



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

**D4.4 Report on Practices and their
Implications**

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EXECUTIVE SUMMARY

Introduction

The aim of this report is to provide a detailed analysis of evidence gathered through fieldwork in the nine European countries (Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania and the UK) participating in the *Creative Little Scientists* project. The Report builds on *Country Reports* (D4.3) that drew together data gathered from each partner country to examine and illustrate the potential for creativity and the role of inquiry in the classroom realities of preschool and early primary school science and mathematics education. It includes a selection of exemplary episodes of learning and teaching from each partner country illustrating the variety of approaches observed and the possibilities identified for creativity in early science and mathematics.

Analysis of findings from fieldwork is grounded in concepts and synergies identified in the *Conceptual Framework* (D2.2) and operationalised in the *List of Mapping and Comparison Factors* (D3.1) developed previously in the project. Moreover, the contents of this report aim to complement those of the *Report on Mapping and Comparing Recorded Practices* (D3.2) and the *Report on First Survey of School Practice* (D3.3), previous project deliverables that addressed the same goals through the analysis of relevant policy records and teacher survey data respectively.

Methodology

Research questions

The research questions for this report, as outlined below, originate from the project research questions as identified in the *Conceptual Framework* (D2.2) namely:

- What approaches are used in the teaching, learning and assessment of science and mathematics in early years in the partner countries and what role if any does creativity play in these?
- In what ways do these approaches seek to foster young children's learning, interest and motivation in science and mathematics, and how do teachers perceive their role in doing so?
- How can findings emerging from analysis in relation to these questions inform the development of practice in the classroom and in teacher education (ITE and CPD)?

As in previous reports from the *Creative Little Scientists* project, these questions are examined in relation to a framework based on the curriculum components associated with 'the vulnerable spider web' (van den Akker, 2007, p.39), which identifies key questions about aspects of learning in schools as follows:

- Rationale or vision: Why are children learning?
- Aims and objectives: Toward which goals are children learning?
- Content: What are children learning?

- Location: Where are children learning?
- Learning activities: How are children learning?
- Pedagogy: How is the teacher facilitating learning?
- Materials and resources: With what are children learning?
- Grouping: With whom are children learning?
- Time: When are children learning?
- Assessment: How to measure how far children's learning has progressed, and how is s/he using this information to inform planning and develop practice?

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

Research Instruments

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

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

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

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

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

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

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

Data Collection

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

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

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

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

Ethical issues

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

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

Data Analysis and Reporting

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

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

Limitations

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

The sample of sites selected for fieldwork in each country was small. It was constrained by issues of access, geographical and financial considerations and details of school timetables. This limits the scope for generalization and comparison. However, as indicated in the research design, the intention was not to make comparisons between countries or sites but to illustrate and comment on the potential for creativity in varied contexts across the consortium.

The short time frame and available resources necessarily limited the scope of data collection. Time available for classroom observation was limited. It was only possible to gain snapshots of classroom practices that may not have been representative of everyday approaches to learning and teaching. It was also not always feasible for two researchers to be present to manage the range of fieldwork instruments or to capture the rich diversity of classroom practices, particularly in in preschool settings where many varied activities were often taking place simultaneously.

Partners also reported limitations associated with schools' varied experiences of involvement in research or classroom observation. In some countries and settings this is common practice, for example associated with teacher professional development processes or inspection. In other settings classroom observation was much less part of school culture. In some instances this had an impact on the conduct of the fieldwork, in particular the opportunities for dialogue with teachers and children. Building on the comments above about the limitations of time, further time to develop further the trust and confidence of participants might have afforded more detailed insights into their perspectives on learning and teaching.

Key Findings

Key findings from fieldwork in relation to the research questions are presented below.

What approaches are used in the teaching, learning and assessment of early years science and mathematics in partner countries: What role if any does creativity play in these?

Findings from fieldwork across partner countries provided considerable evidence of the potential for creativity in learning in early science and mathematics. *The learning activities* observed included examples of the full range of cognitive and social dimensions of inquiry in science and mathematics (as identified in D3.1 *List of Factors*). This provided children with rich opportunities for *generating and evaluating* new and alternative ideas and strategies, identified in the *Conceptual Framework* (D2.2) as associated with creativity. In particular opportunities for *observation and making connections* featured strongly across the episodes reported. Promotion of reflection and reasoning involved in developing and *communicating explanations based on evidence*, featured more strongly in the episodes than might have been anticipated from the teacher and policy surveys conducted in earlier phases of the project.

Fieldwork provided many examples of teaching approaches associated with creativity. Teachers planned *motivating contexts* for learning linked for example to children's interests, everyday events and familiar stories. They provided a *rich physical environment* for inquiry making good use of everyday and household materials and natural resources. *Very few relied on published resources* but planned or adapted activities appropriate to their children and their contexts. *Group work* was another common feature of teachers' practices affording opportunities for *dialogue and collaboration*. Findings indicated considerable potential for *child-initiated inquiry* and *children's agency* in preschool however this was not always recognized by teachers. There were more limited examples of child-initiated inquiry in primary school, but episodes reported still included scope for children's decision making. Varied approaches to *scaffolding* were evident in teachers' practices. The strongest episodes provided examples of sensitive scaffolding to support children's independence and extend inquiry, for example through choice of materials, questioning or the introduction of skills and equipment, with teachers listening and observing carefully to judge when to intervene and when to stand back. Episodes also illustrated the important role of teacher scaffolding in promoting *reflection and reasoning*. Findings suggested areas for further development. Opportunities for *play and exploration* were common in preschool settings but were more limited in primary classrooms. The important roles of play and exploration in fostering questioning, eliciting and generating ideas and developing appreciation of phenomena could be more widely recognized in both phases of education. Findings suggested that greater use could be made of *varied forms of representation* including children's use of ICT, not just for recording outcomes, but also for fostering reflection and reasoning processes. Only a small number of episodes reported (particularly in mathematics) included use of the *outdoor or wider school environment*, although the few examples reported illustrate the rich potential for inquiry and creativity this can offer.

Fieldwork suggested (as in previous phases of the project) that *assessment* is an area that is underdeveloped in both policy and practice. Classroom observations provided limited evidence of teachers' assessment practices. *Informal and formative assessment* approaches involving the use of questioning and observation were evident in some episodes with teachers building on assessment information to inform future practice. However examples of *children's involvement in assessment* were very limited.

The *aims of activities* observed indicated a strong focus on social and affective as well as cognitive dimensions in learning, reflecting findings from the teacher survey conducted in an earlier phase of the project. In many instances aims were not explicit. Teachers rarely focused on the *nature of science* or the promotion of *children's creativity*, although the potential for both was suggested in the episodes as indicated above. Indeed a number of teachers indicated that they had not previously considered the nature of inquiry or creativity in science and mathematics learning.

