'Creative Little Scientists' project: Mapping and comparative assessment of early years science education policy and practice

Fani Stylianidou, fani@ea.gr, Ellinogermaniki Agogi, Dim. Panagea Str., GR-153 51 Pallini, Greece

Esme Glauert, e.glauert@ioe.ac.uk, UCL Institute of Education, 20 Bedford Way, London WC1H 0AL, UK

Dimitris Rossis, drossis@ea.gr, Ellinogermaniki Agogi, Dim. Panagea Str., GR-153 51 Pallini, Greece

Sari Havu-Nuutinen, sari.havu-nuutinen@uef.fi, University of Eastern Finland, School of Applied Education Science and Teacher Education, Tulliportinkatu 1, 80100 Joensuu, Finland

Abstract

Creative Little Scientists was a 30-month (2011-2014) EU/FP7-funded research project focusing on the synergies between early years science and mathematics education and the development of children's creativity, in response to increasing interest in these areas in European educational policy. Using a variety of methods, including desk research, a teacher survey and classroom-based fieldwork, the research provided insights into whether and how children's creativity is fostered and appropriate learning outcomes, including children's interest, emerge. Based on these the project proposed changes in policy and teacher education encompassing curriculum, pedagogy and assessment.

This paper focuses on results from the first research phase, where existing policies and reported practices in early years science and mathematics education in the sample countries were mapped and compared, by means of a) desk research examining national policies, curricula and assessments; and b) a survey aiming to gain insights into teachers' conceptualizations of their own practice. Findings across the varied contexts in partner countries, indicate potential for inquiry and creativity, but also suggest a number of areas for policy development and attention in early years teacher education,

Keywords: early years, science education, creativity, comparative study, policy

1. Introduction

Creative Little Scientists was a 30-month (2011-2014) EU funded comparative study working across nine participating countries: Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania and the UK. The *Creative Little Scientists* project sought to build a picture of policy and practice in science and mathematics education for children aged 3-8 and their potential to foster creativity and inquiry learning and teaching.

The project aimed to add to previous EU reports in science and mathematics education in its focus on the nature of science and mathematics education in the *early years* and in seeking to characterise and investigate opportunities for *creativity in learning and teaching within the specific contexts of science and mathematic*s. A significant strand of the project was also the development of guidelines for policy and teacher education building on findings from the different phases of the study and ongoing collaboration and dialogue with participants and other stakeholders. The study aimed to mainstream good practices by proposing changes in teacher education and classrooms encompassing curriculum, pedagogy and assessment.

2. Background, Objectives and Framework

2.1 Core drivers for *Creative Little Scientists*

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

- *The role of an economic imperative within education*, demanding capable scientists and creative thinkers in an increasingly knowledge-based globalised economy (European

Commission 2011), requiring capabilities such as reasoning skills, innovative thinking and positive attitudes.

- *The role played by science, mathematics and creativity in the development of children and of citizens*, demanding early understanding and interaction with phenomena in nature and technology, which empower students (and therefore future adults) to take part in societal discussions and decision-making processes (Gago et al. 2004; Harlen 2008).
- *The role of early years education in building on children's early experiences and in promoting positive skills and dispositions* (Sylva 2009), informed by increased awareness of the child as an active and competent meaning-maker, who can take ownership of their own learning and take part in decision making in matters that affect their lives in the present (Goswami 2015).
- *The role of a digital or technological imperative within education*, enabling but also demanding the development of children's capabilities in science, mathematics and creativity (Wang et al. 2010).

2.2 Objectives for Creative Little Scientists

In the light of the above, the *Creative Little Scientists* project set the following objectives:

- **To define a clear and detailed Conceptual Framework** comprising the issues at stake and the parameters needed to be addressed in all stages of the research.
- **To map and comparatively assess existing approaches** to science and mathematics education in pre-school and first years of primary school (up to the pupil age of eight) in the nine partner countries, highlighting instances of, or recording the absence of, practices marrying science and mathematics learning, teaching and assessment with creativity.
- **To provide a deeper analysis of the implications of the mapped and compared approaches,** which would reveal the details of current practice and provide insights into whether and how children's creativity is fostered and the emergence of appropriate learning outcomes in science and mathematics is achieved.
- **To propose a set of curriculum design principles as concrete guidelines for European initial teacher training and continuous professional development programmes**, which would foster creativity-based approaches to science and mathematics learning in preschool and the first years of primary education. The proposed principles would be accompanied by **illustrative teacher training materials** aiming to clarify their applicability in complex and varied European educational contexts, thus facilitating implementation, evaluation and further development across Europe.
- **To exploit the results of the research at the European level as well as at national and institutional level**, making them easily available to educational policy makers and other stakeholders, through the synthesis of all research outputs and their transformation into a 'Final Report on Creativity and Science and Mathematics Education for Young Children' (CREATIVE LITTLE SCIENTISTS 2014a) and also a 'Set of Recommendations to Policy Makers and Stakeholders' (CREATIVE LITTLE SCIENTISTS 2014b).

