Knowledge Exchange Seminar Series (KESS)

Creative Little Scientists: Enabling Creativity through Science and Mathematics in Preschool and First Years of Primary Education

Policy Briefing

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Introduction

The *Creative Little Scientists* [CLS] research project is an EU-funded research project running until from September 2011- March 2014. It involves 12 university partners across nine European countries, coordinated by Ellinogermaniki Agogi, Greece, and set out to *examine the potential for inquiry and creativity in learning and teaching in early years science and mathematics and to build on research findings to suggest implications for policy and practice in schools and teacher education*. The project has involved a number of, often concurrent, strands, or 'work packages', including both desk-studies (e.g. reviews of the literature and national policies in participating countries) and empirical work (e.g. online practitioner-surveys, classroom-based fieldwork and online and face-to-face focus-groups). The findings from these work packages are being used to develop teacher-training materials. This paper focuses briefly on the policy work package and then substantially on the fieldwork

Policy survey

The policy survey indicated varied emphases on science across countries in relation to the expressed aims and objectives. The radar diagrams below indicate the extent to which cognitive factors of learning: understanding of science content, understanding about scientific inquiry and capabilities to carry out scientific inquiry, and social and affective factors are emphasized in policy across the four countries of the UK. Use of equipment (d), communicating explanations (f), and planning investigations (j) are emphasized in England, Scotland and Wales, but not mentioned explicitly in Northern Ireland policy in either phase. Although in England, inspection processes (Ofsted, 2011) have raised concerns about the limited opportunities for children to engage in inquiry and '*to plan and evaluate their own investigative work*' (p. 12). Across all countries, the nature of science scarcely features in the aims of science in preschool. With the exception of England, it is also given very limited attention in the primary age phase. In comparison with the curricula for England and Wales, the curricula for Scotland and Northern Ireland give greater priority to the development of positive attitudes in both phases of education. All four countries make some reference to being able to collaborate as an aim for early years science.