Fieldwork highlighted the important influence of a number of wider contextual factors on the opportunities for inquiry and creativity. Episodes illustrated the positive impact of *whole school philosophy* and ethos in for example, providing support for experiential and child-centred approaches to learning and teaching, the attention given to provision for learning in the whole school environment, both indoors and out, support for *team working* and for *further professional development* and scope for trying out new ideas. In interviews with researchers teachers made reference to a number of barriers in fostering inquiry and creativity in mathematics and science. Restrictions of *space, time and curriculum requirements* were often highlighted. Teachers in primary settings also noted that *levels of staffing* limited their use of the outdoor environment and their employment of a wider range of assessment strategies.

In what ways in which these approaches seek to foster young children's learning, interest and motivation in science and mathematics?

Fieldwork provided rich evidence of the varied ways in which approaches to learning teaching and assessment fostered skills, attitudes and understanding associated with inquiry and creativity in early mathematics and science. It also provided strong illustrations of young children's capabilities and interests in science and mathematics as discussed in D2.2 Appendix 1 *Review of science and mathematics education in preschool and early years of primary school*. Across the episodes there were many examples of children *observing* and *making connections* for example with prior learning or between experiences. Opportunities for children's *questioning* were also evident, sometimes made explicit, but often in preschool implicit in the focus and direction of children's explorations. There was greater evidence of children's engagement in the social dimensions of inquiry, *explaining evidence* and *communicating explanations* than might have been expected from the policy and teacher surveys, often prompted by dialogue with peers and adults. Explicit examples of children's appreciation *of the nature of science* were limited, but starting points for the development of understanding of the nature of science were indicated in a number of episodes, for example in children's reflections on learning shown 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 suggesting ways to solve problems and in offering explanations.

How do teachers perceive their role in doing so?

The case studies included in the Country Reports summarised key features of teachers' perspectives on learning and teaching gained from interviews with researchers to discuss the episodes observed. These offer insights into teachers' views of their roles in fostering children's learning interest and motivation in science and mathematics. In many instances teachers indicated that this was not something that they had considered previously and that fieldwork processes had prompted reflection on the nature of inquiry and creativity in early mathematics and science and how this might be fostered.

In reflecting on their roles in supporting learning in science and mathematics teachers made reference to a number of features of pedagogy associated with creative and inquiry-based approaches. Most teachers highlighted the importance of *encouraging and supporting young children's engagement* in early years science and mathematics as an important starting point for learning. Other dimensions mentioned by a number of teachers included the importance of *fostering motivation and collaboration* and *providing a rich environment with space and time for exploration and problem-based learning*, reflecting findings from the teacher survey undertaken in an earlier phase of the project. Another role commonly identified was encouraging children to *reflect and make connections* across experiences to promote conceptual understanding and application of ideas in varied settings. A number of teachers also underlined the key roles of careful *listening and observing* in supporting learning (linked to the key role of assessment). However limited explicit reference was made to the role of creativity or features of inquiry in science and mathematics.

Implications

Findings from the case studies examined in the Country Reports suggested a number of implications for teacher education, for policy development and for further research as outlined below.

Teacher education

Areas identified for attention in teacher education programmes to support inquiry and creativity in early science and mathematics education include:

- Perspectives on the nature of science and mathematics and the purposes 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.

Policy

The report makes broad recommendations to inform the development of policy to support inquiry and creativity in early science and mathematics education. They include the need for:

- Ongoing opportunities for professional development in science and mathematics through initial and continuing teacher education, focusing in particular knowledge and understanding of early learning and opportunities for creativity in early science and mathematics
- Training of subject leaders in school to support the development of whole school policy in early science and mathematics teaching and learning
- Training for teacher educators to ensure they have the understanding and skills to support teacher professional development required to foster creativity and inquiry in early science and mathematics
- Greater coherence in policy for example the need for time and space in the curriculum for problem solving and inquiry, and a greater match between aims of the curriculum associated with inquiry and creativity and assessment requirements
- Greater value and attention to the key role of formative assessment in policy, including dialogue between teachers and children
- Provision of resources and teacher training to enhance the role of ICT in learning and teaching in early science and mathematics education
- Investment in the development of the wider school environment both indoors and out to provide opportunities for inquiry and problem solving.

Research

Experiences during fieldwork and analysis of data suggested a number of areas for further investigation, based on areas for development identified and important aspects of learning and teaching it was not possible to explore within the limitations of time and resources on the project. They include:



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- The role of free flow play in fostering inquiry and creativity over time
- Opportunities for outdoor learning in the wider school environment
- The contribution of informal and non-formal approaches to young children's learning in science and mathematics
- The potential of children's use of ICT to enhance inquiry and creativity
- The role of representation in varied modes in fostering young children's reflection and reasoning
- Opportunities for exploring the nature of science with young children
- The contribution of peer and self-assessment to the development of creative dispositions in early science and mathematics.

Partners collected a rich range of data during fieldwork, beyond that directly associated with the episodes reported, including detailed interviews with teachers and children and a wide range of photographs of play activities and of school and classroom environments. This offers considerable scope for further analysis.





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1. Aims of this Report

This *Report on Practices and their Implications* (Deliverable D4.4) of the EU-funded project *Creative Little Scientists* is the final outcome of *Task 4.2 In-depth fieldwork* conducted in schools across the partner countries. It builds on D4.3 *Country Reports* that drew together fieldwork data and information gathered from each partner country. The aim of the Report is to provide a detailed account of the analysis of evidence gathered through fieldwork in the sample countries. The Report includes a selection of exemplary episodes of learning and teaching from each partner country illustrating the variety of approaches observed and the possibilities identified for creativity in early science and mathematics.

The fieldwork was carried out during the months January-April 2013 in each of the nine participating European countries (Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania and the UK) representing a wide spectrum of educational, economic, social and cultural contexts. The aim of this qualitative study was to reveal the potential for creativity and the role of inquiry in the day-to-day classroom realities of pre-primary and first years of primary science and mathematics education. Analysis of the findings is grounded on concepts and synergies identified in the *Conceptual Framework* (D2.2) and operationalised in the *List of Mapping and Comparison Factors* (D3.1) developed previously in the project. Moreover, the contents of this report aim to complement those of the *Report on Mapping and Comparing Recorded Practices* (D3.2) and the *Report on First Survey of School Practice* (D3.3), previous project deliverables that addressed the same goals through the analysis of relevant policy records and teacher survey data respectively.

The focus of the fieldwork in each country was on sites where there were indications that we would find 'exemplary practices' in fostering creativity and inquiry in early science and mathematics, covering all pupil age groups from age 3 up to 8 years and the range of provision of pre-primary and early primary education in the country. The characteristics of 'exemplary practices' emerged from reflection on findings of previous project deliverables: the *Conceptual Framework* (D2.2), the *Report on Mapping and Comparing Recorded Practices* (D3.2) and the *Report on First Survey of School Practice* (D3.3). This has enabled the project to document and analyse practice at the cutting edge of creativity in early science and mathematics, revealing insights into whether and how:

- children's creativity is fostered, and
- the emergence of appropriate learning outcomes is achieved.