2.3 Conceptual framework for *Creative Little Scientists*

The first of these objectives was achieved through extensive reviews of policy-related and research-based literature at the beginning of the project covering areas as diverse as science and mathematics education with a focus on pre-school and first years of primary school, creativity in education, creativity as a lifelong skill, teaching and teacher training approaches, as well as cognitive psychology and comparative education. The resulting Conceptual Framework (CREATIVE LITTLE SCIENTISTS 2012) 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.

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) -*"Purposive, imaginative activity generating outcomes that are original and valuable in relation to the learner"* - insofar as this effort toward originality and value through imaginative activity drives creativity in other domains including early science and mathematics.

The Conceptual Framework for *Creative Little Scientists* also explored synergies and differences between inquiry-based (IBSE) and creative approaches (CA) to science and mathematics. Although definitions of IBSE vary, there is considerable agreement internationally, reflected in both policy and research, about the value of inquiry-based approaches to science education (Minner et al. 2010). CA, on the other hand, does not refer to a recognised set of approaches to education and learning, but nonetheless such approaches have gained considerable attention in research and policy contexts in recent years (Chappell et al. 2008). Both sets of approaches are pedagogically associated with a range of child-centred philosophies from European and North American thinkers, which situate the child as an active and curious thinker and meaning maker and highlight the role of experiential learning. Common synergies are:

- **Play and exploration**, recognising that playful experimentation/exploration is inherent in all young children's activity, such exploration is at the core of IBSE and CA in the Early Years (see e.g. Goswami 2015; Cremin et al. 2006; Poddiakov 2011).
- **Motivation and affect**, highlighting the role of aesthetic engagement in promoting children's affective and emotional responses to science and mathematics activities (see e.g. Craft et al. 2012b; Koballa and Glynn 2008).
- **Dialogue and collaboration**, accepting that dialogic engagement is inherent in everyday creativity in the classroom, plays a crucial role in learning in science and mathematics and is a critical feature of IBSE and CA, enabling children to externalise, share and develop their thinking (see e.g. John-Steiner 2000; Mercer and Littleton 2007).
- **Problem solving and agency**, recognising that through scaffolding the learning environment children can be provided with shared, meaningful, physical experiences and opportunities to develop their creativity as well as their own questions and ideas about scientifically relevant concepts (see e.g. Cindy et al. 2007; Craft et al. 2012a).
- **Questioning and curiosity**, which is central to IBSE and CA, recognising across the three domains of science, mathematics and creativity that creative teachers often employ open ended questions, and promote speculation by modelling their own curiosity (see e.g. Chappell et al. 2008).
- **Reflection and reasoning**, emphasising the importance of metacognitive processes, reflective awareness and deliberate control of cognitive activities, which may be still developing in young children but which are incorporated into Early Years practice, scientific and mathematical learning and IBSE (see e.g. Kuhn 1989; Bancroft et al. 2008).
- **Teacher scaffolding and involvement**, which emphasises the importance of teachers mediating the learning to meet the children's needs, rather than feel pressured to meet a given curriculum (see e.g. Rittle-Johnson and Koedinger 2005; Bonawitz et al. 2011).
- **Assessment for learning**, emphasising the importance of formative assessment in identifying and building on the skills attitudes, knowledge and understandings children bring to school; supporting and encouraging children's active engagement in learning and

fostering their awareness of their own thinking and progress (see e.g. Harrison and Howard 2011; Feldhusen and Ban 1995).

3. Research approach and design

3.1 Research questions and approach for Creative Little Scientists

The project's *Conceptual Framework* also developed the methodological framing of the study and identified the following research foci:

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 and Continuing Professional Development)?

These questions were examined in relation to three broad strands: *Aims, purposes and priorities*; *Teaching, learning and assessment*; and *Contextual factors*, broken down into more narrowly-defined dimensions drawing on the framework of curriculum components 'the vulnerable spider web' (van den Akker, 2007), comprising key aspects of learning in schools: Rationale or Vision; Aims and Objectives; Learning Activities; Pedagogy (or Teacher Role); Assessment; Materials and Resources; Location; Grouping; Time; Content. These were complemented by dimensions focusing on teachers' backgrounds, attitudes and education.

Within these dimensions a List of Factors was identified, drawing on the Conceptual Framework, and encompassing key features and processes that had been found to be associated with creativity in early science and mathematics (see Appendix 1). The curriculum dimensions and associated List of Factors provided an essential common framework across the different phases of research for capturing an in-depth empirical picture of conceptualisations, practices and outcomes related to opportunities for creativity in early science and mathematics across partner countries.

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, alongside qualitative approaches employed in the case studies of classroom practice and iterative processes associated with curriculum design research. It was 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 reported in separate National Reports. These were then synthesized to form overall *Creative Little Scientists* project reports, available on the project's website (www.creative-little-scientists.eu).

