and mathematics. This would need to develop: teachers' recognition of the value of developing creativity in and through mathematics and science and the mutual benefits afforded; teachers' capacities to recognise opportunities for promoting creativity through science and mathematics, by considering the curriculum potential, and teachers' sensitivity to expressions of creative engagement by children in these aspects of learning, so as to recognise, engage with and extend these.

✓ **Training for science and mathematics co-ordinators**

Science and mathematics coordinators need specialist training and support for the development of school level policy and practice if they are to play key roles in the development of whole-school approaches in this area. School wide approaches can help to ensure greater consistency and progression in children's experiences. They can provide a framework for professional reflection on provision that seeks to develop children's creativity in early science and mathematics, building on this over time.

✓ **Potential of projects and initiatives to raise the profile of science**

The potential of recent national initiatives and award schemes to support schools in raising the profile of science and mathematics in the curriculum was demonstrated. The value of such initiatives and projects related to science and mathematics could be more widely recognised in policy. Wider dissemination and sharing of examples such as working towards awards (e.g. Gold Quality Mark, Eco School Status or using

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the Healthy Schools toolkit) would help generate enthusiasm and encourage other schools seeking to enhance learning and teaching in science and mathematics.

✓ **Policy coherence**

There is a need for increased coherence across policy and associated guidelines related to curriculum, pedagogy and assessment. While the importance of inquiry and creativity is often recognised in the rationale and aims of the curriculum, these dimensions are reflected to varying degrees in curriculum or assessment requirements or in guidance in relation to pedagogy.

✓ **Curriculum space and time**

Early primary teachers found it more challenging (due to a crowded curriculum and performative pressures), than their early years counterparts to find the time and space for children to pose and respond to their own questions, and to investigate and generate creative responses. Policy frameworks for science and mathematics need to allow sufficient flexibility in space and time by ensuring the curriculum itself is not overcrowded, and that the breadth of inherent possibility in any aspect of the curriculum is not so narrow as to stifle creative engagement by children.

✓ **Valuing formative assessment**

Whilst children's engagement in peer and self-assessment offered opportunities for considering alternative ideas, and varied approaches to representation and expression allowed children and teachers to reflect on learning, on the whole formative assessment was often implicit in practice, rather than employed in strategic ways to support and evaluate learning and teaching. Assessment was also an area in which a number of teachers indicated they were less confident. There is thus need for greater recognition of the importance of formative assessment in policy and the development of associated guidance for teachers.

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7. REFERENCES

Craft, A. (2001). Little c Creativity. In Craft, A., Jeffrey, B. and Leibling, M. *Creativity in Education*. London: Continuum. pp 45 – 61.

OECD (2011). School Evaluation in the Flemish Community of Belgium 2011, OECD Reviews of Evaluation and Assessment in Education, OECD Publishing. Available at: <http://dx.doi.org/10.1787/9789264116726-en> [Accessed 2 July 2013]

Siraj-Blatchford I., Sylva, K., Muttock, S., Gilden, R. and Bell, D. (2002). *Researching Effective Pedagogy in the Early Years*. Department of Education and Skills Research Report RR 356. Norwich: DfES. p. 24.

van den Akker, J. (2007). Curriculum Design Research. In Plomp, N. and Nieven N. (Eds.) *An Introduction to Educational Design Research.* SLO Netherland Institute for Curriculum Development. pp. 37 – 53.

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