As far as the latter is concerned, focus was placed on (but not limited to) issues of central importance in current science and mathematics education discourse, including generating children's interest in science and mathematics, avoiding emergence of misconceptions and stereotypical images, and considering gender, socio-economic and cultural issues. It should be noted that whilst empirical work was undertaken across partner countries it was not the intention to engage in a systematic comparative study in the sense of comparing 'like with like', rather to exemplify practices that foster inquiry and creativity in each national context. Given the diversity of provision across

partner countries it was anticipated that fieldwork would provide a rich range of examples of the opportunities for creativity in science and mathematics in the early years.

The in-depth field work followed the research design and methodology specified for the project and set out in detail in the *Methodology for in-depth fieldwork* (D4.1), and involved the use of interviews and classroom observations involving both teachers and children, recorded using field notes, photographs and audio or video recording where permitted.

This report provides an overview of the research methodology, including the research questions and approaches to data collection and analysis. This is followed by a summary and discussion of findings and their implications for teacher education, policy and future research. A selection of exemplary episodes of learning and teaching are included in Appendix 3. These are drawn upon in the summary and discussion of findings to illustrate the opportunities for creativity identified.

2. Methodology

The full range of methodological planning and framing for the fieldwork that forms the basis for the Country Reports and this final Report for Work Package 4 is set out in the *Methodology for in-depth fieldwork* (D4.1). The sections below serve as a reminder of some of its essential elements, and provide the details of how this methodology was implemented in the fieldwork carried out in different partner countries. This is followed by an explanation of the processes and phases of data analysis involved in the production of the *Country Reports* (D4.3) and the synthesis of their findings in this *Report of Practices and their Implications* (D4.4).

2.1 Research Questions

The research questions for this report, as outlined below, originate from the project's overall research questions as they are identified in the *Conceptual Framework* (D2.2):

- RQ1** How are the teaching, learning and assessment of science and mathematics in early years in the partner countries conceptualised by teachers and what role if any does creativity play in these?
- RQ2** What approaches are used in the teaching, learning and assessment of science and mathematics in early years in the partner countries and what role if any does creativity play in these?
- RQ3** In what ways do these approaches seek to foster young children's learning, interest and motivation in science and mathematics, and how do teachers perceive their role in doing so?
- RQ4** How can findings emerging from analysis in relation to questions 1-3 inform the development of practice in the classroom and in teacher education (ITE and CPD)?

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

As mentioned above, this report is dedicated to revealing current practice in the intersection between science, mathematics and creativity in both preschool and first years of primary education in the partner countries. As such, the *Country Reports* and this *Report on Practices and their Implications* focus on research questions RQ2, RQ3 and provide input towards RQ4.

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

- **Aims/purpose/priorities**, including teachers' explicit and implicit perspectives and identities as scientists and mathematicians, and in relation for example to: aims and purposes of creativity in science and mathematics education; how science and mathematics are taught and learned in relation to other domains of knowledge; how these shift from preschool to primary across the consortium; how these relate to inquiry-based science education (IBSE); views of creativity in relation to perceived purpose.
- **Teaching, learning and assessment**, including learning activities, pedagogy and resourcing, and in relation for example to: multimodal expression and experience; learning activity types; resources used; dynamics between adults and children; exploration; questioning and argument; also how teachers assess creativity in early science and mathematics education.
- **Contextual factors**, including ethos, teacher characteristics and teacher general education and knowledge, skills and confidence, curriculum, institutional factors, home-school links and the wider cultural background, location, grouping, time.

Furthermore, these three broad strands were broken down into more narrowly-defined dimensions drawing on the framework of curriculum components 'the vulnerable spider web' (van den Akker, 2007, p.39), which focus on key questions about aspects of learning in schools.

Within these dimensions and sub-questions a number of factors were identified, drawing on the *Conceptual Framework* (D2.2) as having a strong potential to foster the development of creative skills in children as outlined in the *List of Mapping and Comparison Factors* (D3.1). These factors have been employed across the project in mapping and comparing existing approaches as reported in the *Report on Mapping and Comparing Recorded Practices* (D3.2), the *Report on First Survey of School Practice* (D3.3) and the *Comparative Report* (D3.4) and are explicitly addressed in this report.

Table 1 shows these dimensions, sub-questions and factors, and their codes. Factors highlighted in yellow concern important issues identified in the previous deliverables (*Conceptual Framework*

(D2.2), Report on Mapping and Comparing Recorded Practices (D3.2) and Report on First Survey of School Practice (D3.3)) as needing further investigation. This report focuses on these factors as they enable the mining of key issues identified by previous reports and thus ensure continuity and consistency amongst the various parts of the research study.

The coding list in Table 1 is 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 1, namely

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

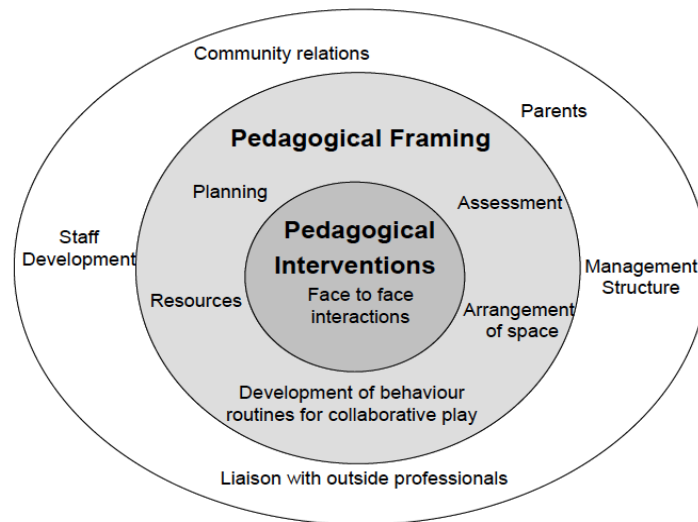


Figure 1: Pedagogical interventions in context (Siraj-Blatchford et al, 2002)

Table 1: Dimensions, Sub Questions and Factors

Dimensions	Sub questions	Factors important to nurturing creativity in science and mathematics in the early years	Coding
Learning Activities <i>Interaction</i>	How are children learning?	<p><i>Focus on cognitive dimension incl. nature of science</i></p> <ul style="list-style-type: none"> Questioning Designing or planning investigations Gathering evidence (observing) Gathering evidence (using equipment) Making connections <p><i>Focus on social dimension</i></p> <ul style="list-style-type: none"> Explaining evidence Communicating explanations 	<ul style="list-style-type: none"> LA: Ques LA: Plan LA: Obs LA: Equip LA: Connect LA: Expl LA: Comm
Pedagogy <i>Interaction</i>	How is teacher facilitating learning?	<ul style="list-style-type: none"> 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 	<ul style="list-style-type: none"> P: Play P:Affect P:Collab P:Dialog P:Agency P:Ques P: Express P: R and R P: Scaff
Assessment <i>Framing and Interaction</i>	How is the teacher assessing how far children's learning has progressed, and how does this information inform planning and develop practice?	<p><i>Assessment function/purpose</i></p> <ul style="list-style-type: none"> Formative Summative Recipient of assessment results NO CODE <p><i>Assessment way/process</i></p> <ul style="list-style-type: none"> 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 	<ul style="list-style-type: none"> A:Form. A:Summ. A:Strat. A:Evid. A:Peer /self