3.2 Comparative assessment of conceptualisations by teachers and in policy

This paper is concerned with presenting findings from the first stage of the research, focused on the comparative assessment of how early years science and mathematics is conceptualised by teachers and in policy in the nine partner countries, highlighting instances of, or recording the absence of, practices marrying science and mathematics learning, teaching and assessment with creativity. It thus addresses parts of RQ1 and RQ4 above. The research used the methodology of comparative education employing the same methods of data collection and analysis in making comparisons, drawing on data collected via two routes:

1. **A desk survey of policy** to examine how teaching, learning and assessment of science and mathematics in the early years are conceptualised in 134 national policy documents, including curricula, reports and assessments of school practice.
2. A **teacher survey,** which gathered data through a teacher questionnaire addressed to a sample of 815 teachers from 605 schools (238 preschools and 367 primary schools) across all partner countries, aimed towards gaining insights into practicing teachers' conceptualisations of science, mathematics and creativity in early years education.

The planning of the two pieces of research commenced at the same time to achieve maximum coherence between the studies. In addition, as research instrument, they both used a similar 4-point Likert Scale questionnaire based on the curriculum components of Van den Akker (2007) and on the creativity and inquiry approaches identified in the List of Factors. In the case of the **policy** survey, the questionnaire aimed to assess the extent to which these approaches were emphasised in policy documents and how far the role of creativity was emphasised. In the case of the **teacher** survey, it aimed to assess the extent to and frequency with which teachers use these approaches in their classrooms. Aligning the two surveys facilitated subsequent comparison of their results.

3.3 Phases of data analysis

In the **first phase**, partners carried out separate analyses of their country's policy and teacher data to produce National Reports discussing the findings and situating them within their country's educational context.

Data gathered across partner countries for each survey were then amalgamated, grouping questionnaire items according to the dimensions and approaches identified by the List of Factors and analysed as a whole, using descriptive statistics. For example, frequency tables presented teachers' responses to questionnaire items as percentages, means and standard deviations. Preschool and primary school data were considered separately. This produced an overview of the current situation across the nine partner countries. Comparisons were made between findings at the partner country level, as follows:

a. For the comparative analysis of **policy conceptualisations**, National Reports were drawn upon to identify similarities and differences in approaches amongst national polices. Comparisons of ratings for each questionnaire item indicated similarities and differences, and justifications for the ratings and related commentary provided by the partners gave further insights into such similarities and differences.

b. For the comparative analysis of **teachers' conceptualisations** statistical comparisons were performed using SPSS and Microsoft Excel software to identify similarities and differences between teachers' responses across partner countries, in relation to the dimensions and approaches identified by the List of Factors; information provided in the National Reports was used to interpret these similarities and differences.

In the **second phase**, the **policy** survey findings were compared with the relevant findings from the **teacher** survey with a view to revealing any similarities and differences between policy and teachers' conceptualisations of teaching, learning and assessment in early years science and mathematics education, and the role of creativity in these. Again, this comparison took place according to the pre-identified factors and dimensions, at two levels:

a. At a partner country level, using data from the National policy and teacher surveys.

b. At a European level, drawing on the overall findings from the policy and teacher surveys.

At the partner country level comparative tables were created for each item in the survey, presenting the data from both surveys by country and school phase (preschool and school). These permitted a quick identification of the core similarities and differences in policies and practices within and between countries. Where these similarities and differences appeared more significant radar charts were created to show policy and teacher ratings (means) for the respective item, by school phase across countries. These charts allowed both a visual and a more in-depth comparison of national findings.

The synthesis of comparisons, focused on the List of Factors and dimensions targeted in the project, brought out issues and tensions in science and mathematics early years education, most relevant to the role of inquiry-based approaches and the potential for creativity.

3.4 Methodological issues and challenges

From the outset language was a key challenge, common in comparative policy studies across countries. Terms, such as 'inquiry' or 'creativity' did not translate easily between countries. It was also important to recognise that even if terms appear comparable, they may differ in the meaning attributed. Therefore, making comparisons by measuring the use, or absence, of particular terms is problematic. Furthermore, educational policy or practice in a country may embody much of what is signified by a word without using this word explicitly. This is highly relevant for examining the term 'creativity', where its role may not be reflected by explicit use of the term. It was therefore important to give attention to *implicit* as well as *explicit* references to creativity drawing on definitions from the Conceptual Framework.

In relation to the **policy survey** another issue was to identify what was meant by national policies. It was important first to clarify the different jurisdictions across the partnership. Then given the wide range of policy documentation and varied degrees of regulation, partners needed to make judgments about the documents that best captured curriculum, assessment and pedagogy in early science and mathematics. This could include for example generic or phase specific policies alongside subject specific documentation. Policy in a number of countries was in transition and it was necessary to review previous or future policy documents that would be in operation during fieldwork. Coding and rating the documents according to the survey tool based on the List of Factors was also not straightforward, particularly in relation to rating the emphasis on creativity. Here the Conceptual Framework and dialogue between partners provided vital support. Partners were asked to provide policy references and comments to support their ratings.