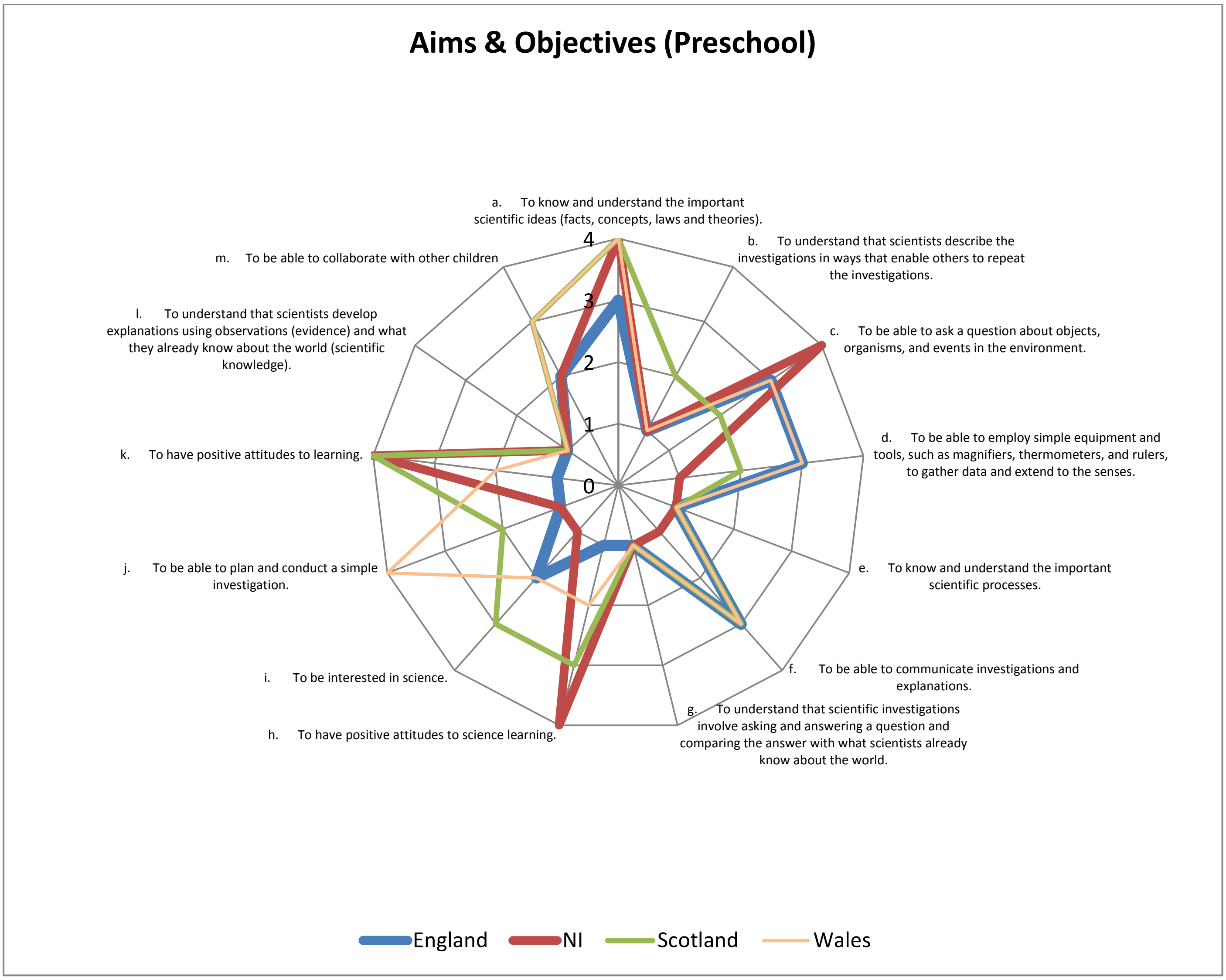

Figure 1: Radar diagram for Early Years aims and objectives

In terms of references to creativity in mathematics and science, the importance of creativity is explicit and features strongly in the overarching aims of the curriculum in both Northern Ireland and Scotland. For example, in Northern Ireland 'Being Creative' is an explicit dimension of the 'Thinking Skills and Personal Capabilities Framework'. Connections to creativity in the more detailed aims for science and mathematics in all four countries of the UK are generally implicit, but connections identified suggest positive potential for the promotion of creativity and inquiry. In Northern Ireland, the curricula for 'Mathematics and Numeracy' and 'The World Around Us' make little or no explicit reference to creativity. In Scotland however, there are references to creativity in outlining "Principles and Practices" in the "Sciences" within the *Curriculum for Excellence* (Scottish Executive, 2004, p. 253) "There are no explicit references to creativity in mathematics. In Wales, there are references to creativity in the science curriculum for Key Stage 2, for example within the context of developing positive attitudes towards learning and in developing innovative thinkers, "Activities should foster curiosity and creativity and be interesting, enjoyable, relevant and challenging for the learner" (DCELLS, 2008b, p. 10).In England, the term creativity is used to a very limited extent and whilst the first general aim of the new curriculum does make a reference to creativity, this is learning about the creativity of others, by implication creative geniuses, rather than developing it themselves(DfE, 2013).

The *Creative Little Scientists* project has drawn on the following definition of creativity in science and mathematics 'generate alternative ideas and strategies as an individual or community and reason critically between these'. Links to this definition can be seen for example in the focus on children *raising questions* and *exploring ideas*, both important features of *problem finding* and *problem solving*. Skills of *reasoning and evaluation* feature less strongly, especially in preschool, but are associated with common references to *making connections, testing ideas and explaining ideas using evidence.* There are also references to important creative dispositions in policy, in particular the emphasis on curiosity and a common focus on thinking skills and collaboration.