Dimensions	Sub questions	Factors important to nurturing creativity in science and mathematics in the early years	Coding
Materials and Resources <i>Framing and Interaction</i>	With what are children learning?	<ul style="list-style-type: none"> 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 	<ul style="list-style-type: none"> M:Explor. M: Cr M:Space M:Outd. M:Inf. M:ICT M:Variet. M:Human M: Pol.
Aims and Objectives <i>Framing and Interaction</i>	Toward which goals are the children learning?	<ul style="list-style-type: none"> Knowledge/understanding of science content Understanding about scientific inquiry Science process skills; IBSE specifically planned Capabilities to carry out scientific inquiry or problem-based activities; use of IBE/PBL Social factors of science learning; collaboration between children valued Affective factors of science learning;efforts to enhance children’s attitudes in science and maths Creative dispositions; creativity specifically planned 	<ul style="list-style-type: none"> AO: Kn.Sc AO: Und. SI AO: Sc Proc Skills AO: IBSE /PBL AO: Social AO: Affect AO: Creative
Location <i>Framing and Interaction</i>	Where are they learning?	<ul style="list-style-type: none"> Outdoors/indoors/both - recognition of out of school learning Formal/non-formal/informal learning settings/ Small group settings 	<ul style="list-style-type: none"> L.Out/In/ Both L.Formal/ Non-formal/ Informal L.grp
Grouping <i>Framing and Interaction</i>	With whom are they learning?	<ul style="list-style-type: none"> Multigrade teaching Ability grouping Small group settings Number of children in class 	<ul style="list-style-type: none"> G:MG G:Abil. G:SmallG G:No.
Time <i>Framing</i>	When are children learning?	<ul style="list-style-type: none"> Sufficient time for learning science and mathematics 	<ul style="list-style-type: none"> Ti: Suffic.

Dimensions	Sub questions	Factors important to nurturing creativity in science and mathematics in the early years	Coding
Content <i>Framing</i>	What are children learning?	<ul style="list-style-type: none"> • 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 NO CODE • Content across key areas of knowledge 	<ul style="list-style-type: none"> • C:Sci/M Sep • C:Detail • C:Sci/M Integ • C:CoreK
Teacher Personal Characteristics <i>Framing</i>	Who is the teacher?	<ul style="list-style-type: none"> • Gender • Age 	
Teacher General Education and Training <i>Framing</i>		Qualifications: <ul style="list-style-type: none"> • Level • Focus / content • Professional 	
Teacher Science and Mathematics Knowledge, Skills and Confidence <i>Framing</i>		<ul style="list-style-type: none"> • Pedagogical competence • Scientific competence • Teachers preconceptions of science and mathematics in terms of creativity • Confidence in teaching science and mathematics – do they feel well prepared • ICT skills • Views on own ITE/CPD (what/how) 	
School factors <i>Framing</i>	What is the school?	<ul style="list-style-type: none"> • Rich CPD approach (whole school) • Whole school planning + teacher agency 	

2.2 Research Instruments

The methodology document for the fieldwork (D4.1) set out a series of core and repertoire research instruments. All partners were expected to use the same core instruments so as to collect similar data to enable comparisons. Additionally, each partner was encouraged to select from an agreed repertoire of instruments, depending on preferred approaches and existing expertise. Data was to be collected across four areas spanning site and case (see D4.1, p33):

1. **WIDER SITE CONTEXT:** encompassing data from existing Deliverables D3.2, D3.3, and D3.4.
2. **CASE PEDAGOGICAL CONTEXT:** the setting’s teaching and learning policies and planning documents as appropriate, assessment records if they exist, overview of resources and a map of the space.

3. CASE OBSERVATION OF PEDAGOGICAL INTERACTION AND OUTCOMES (episodes of learning involving children and teachers):

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

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

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

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

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

All core instruments as outlined above were used during the fieldwork in partner countries: a map of the classroom, sequential digital images, fieldnotes, audio recording, timeline, individual interviews with teachers, learning walks with children and artefacts such as teachers' files and journals, lesson plans, marking schemes, curricular documents, and examples of children's work. In some countries it was also possible to make use of some of the repertoire instruments suggested. Permission was obtained to use video recording in some settings and researchers in some partner countries were able to make use of Fibonacci style tools to support diagnostic observation, the Laevers Involvement Scale or conceptual drawing. Although the core instruments were used in each partner country, the case studies did not always draw on every instrument, depending on relevance. Some of the class teachers involved in the fieldwork had completed the CLS teacher questionnaire in 2012 during Work Package 3. Those who had not were asked to complete it in 2013. In addition to these sources of evidence, researchers used information from school policies and websites, inspection reports and national and local curriculum documents to establish the context of the research.

2.3 Data Collection

2.3.1 Sampling principles

The *Methodology for in-depth fieldwork* (D4.1) specified that each partner should visit a minimum of four sites (i.e. schools/preschools), five where possible, and gather data from a minimum of six cases (i.e. one teacher and the children they work with) reflecting both settings (preschool and primary education). In order to reflect the science and mathematics focus of the project, partners were asked to aim to identify three episodes of activity per case (ensuring at least one each of science and mathematics) resulting in a total of 18 episodes to be reported per partner. The episodes were intended to provide illustrations of actual practice - chosen because they exemplify one or more of

the aspects identified in Table 1 as having a strong potential to foster the development of creative skills in children in early science and mathematics.

The sample of cases was thus deemed to be a purposive one, involving a range of contexts, learning opportunities and teacher populations and age ranges of children. Moreover, the following selection criteria were identified to inform the selection of each national sample (see D4.1, p28):

- Includes appropriate diversity (e.g. in respect of culture, circumstance, language).
- Covers appropriate age span 3-8.
- Represents span of mainstream (i.e. not special) early years provision.
- Settings primarily focused on education not care.
- There are indications of good practice of early years mathematics, science and creativity.
- Allows us to mine one or more of the important research foci (identified in previous deliverables and shown in Table 1).
- Geographical accessibility for researchers.

2.3.2 Ethical issues

Any fieldwork undertaken with young people can potentially carry ethical implications, both in terms of the conduct of the researcher whilst undertaking fieldwork, and in the collection and use of data following the fieldwork period.

The consortium identified the following minimum standards that were applied by all partners in all cases:

- Participation in the research was on an informed voluntary basis. Letters for school staff and parents were developed for this purpose (see D4.1, Appendix 4, p72). Written consent was obtained before the fieldwork was undertaken. The right to withdrawal was clearly communicated.
- Explicit permission was requested to take and use photographs (and videos where appropriate) of the children and staff for the project in project reports and publications.
- Explicit permission was requested to interview children as part of focus groups.
- Any electronic data collected was stored on password protected encrypted storage systems, where only authorised staff had access. An agreed protocol for storage and labelling of data was agreed (see D4.1, Appendix 7, p85).

In all cases the importance of confidentiality and anonymity was emphasised. The sites used, and the adults and children who were involved were given pseudonyms to protect their identities.