In relation to the **teacher survey**, motivating teachers to participate proved difficult in some partner countries. Partners indicated a number of factors that might have contributed to this, including the timing of the survey in the school term, attitudes to research participation, pressures on teachers in particular policy contexts and the extent of partners' networks and previous contacts with schools.

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

This section provides an overview of key themes emerging from the comparison of research findings from the policy and teacher surveys at the European level, presented under the main strands and curriculum dimensions of the project. Specific results on which this overview is based are included, only on an exemplary basis, given limitations of space.

4.1 Aims, purpose, priorities

4.1.1 Rationale for Early Years science and mathematics

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

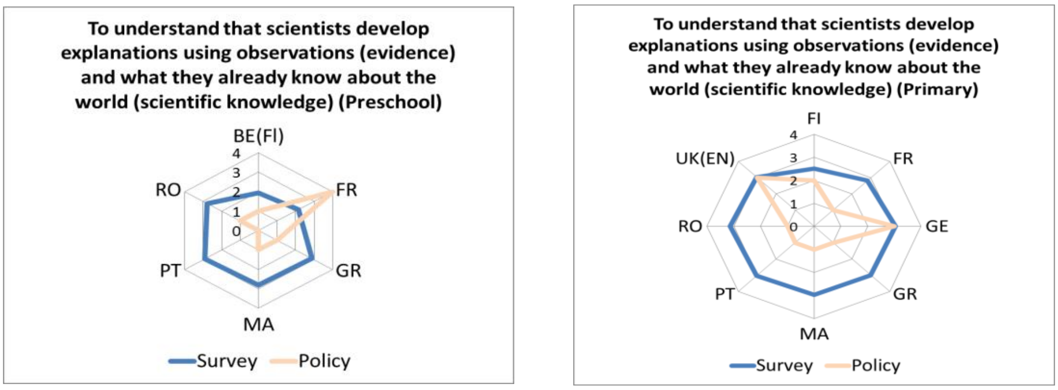
The results of the **teacher survey** showed that teachers across all partner countries largely agreed with the two main emphases in the policy rationale provided for early years science education. In addition, the view of science learning as an economic imperative was reflected in very few **policy** documents and this view was mirrored in the **teacher** survey.

4.1.2 Curriculum Aims and Content

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

In comparison, **teachers** reported pursuing most often *affective* and social dimensions of learning. More limited attention was afforded to cognitive outcomes especially by preschool teachers. In relation to aims related to inquiry-based science learning teachers fostered quite or very frequently the development of children's capabilities to carry out scientific inquiry, such as to ask questions, gather and communicate findings, but to a lesser degree, children's abilities to plan and conduct simple investigations. Learning aims related to understandings *about* scientific inquiry, were the least frequently pursued by teachers, though still quite high compared to the limited emphasis put on understandings related to the nature of science in policy (Fig. 4.1).

Fig. 4.1 Learning aims related to understandings about the nature of science: Results from policy review and teachers responses (means), per partner country



Policy: 0*: Not rated* ***1****: Not mentioned* ***2****: Single mention* ***3****: Various mentions* ***4****: Emphasised*
Survey: 1: *Never* ***2:*** *Rarely* ***3:*** *Quite often* ***4:*** *Very often*

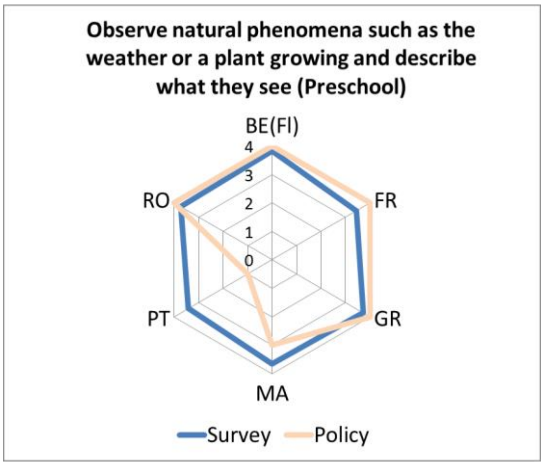
4.2 Approaches to teaching, learning and assessment