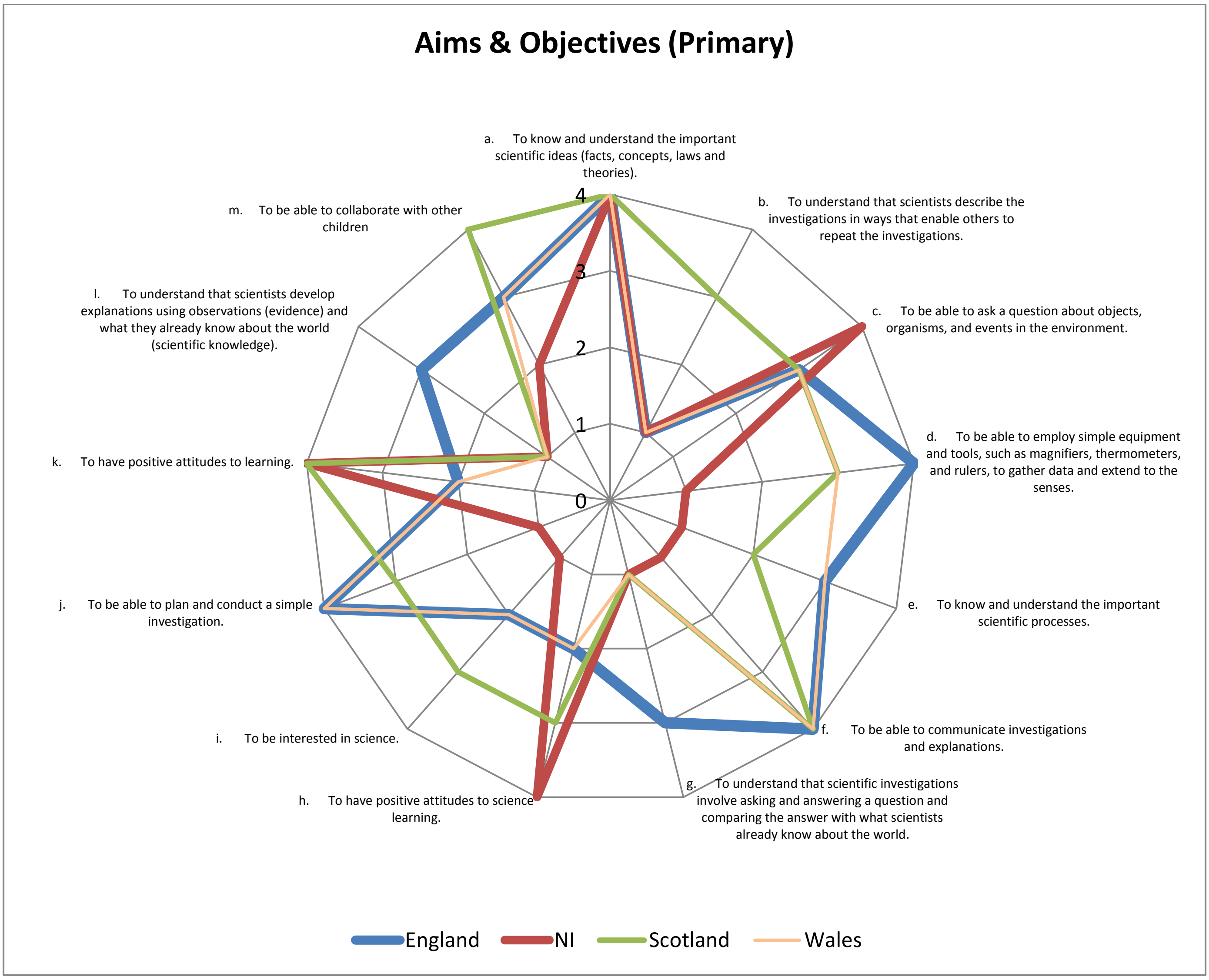

Figure 2: Radar diagram for primary aims and objectives

Classroom-based fieldwork

The in-depth classroom-based fieldwork took place during the spring term of 2013 and was undertaken by university partners in all nine European countries involved in the project, including sites in all four United Kingdom nations. Each consortium university-partner worked in a range of pre-school and school classrooms, with a focus on a minimum of six 'cases' – one teacher and the children they were responsible for working with – within the 3-8 age span. From each case study, 'episodes' of creativity in science and/or mathematics teaching and learning were identified – instances of classroom activity during which creativity could be observed – with each case producing at least three episodes.