In addition each partner was required to identify and meet the ethical approval policies for their institution, school system, region and country as appropriate. This included for example gaining ethical approval from institutional ethics committees, municipal education authorities or educational directorates and obtaining official clearance for work with children in line with local or national child protection procedures.

2.4 Data Analysis and Reporting

2.4.1 Analysis of data from fieldwork

As already mentioned, the methodology agreed for the fieldwork specified that each partner would produce a minimum of six identified cases, with a minimum of three narrative episodes per case to explore fully the opportunities presented for the fostering of creativity in early years science and mathematics education. A narrative episode in this case was defined as a written narrative account that describes an observed event or series of connected events of science and mathematics teaching/learning with a creativity focus, which forms a coherent story in itself. These were to be drawn from observations selected for their relevance to the pre-identified project factors and supported by information gathered through a minimum of two types of core data. Where possible the views and thoughts of the children in addition to those of the teachers were sought; extracts from relevant transcripts, containing the key areas of interest specific to the focus of the episode were provided to support the narrative account.

As already mentioned, all data were coded using a set of deductive codes, based on the project factors (see Table 1), and were reported in terms of Siraj-Blatchford et al.'s (2002) framework to explore features of pedagogy in terms of pedagogic framing and pedagogic interventions. Examples of opportunities for science or mathematics creativity were highlighted. All partners were required to provide an appendix to the account of each episode. This included the factor grid shown in table 1, highlighted to indicate the factors identified in the episode, supported by coded extracts from field notes and other sources of data as appropriate.

Finally, the episodes were combined in overall cases, which included information about the site, the setting and the teacher. In addition partners provided factor grids summarizing the factors identified in the episodes reported.

2.4.2 Production of the D4.3 Country Reports

The *Methodology for in-depth Fieldwork* (D4.1) and the *Internal Training Workshop* (D4.2) provided a common basis for the conduct of fieldwork and analysis of data across the consortium. During the *Internal Training Workshop* procedures were also established for sharing and discussing issues arising fieldwork, for moderating judgements and promoting consistency in the presentation of the Country Reports. The 11 partners were divided into four sub-teams, each led by a WP4 team leader to provide mutual support during the course of the work package. Members of sub-teams met both formally and informally through Skype on a regular basis to discuss progress and raise issues for wider consideration in monthly meetings of the WP4 team leaders. These meetings provided important opportunities to discuss the identification, selection and presentation of episodes, issues raised in implementing the framework for data analysis, the table of contents for Country Reports and emerging findings to feed into D4.4 *The Report of Practices and their Implications*. Building on these meetings common specifications were developed for the presentation of cases and episodes and the structure of the Country Reports. This provided a useful foundation for the synthesis of findings in D4.4.

2.4.3 Development of D4.4 Report on Practices and implications

This *Report of Practices and their Implications* draws together findings from across the *Country Reports*. As indicated earlier in section 1 *Aims of this Report*, the intention was to examine and exemplify opportunities for creativity in early years science and mathematics and to consider implications for teacher education, policy and research.

The summary of findings is based on synthesis and further analysis of data from the *Country Reports*, presented according to the dimensions and factors used across the *Creative Little Scientists* project in mapping and comparing practices under the following headings: *Factors identified Across Episodes*; *Themes and Issues identified in the Country Reports*; and *Selected Episodes: Opportunities for Creativity in Learning and Teaching*.

Quantitative analysis of factors identified in the reported episodes

Each partner produced a grid summarising the factors identified in each episode reported in their *Country Report*. These grids were then combined to provide a broad overview of the frequency of each factor across the episodes as a whole, and a breakdown according to preschool and primary school and science and mathematics episodes. These are shown in Appendix 2. This analysis provided the basis for commentary in relation to each dimension on the extent to which different factors were represented in the episodes reported, and any notable differences between preschool and primary school or science and mathematics. It should be emphasised however (as outlined in in section 1 *Aims of this Report*) that these data were not used to make comparisons between countries or sites, but rather to support reflection on opportunities and challenges for creativity in early science and mathematics. The sample, as indicated in the section 2.3 *Data Collection* was not chosen to be representative of typical practice and the coding did not indicate the strength of each factor in a particular episode, rather presence and absence.

Synthesis of discussion of findings from the Country Reports

Each *Country Report* included a *discussion of findings*, providing reflective commentary on opportunities and challenges for creativity in learning and teaching across the case studies reported. This focused on enabling factors at the contextual level, the extent to which different mapping and comparison factors were represented and any notable differences between preschool and primary school, or between science and mathematics across cases and episodes. Qualitative analysis was undertaken to identify themes and issues highlighted across the *Country Reports* and to offer further insights into patterns reported in the quantitative analysis of factors from the episodes. Themes and issues identified from across the consortium were validated through discussion in WP4 team leader and sub-team meetings, feedback on an early draft of the report and discussion at the 4th *Creative Little Scientists* Project Meeting.

Selected Episodes from each country to exemplify opportunities for inquiry and creativity in early science and mathematics

A key requirement of the *Description of Work* for D4.4 is that it should include a series of classroom examples to illustrate the approaches observed and possibilities identified for promoting inquiry and creativity in early science and mathematics. As a first step in selecting exemplary episodes, partners were invited to select their three strongest episodes from those included in their Country Reports, providing a clear indication of the bases for selection with reference to the mapping and comparison factors used in analysis of fieldwork data. In seeking to ensure exemplification of a broad range of factors, a grid was produced of the key factors partners had highlighted in the selected episodes. Where there were gaps, partners were invited to offer additional episodes to illustrate these. The final grid showing key factors illustrated in the selected episodes is included in Appendix 1. The narrative accounts of the *Selected Episodes* were summarised for inclusion in this report. Partners were asked to provide additional detail to ensure accessibility outside their wider case context. They also selected key extracts from their fieldwork data that best illustrated the opportunities for inquiry and creativity identified. This approach to presenting the *Selected Episodes* was trialled with teachers in a number of courses and conferences in partner countries and at the *Creative Little Scientists* Summer School in July 2013 and then refined at the 4th *Creative Little Scientists* project meeting that followed in July 2013. The full version of each episode can be found in the relevant Country Reports. The *Selected Episodes* can be found in Appendix 3 to this report. They are used to exemplify opportunities for creativity in learning and teaching in each section of the summary of findings below.

These different but interconnected sources of evidence provided the basis for discussion of findings and their implications in subsequent sections of this report.

2.5 Final sample

Details of the final sample of sites, cases and episodes selected for fieldwork are provided in Tables 2, 3 and 4 below.

Table 2 indicates the number of sites (and cases) included in each Country Report and characteristics of the sites selected. Fieldwork was conducted on 48 different sites across partner countries resulting in 71 case studies of practices in early science and mathematics. The case studies focused on individual teachers and the opportunities for inquiry and creativity within their classroom practice. The case studies included background information about the teachers and their school and class context, as well as a narrative account of three episodes of their teaching. In line with the sampling principles set out in *D4.1 Methodology for in depth fieldwork*, the sample included provision for preschool and primary education in a range of contexts, urban, suburban and rural, and with an intake of varied diversity.