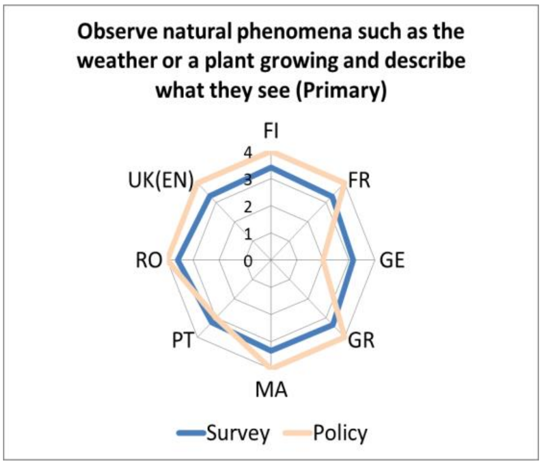
4.2.1 Learning Activities

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

Partners' commentaries in their National Reports for the **teacher survey** pointed to a common emphasis on hands-on approaches and activities *linked to children's everyday lives*. The learning activities reported as used most commonly by teachers were predominantly linked to *eliciting children's curiosity* in natural phenomena and allowing them opportunities *to gather evidence* and *ask questions*. The National Reports from the **policy survey**, in common with the teacher survey results, indicated an emphasis on hands-on approaches and activities linked to children's everyday lives. Observation and communication featured strongly in learning activities recommended for both phases in almost all partner countries (see Fig. 4.2). Questioning was also commonly mentioned in some countries, more particularly by teachers in relation to preschool.

Fig. 4.2 Promoting observation in learning activities: Results from policy review and teachers responses (means), per partner country





Policy: 0*: Not rated* ***1****: Not mentioned* ***2****: Single mention* ***3****: Various mentions* ***4****: Emphasised*
Survey: 1: *Never* ***2:*** *Rarely* ***3:*** *Quite often* ***4:*** *Very often*

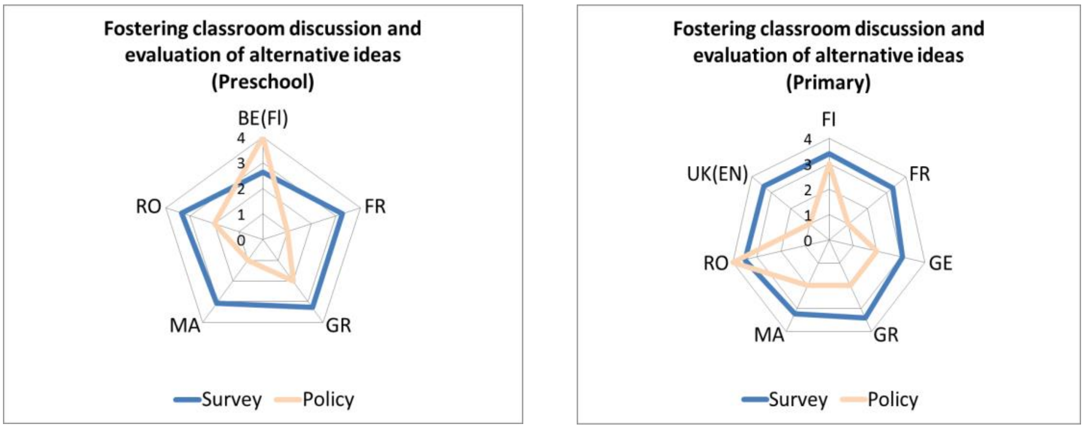
In the majority of countries, conducting investigations or projects and using simple equipment were also included in guidance provided. There was more variation in relation to planning investigations and using data to construct reasonable explanations. These activities featured more strongly in early primary school policy.

4.2.2 Pedagogy

As mentioned above, there was a common emphasis in **policy** across partner countries on hands-on approaches and activities linked to children's everyday lives. In preschool in particular providing a broad range of experience and making links across the curriculum was widely recommended. There was a considerable focus on *play* and *fostering autonomous learning*. *Encouraging problem solving* and *children trying out their own ideas* in investigations were advocated in the majority of countries. Approaches given the least attention included the *use of drama, stories, history, field trips and everyday experiences* as contexts for learning. Moreover, in the aspects of inquiry discussed, most limited reference was given to *connecting explanations to scientific knowledge* and *reflection on inquiry processes and learning*. It is notable that in most countries limited references were made to the role of *imagination* or the *discussion of alternative ideas* in policy (see Fig. 4.3) – also linked with creative approaches to learning and teaching. Some differences were evident between phases of early years education. In preschool, *play* was strongly emphasised and greater attention was given to *questioning* and *fostering autonomous learning*. In primary school greater importance was afforded to *investigation* and *problem solving*.

The results from the **teacher survey** suggested a consensus amongst teachers that the teaching of science should *build on children's prior experiences* and help *relate science to everyday life*. Teachers consistently and uniformly across the partner countries reported appreciation for all pedagogical contexts and approaches that promote *dialogue and collaboration* in science amongst children, but did not recognise the potential of these approaches for developing creativity. Furthermore, *using drama or history* to teach science, or *fostering children's autonomy* in learning were not practices very commonly used by teachers across the partner countries, nor were they considered very 'creativity enabling' by them. It should therefore be noted that although uniformly teachers strongly endorsed *affective* learning outcomes in their teaching of science, the way they perceived the contexts and approaches identified in the research literature as enhancing motivation and affect in children, such as using drama or field trips, varied. The *physical exploration of materials* was frequently promoted by the large majority of all teachers and considered as a creative practice. Finally, all *problem solving* science contexts and approaches were thought of as amongst the most 'creativity enabling' by a large number of teachers, who also reported using them quite or very frequently.