The fieldwork took a naturalistic approach to data collection, looking to collect a rich data set with respect to creativity in science and mathematics with children aged 3 to 8. The fieldwork documented teaching, learning and assessment and also children's and early years practitioners' perspectives on this. Data included fieldnotes, audio-recordings and sequential digital images of classroom activity, interviews with teachers and artefacts from the classroom such as copies of children's work and lesson plans. A minimum of three visits by a core researcher of at least three hours duration each were undertaken for each case. Analysis led to the construction of detailed case studies for each of the practitioners involved in the study. The outcomes of the case study analyses were compiled to produce one report for the whole UK that identified commonalities across the 24 case studies from the four UK nations, including the four cases identified in Northern Ireland.[1]

Sample

Potential participants for the fieldwork were identified through a variety of means, often remote. This included existing knowledge of schools, recommendations from colleagues based in the target countries (often based on existing research links), schools rated as 'outstanding' in national inspection reports and visiting school's websites with a view to establishing what, if any, emphasis the pre-schools and schools placed on creativity. Schools were also identified from respondents to an online survey undertaken six months previously during the summer 2012 (CLS, 2012a).

In Northern Ireland, schools were contacted through the headteacher via email. Positive responses were received from three schools and two sites were identified as appropriate based on accessibility. As such, rather than necessarily being a representative, random sample, it was both a purposive and convenience sample (Stake, 1994). The two sites were one nursery setting – 'County Park Nursery School' – and one integrated primary school – 'Ashford Integrated Primary School' – both in the same small town outside Belfast. Each of the settings elicited two cases. Each case was visited at four times with a view to observing both creativity in both science and mathematics education.

Analysis

A deductive framework was developed before visiting classrooms in order to guide analysis, informed by the initial literature review (CLS, 2012b), which sought to identify the key features of creativity in early years science and mathematics education. As well as providing a useful tool for analysis, adopting this deductive framework meant that it would be possible for analysis to be consistent in all 12 partner-universities across Europe. This was particularly

[1] *D4.3 Country Reports,* available at http://www.creative-little-scientists.eu/content/deliverables

important, as the results of the analysis from across the consortium were compared and compiled into one overall report (CLS, 2013).

The deductive framework outlined two areas of 'mapping factors', that is, groups of identifiable features or characteristics that might be identifiable in the classroom. These were described as 'pedagogical interactions' and 'pedagogical framing'. 'Pedagogical interactions' foregrounded four dimensions: Learning activities (or how children were learning); practitioners' approaches to pedagogy; their approaches towards assessment, and finally; the materials and resources involved. 'Pedagogical framing' of teaching and learning in the classrooms visited includes; the practitioners' perceived aims and objectives of science education; the location in which learning was occurring; the grouping in the classroom and; again, assessment

Pedagogical interactions

1. *Learning activities*

In preschool contexts questioning, observing, using equipment and making connections all were common and featured in the majority of episodes. Opportunities for questioning, observing and using equipment were similar in primary schools although tended to occur in a more closely formalised way. It was notable that making connections was a feature of almost all of the primary episodes, possibly reflecting the greater emphasis in this phase on science knowledge and understanding and specific learning outcomes, as well as children's greater knowledge and experience. Explaining evidence and communicating explanations were evident in about half of the preschool episodes.

Across the whole data set, 'children's own planning' was evidenced in only third of the episodes; often implicitly evidenced through children's own clear sense of direction. Where it was observed, children's own planning was fostered in pre-schools by access to a wide range of resources and time to for explorations to develop into more focused inquiries. This was less evident in primary school contexts, where children usually had more restricted opportunities to develop their own investigations. They were often only able to plan and design some parts of an investigation, such choice of resources, procedures associated with fair testing, measuring or ways of recording, linked to the particular learning objectives for the session.

2. *Pedagogy*

Across the UK, it was apparent that practitioners tended to act more as facilitators than instructors, particularly at preschool. Practitioners were able to scaffold children's learning and foster learners' creative engagement through the planned structure of the activities and their pedagogical interactions. Indeed, teacher-scaffolding was characteristic of both preschool and primary school pedagogical approaches. Such scaffolding was apparent in the activity structure when relatively open-ended problems were offered as supportive scaffolds for learning, and in the teacher's on-going interactions with children, such as individual intervention or whole class discussion, reminding them of, say, the significance of the learning objectives and/or the need to develop an appropriate problem solving/investigative approach. Practitioners also used scaffolding as a way of modelling the language they wished the children to use and develop.