Table 3 provides information about the number of cases reported in each country and the age ranges covered by these cases. The sample covered the appropriate age span of 3-8 years. The sample of cases included a small number of mixed age classes.

Table 4 provides an overview of the number and nature of the episodes reported across the partnership, indicating the numbers of preschool and primary cases and episodes included in each Country Report and their distribution in terms of subject content (science, mathematics or integration of science and mathematics). A total of 218 episodes were analysed and reported, including episodes focusing on science and mathematics and instances where science and mathematics were integrated in the episodes observed.

In accordance with the sampling principles detailed in D4.1 *Methodology for in depth fieldwork*, in the great majority of countries it was possible to visit at least 4 sites and gather data from a minimum of 6 cases. The 3 partners in the UK in particular, had to gather data from a minimum of 25 cases as prescribed in the Description of Work, given the anticipated wider variety of practices of science and mathematics education in preschool and early primary education in its four constituent countries (England, Wales, Scotland and Northern Ireland). The aim overall across the consortium was for a minimum of 66 cases and 198 episodes (3 episodes per case). As can be seen in Table 4 the total numbers of cases (71) and episodes (218) well exceeded this minimum requirement.

Finally partners drew on a range of information in selecting sites and settings which would offer opportunities for observation of 'exemplary practices' in fostering inquiry and creativity in early science and mathematics. In some partner countries it was possible to draw on data based on inspection reports or children's attainments. Partners also made use of local information, for example from local education authorities or teacher training institutions, about the quality of particular settings. In addition partners were able to refer to findings from the *Creative Little Scientists* teacher survey associated with Work package 3. Details of the bases for selection of schools are included in each Country Report.

Table 2: Sample of fieldwork sites across the consortium

Country		Belgium	Finland	France	Germany	Greece	Malta	Portugal	Romania	UK	Total
Fieldwork Sites (number of cases)		4 (6)	5 (6)	5 (6)	4 (6)	4 (6)	4 (6)	3 (5)	4 (6)	15 (24)	48 (71)
Phase	Preschool	3	3	3	2	2	1	3	2	10	29
	School	1	2	2	2	2	3	2	3	10	27
Governance	Non-fee paying	4	2	4	3	3	3	2	3	15	39
	Fee paying	0	3	1	1	1	1	1	1	0	9
Special school		0	0	0	0	0	0	0	0	0	0
High Diversity	SEN	3	5	1	1	0	0	0	0	5	15
	Non-native speakers	4	1	2	2	2	1	0	0	6	18
	Socio-economic disadvantage	2	5	1	0	2	1	0	0	8	19
Location	Urban	2	0	2	2	1	0	2	4	7	20
	Suburban	0	3	2	2	2	3	1	0	6	19
	Rural	2	2	1	0	1	1	0	0	2	9

Table 3: Number of cases across the age span 3-8 covered by the project

Country		Belgium	Finland	France	Germany	Greece	Malta	Portugal	Romania	UK	Total
Fieldwork Sites (number of cases)		4 (6)	5 (6)	5 (6)	4 (6)	4 (6)	4 (6)	3 (5)	4 (6)	15 (24)	48 (71)
Number of cases including children of this age group	2-3	1	0	0	0	0	0	0	0	0	1
	3-4	2	1	3	2	0	1	0	1	8	18
	4-5	2	1	2	3	1	0	3	0	6	18
	5-6	3	3	0	3	2	2	0	2	7	22
	6-7	1	2	1	2	2	1	0	1	3	13
	7-8	1	3	2	1	1	2	1	2	2	15
	8-9	0	3	1	0	0	0	1	0	1	6
Mixed age groups		2	6	2	3	0	0	0	0	3	16

Table 4: Sample of episodes across the consortium

Partner	AUC		UEF		UPJV		GUF		EA		UoM		UMinho		NILPRP		BG, IoE, OU		TOTAL		
	BE Pre	BE Sch	FI Pre	FI Sch	FR Pre	FR Sch	GE Pre	GE Sch	GR Pre	GR Sch	MA Pre	MA Sch	PT Pre	PT Sch	RO Pre	RO Sch	UK Pre	UK Sch	Pre	Sch	ALL
Cases	4	2	3	3	4	2	3	3	3	3	1	5	3	2	3	3	13	11	37	34	71
Episodes	13	6	10	8	12	6	9	9	9	9	3	17	7	6	9	10	43	32	115	103	218
Science	3	2	4	5	7	0	5	4	5	6	2	9	4	3	7	8	31	17	68	54	122
Mathematics	2	4	3	3	5	6	1	1	4	2	1	7	3	3	0	2	10	14	29	42	71
Science and Mathematics	8	0	3	0	0	0	3	4	0	1	0	1	0	0	2	0	2	1	18	7	25

2.6 Limitations

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

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

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

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

3. Summary and Discussion of Findings: Revisiting the Mapping and Comparison Factors

This section draws together findings across the nine Country Reports from partner countries. These are presented according to the dimensions and factors utilised in data analysis, as outlined in the methodology above and shown in Table 1. The discussion of findings is informed by the following definitions of ‘creativity’ and ‘creativity in mathematics and science’ proposed in the *Conceptual Framework* for the project (D2.2) namely:

Little ‘c’ creativity - Purposive and imaginative activity generating outcomes that are original and valuable in relation to the learner - something of which we are all capable.

Creativity in mathematics and science - Generating alternative ideas and strategies as an individual or community and reasoning critically amongst these and between them and existing, widely accepted explanations and strategies.

First, in relation to each dimension an overview is provided of the extent to which the factors identified in D3.1 *List of Factors* as associated with creativity were represented across the episodes reported. This draws on the *Factor Summary Grid* provided in Appendix 2. This shows the frequency of each factor across all episodes as well as a breakdown of frequencies according to preschool and school and mathematics and science. This is followed by a synthesis of themes and issues identified in the relevant discussion sections of the Country Reports. In both instances commentary is included on any notable differences between preschool and school settings and between science and mathematics. Finally, examples are provided from the *Selected Episodes* (included in Appendix 3) to illustrate and discuss opportunities for inquiry and creativity. The key challenges highlighted in the Country Reports are summarised.

3.1 Aims and objectives

3.1.1 Factors identified across episodes

Overall features of episodes

Across the episode data set as a whole there were many examples of episodes reflecting the range of aims associated with inquiry and creativity in early years mathematics and science as identified in D3.1 *List of Factors*. Aims associated with *social and affective factors* were most strongly represented. Social factors were identified as aims in about three quarters of the episodes and affective factors in well over half the episodes. *Knowledge and understanding of science content, science process skills, capabilities associated with IBSE/PBL* and aims associated with *creative dispositions* were identified in around half the episodes, although few episodes were explicitly planned to foster creativity. Aims associated with *understanding about scientific inquiry* featured least (only identified in about a quarter of the episodes). This pattern corresponds closely with the findings from the *Teacher Survey* (D3.3) undertaken as part of Work Package 3.