Fig. 4.3 Fostering classroom discussion and evaluation of alternative ideas: Results from policy review and teachers responses (means), per partner country



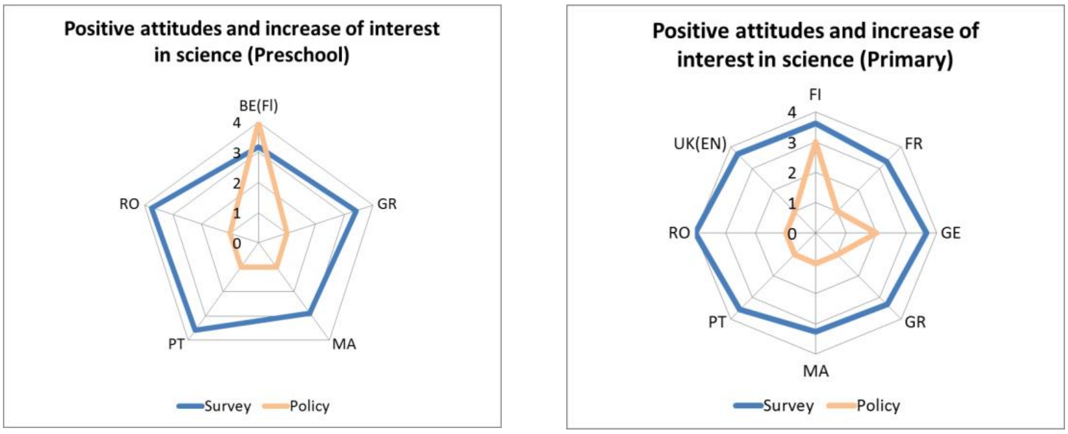
Policy: 0*: Not rated* ***1****: Not mentioned* ***2****: Single mention* ***3****: Various mentions* ***4****: Emphasised*
Survey: 1: *Never* ***2:*** *Rarely* ***3:*** *Quite often* ***4:*** *Very often*

4.2.3 Assessment

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

According to the **teacher survey**, teachers prioritised the *affective* dimensions of learning in science assessment in agreement with their declared rationale, vision, aims and objectives for science education (see Fig. 4.4). In contrast with policy however, they did not consider the assessment of scientific ideas and processes, or scientific inquiry in early years science education as important.

Fig. 4.4 Assessment of positive attitudes to science: Results from policy review and teachers responses (means), per partner country



***Policy: 0**: Not rated **1**: Not mentioned **2**: Single mention **3**: Various mentions **4**: Emphasised*
***Survey: 1:** Never **2:** Rarely **3:** Quite often **4:** Very often*

4.3 Physical and social environment

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

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

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

5. Discussion

5.1 Implications for policy development

5.1.1 Aims and content of the curriculum

The findings suggest that the aims and content of curricula for early years science and mathematics could pay more explicit attention to social and affective dimensions of learning, both also inextricably connected with cognitive dimensions. Greater recognition could also be given to young children's capabilities to engage with processes associated with the evaluation as well as generation of ideas in science and mathematics, and with understandings related to the nature of science.

5.1.2 Approaches to learning and teaching

Policy implications for learning and teaching approaches in early science and mathematics were interlinked with recommendations concerning the aims and content of curricula. Approaches involving play, practical exploration and investigation featured strongly in policy across most partner countries. However, reflecting the need for attention to affective dimensions in the aims and content of curricula, policy guidance and exemplification could pay greater attention to the provision of varied contexts for science learning shown to promote children's motivation, interest and enjoyment in science and mathematics, such as drama, stories, history projects, field trips and children's everyday experiences.

Moreover, in seeking to foster opportunities for inquiry and a role for creativity, greater recognition could be given in policy to the roles of imagination, reflection and consideration of alternative ideas in supporting children's understanding of scientific ideas and procedures. Consideration of alternative ideas is also connected to social factors in learning and opportunities for development of understandings associated with the nature of science. As highlighted above, both these important dimensions of learning deserve greater attention.

5.1.3 Assessment

The findings highlight the need for a closer match between the aims and rationale for science education and assessment priorities and approaches. For example while assessment of science ideas was widely prioritised in policy, more limited attention was given to assessment of inquiry processes and even less to social and affective dimensions of learning, although these dimensions were often highlighted in the rationale and aims set out for early science and mathematics education.

While the importance of formative assessment was increasingly recognised in policy, the results indicate that further guidance would be valuable to support classroom practices in assessment. Areas highlighted in particular include: examples 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.

5.1.4 Role of creativity

Findings 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 were made to creativity in policy they were 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 were often signalled as associated with creativity, such as problem solving and the use of digital technologies, there was often limited indication of how such approaches might be used to foster creativity or inquiry in early science and mathematics.