The pedagogical interactions between practitioners and children and between children and children in all classes encouraged learners to engage in peer dialogue and collaboration and supported metacognition. This was achieved largely through practitioners 'standing back' and allowing free exploration, as 'Maeve' at County Park Nursery School did on multiple occasions.

For example, Maeve set up resources for the children to explore the properties of ice and stood back and observed the children before deciding whether to intervene, only asking open-ended questions to further prompt engagement; children were largely left to the task free from practitioner-intervention. This often appeared to prompt more open-ended questioning from the children, enabling them to scaffold each other's learning.

Approaches towards assessment
Assessment in any form was one of the least-evidenced factors across all the countries involved in the *CLS* project; there was little observable evidence of assessment of science or mathematics in over half of the episodes from the UK. Assessment that was observed was mainly formative, and used in ongoing lesson planning. This might be, for example, using children's questions and interests to inform practitioners' questioning or as a framework for subsequent activities the following day. Summative assessment was rarely used in primary schools and even less frequently in preschool. The limited evidence for science assessment was reflected in the limited evidence for assessment of creativity.

3. *Materials and resources involved*

There was little or no emphasis observed on commercial schemes such as textbooks, particularly in the preschool; books, stories, nursery rhymes and cross-curricular themes provided the context for science learning. One particularly vivid example came from Siobhan's preschool class in Ashford Integrated Primary School. She was using the 'Gingerbread Man' nursery rhyme as the context for learning – with activities in literacy, social development, mathematics and science. One science activity saw the children investigate floating and sinking using everyday objects (such as food trays, toys from the sand tray and so on) in the water tray, aiming to keep plastic gingerbread men toys afloat. The open-ended activity allowed children to develop their own ideas and the rich physical environment, in the story-context in which the activity was situated provided children with an imaginative world in which to explore and ultimately, develop their own creative outcomes[2]. Siobhan shows here how, using an interesting and motivating context, coupled with an appropriately resourced activity, it is possible to provide opportunities for creativity in science activities.

Pedagogical framing

1. *Perceived aims and objectives*

It was apparent from the data collected across the UK that developing knowledge and understanding of science is an important feature of early years education. Development of science knowledge may be through, for example, practitioners' emphasis of specific language related to the concept being taught or, in the case of primary schools, teaching of concepts. In contrast, there were fewer examples of practitioners providing opportunities for children to develop their understanding of science *investigation*. That is to say, while it was apparent that practitioners placed an emphasis on engaging children in science investigations, there was less of an emphasis on engaging children with developing an understanding of the processes of science investigation, such as planning fair tests or testing hypotheses. For example, 'children explaining evidence' was not strongly featured in the data, despite the key role of evidence in developing and reviewing explanations. Explaining evidence was generally only apparent when explicitly prompted by exchange with others, either adults including the researcher, or (on occasion) peers.

2. *Location of learning*

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[2] Case 16: 'Siobhan', in *D4.3 Country Report – Report 9: UK*, accessible at http://www.creative-little-scientists.eu/content/deliverables

'Learning environments' were one of the main pedagogical challenges faced by practitioners as the empirical findings found little evidence of out-of-school learning, such as the use of museum settings, occurring, especially in primary schools. Only one site, in Scotland, appeared to fully engage with outdoor learning, a preschool in Scotland, the local wildlife area was used well to respond to children's interests, such as freezing and melting. Often in other sites, the outdoors was used as an opportunity simply to provide more space, and for others it was as a means of exploring concepts that already learnt in the classroom setting.

3. *Classroom grouping*

Significant differences were seen in how children worked on science activities, particularly between the preschool and primary school settings, these are discussed in more detail below.

4. *Time*

Sufficient time for learning in science and mathematics has emerged across the *Creative Little Scientists* project as a key issue in fostering creativity, along with sufficient time for raising questions, for children's independent exploration and investigation, and for reviewing ideas and deepening understanding. Across all four countries of the UK and phases there is limited policy guidance about time allocations. The teacher survey indicated that considerably more time was spent on mathematics than science. Fieldwork highlighted the importance of flexibility and time to review ideas in fostering inquiry and creativity, and in some instances the pressures of timetable and assessment requirements.