Differences between preschool and school

Few differences were noted between the aims associated with preschool and primary episodes although in primary settings these were more likely to be made explicit.

Differences between science and mathematics

A review of the aims of the episodes focused on science or mathematics and those that integrated both science and mathematics suggested that social factors featured most strongly across episodes regardless of content and framing. The science episodes indicated the greatest opportunities for the development of knowledge and understanding of subject content, understanding about scientific inquiry and development of science process skills. Activities integrating science and mathematics featured more strongly the use of IBSE/PBL approaches, promotion of affective factors and creative dispositions, although this needs to be treated with caution, given the small number of such episodes (25/218) recorded.

3.1.2 Themes and issues identified in the Country Reports

General themes and issues

Aims often not explicit

In a number of Country Reports it was noted that aims of activities were often not made explicit in planning documentation, particularly in preschool settings, reflecting varied levels of detail required in planning at school and national levels and differences in approaches to planning between preschool and school settings. Where such evidence was not available it was necessary to draw inferences about the aims of experiences provided from classroom observations and discussion with teachers. Partners noted that aims related to cognitive factors were most commonly listed in formal planning documents. In contrast, while aims focusing on social and affective factors were considered important by teachers, as evidenced in teacher interviews and classroom observations, they were often not recorded in planning documents. There are connections here to findings from the policy and teacher surveys in Work Package 3 that indicated teachers' strong emphasis on social and affective factors in learning in contrast to the strong focus on cognitive factors in formal assessment requirements in policy. Specific aims related to creativity or IBSE/PBL were rarely indicated in either teacher interviews or planning documents, although they were often implicit in the focus of learning and teaching.

Influence of policy

The Country Reports made reference to the influence of policy on the aims of activities reported in the episodes. In most partner countries, general principles set out for early years education emphasise the importance of a holistic approach combining cognitive, social and affective dimensions in learning. Specific learning goals for science and mathematics tend to focus on cognitive factors related to knowledge and understanding of science and mathematics content and the development of process skills associated with problem solving and inquiry. However, as indicated in *The Report on Mapping and Comparing Recorded Practices* (D3.2) policy documents across the consortium make limited reference to knowledge and understanding of the nature of science and mathematics. While there are

often references in policy to fostering learning dispositions associated with creativity, inquiry and problem solving, limited explicit indication is given of how this might be reflected either in provision for or in assessment of early learning in science and mathematics. Furthermore, there are relatively few explicit policy references to creativity as such and this is arguably mirrored in the lack of focused attention to creativity per se in the aims of many, though not all, of the activities seen in the episodes.

Importance of broad goals

The importance of working with broad goals was emphasised in a number of Country Reports. Partners suggested this offers scope for creativity in making connections across a range of areas of learning, both within and across subjects. They highlighted the dangers of fragmentation into isolated objectives and areas of study. As outlined in the *Report on Mapping and Comparing Recorded Practices* (D3.2) policy requirements in many countries group sciences within broader areas of learning such as 'Study of the Environment' (Greece) or 'World Orientation' (Belgium Flanders), particularly in preschool education. This has the potential to foster connections between different experiences and areas of learning. As indicated above, it was also noted that episodes integrating science and mathematics offered rich opportunities for problem solving, inquiry and creativity.

Importance of teachers' perspectives

Finally it was noted that teachers' perspectives on learning and teaching in early mathematics and science, as shown in teacher interviews and the teacher survey, were very influential in the aims associated with learning experiences, regardless of the policy context. This is illustrated in a number of the case studies associated with the *Selected Episodes* reported in Appendix 3. For example the experiential emphasis in *BE Carpenter Corner* and *UK(NI) Gloop* reflects the influence of the work of Reggio Emilia on the teachers' views about the nature and purposes of early years education. Froebelian perspectives informed the aims and child-centred approaches associated with *UK(SC) Forest School*. The problem based learning in mathematics described in *DE Fermi questions* was informed by Montessori principles and the teacher's involvement in Pri-Sci-Net, an EU programme to promote IBSE at the primary level. The role of school and teacher perspectives in fostering creativity is discussed further in section 3.10 in reflecting on enabling factors and barriers at the contextual level.

Differences between preschool and school

In a number of Country Reports partners commented that the greater emphasis on subject content in some primary episodes reflected more detailed curriculum requirements in the primary age phase. There tended to be a focus in preschool on language development (providing tools for describing and explaining phenomena and experiences and foundations for later conceptual development), and a greater emphasis in primary school on the development of more detailed subject specific knowledge.

Differences between science and mathematics

In a number of countries partners commented that mathematics education is given greater importance in policy than science. Outcomes are monitored more closely in mathematics, for example through testing. Partners suggested that while this may result in greater time allocated to

mathematics activities, particularly in primary school, it may also constrain the aims of activities to focus on factual knowledge at the expense of the development of skills and attitudes associated with inquiry and creativity. Despite this, the mathematics episodes reported provide examples of the ways in which teachers' promotion of attitudes and skills associated with inquiry supported children's developing knowledge and understanding.

3.1.3 Selected Episodes: Opportunities for inquiry and creativity in learning and teaching

The *Selected Episodes* provide rich examples of learning and teaching reflecting the range of aims of science and mathematics education identified in the D3.1 *List of Factors* as associated with inquiry and creativity. In particular there were a number of cases and episodes where the promotion of IBSE/PBL and creativity was made explicit in teachers' aims for activities, in the teaching and learning approaches adopted and in dialogue with children. These episodes also illustrate some of the ways in which aims associated with IBSE/PBL or creativity were interconnected with the promotion of social and affective factors important in learning, and the development of specific skills and understandings in early science and mathematics.

For example in the episode *BE Carpenter Corner* the teacher Maaïke explained her intentions behind the learning and teaching approaches she adopted, emphasising the importance of inquiry, agency and creativity and the important role of evaluation in design processes:

"The product is not always that beautiful but the process is important. Usually we have the following approach: we explore the material (it is in fact inquiry), then we design (with evaluation), then we make it more aesthetic and then we look at the different properties of what we created. The design has to come from their own thinking and creativity, no creation of the children is just copied, they all are original. They also have to evaluate what they have made themselves."

Through their designing and making processes children explored and thus developed their knowledge of properties of materials. In scaffolding children's designing and making processes the teacher fostered collaboration and supported the development of skills associated with using a saw and measuring.

The teachers in episodes *DE Fermi Questions* (Andrea) and *RO Float and Sink* (Maria) had both been involved in initiatives related to IBSE. Features of IBSE were made explicit in both episodes. In *DE Fermi Questions* Andrea underlined her focus on PBL processes in mathematics. She introduced children explicitly to the thinking behind Fermi questions and problems that *"encourage multiple approaches, emphasise processes rather than specific answers or results and promote non-traditional problem solving strategies"*. In her interview Andrea indicated that Fermi questions provide valuable opportunities both to foster process skills and to teach curriculum content. Additionally, the Fermi questions provided space for children's purposeful imaginative activity. A further important focus during this episode was the development of social skills associated with dialogue and collaboration to support children's problem solving. In *RO Float and Sink* Maria asked children to find ways in which a dove could find ways to save an ant that had fallen into a creek. Across the episode there is a strong



emphasis on children suggesting, testing and evaluating possible solutions and fostering reflection and reasoning. Maria sought to promote engagement and motivation through setting the activity in the context of a fairy tale and encouraging connections with children's experiences of events and materials in their everyday life. Features of the nature of science are highlighted through posters in her classroom that focus on 'What do Scientists do?' and an emphasis on empirical evidence in the discussion of findings.