5.2 Implications for teacher professional development and future research

Findings overall, suggest a number of areas for attention in teacher education to support inquiry and creativity in early years science and mathematics education. They include:

- Perspectives on the nature of science and mathematics and the purposes of science and mathematics education in the early years.
- The explicit characteristics and roles of creativity in learning and teaching in early science and mathematics.
- Importance of both cognitive and affective learning outcomes in preschool science and mathematics education.
- The use of drama, stories, history and field trips as motivating contexts for learning.
- Fostering children's autonomy in learning.
- Importance of evaluation of alternative ideas in science and mathematics learning as well as of their generation.

- 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.

Some of these areas also suggest additional implications for future research, since they are related to factors that were not strongly represented in the data such as:

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

Acknowledgments

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement no 289081.

We would also like to mention and thank the following researchers and their teams, who contributed directly to the reported part of the research and were not co-authors of this paper: Prof. Teresa Cremin, Prof. Anna Craft, Dr. Jim Clack, Dr. Andrew Manches, Dr. Ashley Compton, Alison Riley, Dr. Hilde Van Houte, Prof. Annette Scheersoi, Prof. Manuel Filipe Costa, Prof. Paulo Varela, Dr. Dan Sporea, Dr. Adelina Sporea, Dr. Olga Megalakaki, Prof. Suzanne Gatt.

References

Bancroft, S., Fawcett, M. & Hay, P. (2008). *Researching children researching the world*. London: Trentham Books.

Bonawitz, E., Shafto, P., Gweon, H., Goodman, N. D., Spelke, E. & Schulz, L. (2011). The double-edged sword of pedagogy: Instruction limits spontaneous exploration and discovery. *Cognition*, *120*(3), 322–330.

Chappell, K., Craft, A., Burnard, P., & Cremin, T. (2008). Question-posing and Question-responding: the heart of 'Possibility Thinking' in the Early Years. *Early Years*, *28*(3), 267-286.

Cindy, E., Duncan, R. G. & Clark, A. C. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller and Clark 2006. *Educational Psychologist*, *42*(2), 99-107.

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

Craft, A., Cremin, T., Burnard, P., Dragovic, T., & Chappell, K. (2012a). Possibility thinking: culminative studies of an evidence-based concept driving creativity? *Education 3-13: International Journal of Primary, Elementary and Early Years Education*, *40*, 1-19. doi:10.1080/03004279.2012.656671

Craft, A., McConnon, L. & Matthews, A. (2012b). Creativity and child-initiated play: fostering possibility thinking in four-year-olds. *Thinking Skills and Creativity*, *7*(1), 48-61.

CREATIVE LITTLE SCIENTISTS (2012) *Conceptual Framework.* D2.2. Lead Authors: A. Craft, T. Cremin, J. Clack, A. Compton, J. Johnston, A. Riley. http://www.creative-little-scientists.eu/content/deliverables. Accessed 29 December 2014.

CREATIVE LITTLE SCIENTISTS (2014a) *Final Report on Creativity and Science and Mathematics Education for Young Children*. D6.5. Lead Authors: F. Stylianidou & D. Rossis. http://www.creative-little-scientists.eu/content/deliverables. Accessed 29 December 2014.

CREATIVE LITTLE SCIENTISTS (2014b) *Set of Recommendations to Policy Makers and Stakeholders*. D6.6. Lead Authors: D. Rossis & F. Stylianidou. http://www.creative-little-scientists.eu/content/deliverables. Accessed 29 December 2014.

Cremin, T., Burnard, P. & Craft, A. (2006). Pedagogy and possibility thinking in the Early Years. *Journal of Thinking Skills and Creativity*, *1*(2), 108-119.

European Commission (2011). *Science education in Europe: National policies practices and research.* Brussels: Education, Audiovisual and Culture Executive Agency EACEAE9 Eurydice.

Feldhusen, J. F. & Ban, G. E. (1995). Assessing and accessing creativity: An integrative review of theory, research and development. *Creativity Research Journal, 8*(3), 231-247.

Gago, J. M., Ziman, J., Caro, P., Constantinou, C., Davies, G., Parchmann, I., et al. (2004). *Increasing human resources for science and technology in Europe*. Report. Luxembourg: Office for Official Publications of the European Communities.

Goswami, U. (2015). *Children's Cognitive Development and Learning*. York: Cambridge Primary Review Trust.

Harlen, W. (2008). *Science as a key component of the primary curriculum: a rationale with policy implications*. Wellcome: Perspectives on Education: Primary Science 1.

Harrison, C. & Howard, S. (2011). Issues in primary assessment: Assessment for learning; how and why it works in primary classrooms. *Primary Science*, *116*, 5-7.

John-Steiner, V. (2000). *Creative collaboration*. New York: Oxford University Press.

Koballa, T. J. & Glynn, S. M. (2008). Attitudinal and motivational constructs in science learning. In S. K. Abell & N. G, Lederman (Eds.), *Handbook of research on science education* (pp. 75-102). New York: Routledge.