Differences between primary and preschool

Differences observed between primary and preschool settings, such as child: staff ratios or the availability of resources, were common. However, for this project, the more substantive differences were seen in how children worked on science and mathematics activities in preschool and primary school settings. Often in preschool settings, science and mathematics learning was apparent (and indeed planned for) through free play activities. Children in these preschool settings therefore often worked in small, mixed-ability, friendship-based groups on their science tasks. In contrast, science activities in primary school settings were usually whole class activities that were then broken down into smaller ability-based groups. This has a subsequent effect on the pedagogical interactions between the teacher and children. Interactions with primary-aged children will often be directed at the whole class, where the children were often engaged in the same activities, while in the preschool, where children often undertook different activities, practitioners' scaffolding interactions were seen in small group or one to one conversations, in situations which allowed practitioners to stand back and allow the learners to follow their own avenues for inquiry. Here then, teachers act more as facilitators in the preschool than in the primary school.

Recommendations

Teacher education recommendations

- *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 and why they matter. Vignettes could help teachers identify classroom practice and discuss evidence of creativity in learning and teaching, with a view to supporting the explicit planning for IBSE and creativity.

- *Whole school approaches*.
  - Those educational settings that appeared to be most successful at implementing creative approaches were those in which whole school curriculum planning for creative teaching and learning and inquiry based approaches in mathematics and science could be seen and where whole school planning and infrastructures could maximise opportunities for such learning in the school grounds and wider environment.

Recommendations for pedagogical interaction

- *Teacher scaffolding.*
  - Teachers should appreciate the value of establishing open-ended learning activities and to identify moments 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*
  - Less attention was given to children's own questions, planning of investigations or the evaluation of evidence than to, for example, observation. It is suggested that teachers 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.

- *The use of ICT.*
  - The use of ICT was rarely observed in the schools visited in Northern Ireland (or indeed across the UK) except on the part of the teachers during instruction. The use of ICT therefore comprises an area for development for teachers and student teachers, for example in making measurements, collecting data; and/or recording, presenting and analysing data.

- *Teacher questioning*
  - Given the importance of the role of teacher questioning in scaffolding children's inquiries and in eliciting and fostering reflection and reasoning, teachers need 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.

- *Forms of representation and expression.*
  - Where teachers left open how ideas might be recorded or represented, this helped free opportunities children's for exploration, reflection and dialogue about learning. It is suggested then that 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*
  - 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.

Teachers should therefore teachers utilise different assessment strategies and forms of evidence in early science and mathematics, as well as integrating peer and self-assessment into teaching and learning processes and 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, and indeed two practitioners were actively involved in classroom research. Professional enquiry as a mode of learning is worth pursuing.

Recommendations for policy development

- *CPD entitlement*
  - Specifically, CPD that addresses the fostering of creativity in early science and mathematics. This would need to develop teachers' recognition of the value of creativity and their capacities to recognise opportunities for promoting it through science and mathematics.

- *Training for science and mathematics co-ordinators*
  - In particular, science and mathematics coordinators need specialist CPD 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.

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

- *Policy coherence*
  - While the importance of inquiry and creativity is often recognised in the rationale and aims of the curriculum, how these dimensions are reflected in teaching, learning and/or assessment requirements or pedagogy guidance varies. There thus is a need for increased coherence across policy and associated guidelines.

- *Curriculum space and time*
  - Policy frameworks for science and mathematics in primary settings need to reflect the positive aspects of the preschool curriculum by allowing sufficient flexibility in space and time for children to pose and respond to their own questions, investigate and generate creative responses. This may be achieved through ensuring the curriculum is not overcrowded and not so narrow as to stifle children's creative engagement.

- *Valuing formative assessment*
  - Formative assessment was often implicit in practice, rather than employed in strategic ways that might support and evaluate learning and teaching. There is need for greater recognition of the importance of formative assessment in policy and the development of associated guidance for teachers.

References

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