Kuhn, D. (1989). Children and adults as intuitive scientists. *Psychological Review, 96*(4), 674-689.

Mercer, N. & Littleton, K. (2007). Dialogue and the development of children's thinking: A sociocultural approach. London: Taylor and Francis.

Minner, D. D., Levy, A. J. & Century, J. (2010). Inquiry-based science instruction: What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, *47*(4), 474-496.

Poddiakov, N. (2011). Searching, experimenting and the heuristic structure of a preschool child's experience. *International Journal of Early Years Education*, *19*(1), 55-63.

Rittle-Johnson, B. & Koedinger, K. R. (2005). Designing knowledge scaffolds to support mathematical problem solving. *Cognition and Instruction*, *23*(3), 313-349.

Sylva, K. (2009). *Early Childhood Matters: Evidence from the effective pre-school and primary education project*. London: Taylor and Francis.

van den Akker, J. (2007). Curriculum design research. In T. Plomp & N. Nieveen (Eds), *An Introduction to Educational Design Research*. Enschede: Axis Media-ontwerpers.

Wang, F., Kinzie, M. B., McGuire, P., & Pan, E. (2010). Applying Technology to Inquiry-Based Learning in Early Childhood Education. *Early Childhood Education Journal, 37*(5), 381-389.

Appendix 1: Dimensions, Sub Questions, Survey Questions and Factors

<table>
<tr><th></th><th>Dimensions
Sub questions</th><th>Factors important to nurturing creativity in early years science and mathematics</th></tr>
<tr><td rowspan="2">Aims/purpose/priorities</td><td>Rationale or Vision
Why are they learning?</td><td>• science economic imperative
• creativity economic imperative
• scientific literacy and numeracy for society and individual
• technological imperative
• science and mathematics education as context for development of general skills and dispositions for learning</td></tr>
<tr><td>Aims and Objectives
Toward which goals are the children learning?</td><td>• Knowledge/understanding of science content
• Understanding about scientific inquiry
• Science process skills; IBSE specifically planned
• Capabilities to carry out scientific inquiry or problem-based activities; use of IBSE
• Social factors of science learning; collaboration between children valued
• Affective factors of science learning; efforts to enhance children's attitudes in science and mathematics
• Creative dispositions; creativity specifically planned</td></tr>
<tr><td rowspan="3">Teaching, learning and assessment</td><td>Learning Activities
How are children learning?</td><td>Focus on cognitive dimension incl. nature of science
• Questioning
• Designing or planning investigations
• Gathering evidence (observing)
• Gathering evidence (using equipment)
• Making connections
Focus on social dimension
• Explaining evidence
• Communicating explanations</td></tr>
<tr><td>Pedagogy
How is teacher facilitating learning?</td><td>• Role of play and exploration; role of play valued
• Role of motivation and affect ; Efforts made to enhance children's attitudes in science and mathematics
• Role of dialogue and collaboration; collab. between children valued
• Role of problem solving and agency ; use of IBE/PBL, Children's agency encouraged
• Fostering questioning and curiosity - Children's questions encouraged
• Diverse forms of expression valued
• Fostering reflection and reasoning; children's metacognition encouraged
• Teacher scaffolding, involvement, Sensitivity to when to guide/stand back</td></tr>
<tr><td>Assessment
How is the teacher assessing how far children's learning has progressed, and how does this information inform planning and develop practice?</td><td>Assessment function/purpose
• Formative
• Summative
• Recipient of assessment results
Assessment way/process
• Strategy
• Forms of evidence ; excellent assessment of process +product, Diverse forms of assessment valued
• Locus of assessment judgment – involvement of children in peer/self assessment</td></tr>
</table>

	Dimensions Sub questions	Factors important to nurturing creativity in early years science and mathematics
Contextual factors (Curriculum)	**Materials and Resources** *With what are children learning?*	• Rich physical environment for exploration; Use of physical resources thoughtful; Valuing potential of physical materials; • Environment fosters creativity in sci/math • Sufficient space • Outdoor resources; recognition of out of school learning • Informal learning resources • ICT and digital technologies; confident use of digital technology • Variety of resources • Sufficient human resources • NO reliance on textbooks or published schemes
	Location *Where are they learning?*	• Outdoors/indoors/both - recognition of out of school learning • Formal/non-formal/informal learning settings/ • Small group settings
	Grouping *With whom are they learning?*	• Multigrade teaching • Ability grouping • Small group settings • Number of children in class
	Time *When are children learning?*	• Number of children in class • Sufficient time for learning science and mathematics
	Content *What are children learning?*	• Sci/ma as separate areas of knowledge or in broader grouping • Level of detail of curriculum content • Links with other subject areas / cross-curriculum approach; evidence of science and maths integration (planned or incidental) • Subject-specific requirements vs. broad core curriculum • Content across key areas of knowledge