The aims for children's learning in the three episodes above focused on children generating and evaluating alternative strategies and novel ideas, both individually and/or communally, as identified in D2.2 *Conceptual Framework* as key features of creativity in early science and mathematics. The *Selected Episodes* also included examples in which teachers planned explicitly to provide opportunities for children's creativity in representing and expressing ideas in their own ways. For example in the mathematics episode *UK(EN) Counting Minibeasts*, the teacher Lisa aimed to promote children's creativity in devising different approaches to representing counting processes and recording results. In *UK(SC) Day and Night* the teacher incorporated a range of materials for children to represent their growing knowledge of Earth in Space.

Some of the *Selected Episodes* reflected teachers' concerns to promote social factors in learning. For example, the organisation of the sessions *FR Ice Cream Sticks* and *FR Magnet Attraction* indicated the importance given by the teachers to a balance between opportunities for individual and group exploration and collective decision-making and debate. This approach reflected an explicit focus on conceptual development and the promotion of citizenship. Deliberate orchestration of varied groupings associated with *UK(EN) Balancing Pens* was employed to promote collaboration and dialogue in the class and foster reflection and reasoning.

Challenges

As suggested above, partners identified a number of key challenges associated with the aims and objectives of activities. Partners noted that that aims of activities were often implicit, in particular aims associated with social and affective factors and with creativity often remained unstated, embedded within the action but not within specified intentions or teachers' planning. There is evidence from the episodes (for example: *GE Fermi Questions* or *UK(EN) Habitat*) that making aims explicit and sharing them with children can enhance opportunities for creative learning. (This is discussed in Section 3.4 Assessment below.) A second concern raised by partners related to the limited attention given to the nature of science and mathematics. This does not feature strongly as an aim in policy for science and mathematics in the early years, and while potential for discussion of the nature of science was indicated in a number of episodes (for example: *GE Water Enquiry*, *GR Measuring Tables*, *RO Float and Sink* or *PT Swing Game*), particularly in fostering reflection and reasoning (see Section 3.3 Pedagogy below), full advantage was rarely taken of such opportunities. Finally, partners highlighted the dangers of a narrow focus on isolated objectives, sometimes associated with specific curriculum and assessment requirements. They underlined the importance of broad goals, and encouraging children to make connections both within and across subjects to deepen understanding and support application of strategies and ideas across contexts.



3.2 Learning activities

3.2.1 Factors identified across episodes

Overall features of episodes

The learning activities included in episodes across partner countries illustrated considerable potential for inquiry and creativity in early science and mathematics. The episodes recorded included many examples of all the learning activities identified as associated with inquiry and creativity in early science and mathematics (see D3.1 *List of Factors*). *Observing* and *making connections* featured most strongly (in about three quarters of the episodes). *Questioning*, *planning*, *gathering evidence using equipment*, and *communicating and explaining evidence* (more specific to inquiry in science and mathematics) received less attention, however were still represented in more than half the episodes.

Differences between preschool and school

Differences between preschool and school were not particularly marked, although opportunities for questioning and observation were slightly greater in preschool. In primary there was a greater focus on planning and some greater emphasis on social dimensions associated with communicating, explaining evidence and communicating explanations. This reflects differences in policy reported in *Report on Mapping and Comparing Recorded Practices* (D3.2) where an experiential approach was noted in preschool policy and a greater emphasis on the introduction of more formal procedures associated with inquiry and problem solving in policy for the primary age phase.

Differences between science and mathematics

Some differences were evident in comparing science and mathematics episodes and those that included integration of science and mathematics (both planned and incidental). There was a much higher incidence of explaining evidence and communicating explanations in episodes integrating science and mathematics. As indicated in the previous section the number of episodes integrating science and mathematics was small so this would need further investigation. However it does suggest some support for partner commentary in the previous section on the importance of broad goals in fostering opportunities for inquiry and creativity in learning. There was a lower incidence in mathematics episodes, in comparison to episodes featuring science content, of questioning, observing, and making connections.

3.2.2 Themes and issues identified in the Country Reports

Overall features

Commentary in the Country Reports highlighted strongly the focus across episodes on learning activities encompassing both cognitive and social dimensions. Partners drew attention to a number of factors that promoted children's engagement and influenced the range of learning opportunities provided and creativity evidenced in the episodes observed.



They noted the role of rich motivating contexts and the value of setting challenges for children in generating ideas, questions and interest. A number drew attention to the potential of cross-curricular approaches in providing opportunities for making connections with everyday life and children's prior knowledge and experience. Partners also commented on the importance of not just generating, but building on children's imaginative ideas, interests and questions to foster engagement with the range of learning activities. They noted the importance of teacher flexibility to take account of children's suggestions and responses. Detailed structuring of activities in advance was seen to limit children's agency and opportunities for decision-making. Partners highlighted the importance of time in determining the range and scope of learning activities – time to follow up ideas, learn from mistakes, generate and consider alternative ideas and strategies and develop questions. This has implications for policy at different levels as discussed later in this report.

Partners drew attention to the key contributions of group work and discussion in fostering agency and promoting social dimensions of creative inquiry (See later comments in 3.2 Pedagogy related to collaboration). They noted the important role of the teacher in encouraging verbalisation and prompting explanation. The combination of group work with opportunities for collective reflection and discussion was a common feature of primary episodes incorporating social dimensions of inquiry.

Differences between preschool and school

Partners noted differences in emphasis in the nature of learning activities included in preschool and primary episodes. In preschool, play-based learning activities involving manipulation of materials were common, designed to foster questioning, observation and the generation of ideas. The development of positive attitudes to learning and the development of vocabulary were often prioritised. Learning experiences in preschool were often cross-curricular in nature and generally afforded greater opportunities for child-initiated activity than in primary settings. Partners commented that in primary episodes, greater teacher direction and pressures of time often restricted the scope of learning activities, in particular in relation to children raising their own questions or developing or following up their investigations. Although tasks were more often teacher initiated, primary episodes illustrated ways in which there can still be scope for children's agency, decision-making and creative engagement. In addition, partners noted that learning activities in primary settings tended to indicate greater engagement with subject specific procedures and concepts, and reflected greater attention to planning investigations, explaining evidence and communicating explanations.

Differences between science and mathematics

In their Country Reports partners identified a number of differences between science and mathematics episodes in terms of the range of learning activities observed. Exploration and data gathering were more common features of science episodes, and science episodes generally provided opportunities for a wider range of process skills. Mathematics episodes included fewer examples of open-ended problem solving and often provided more limited scope for children's decision making. There was a greater emphasis on knowledge based questions and activities focused on particular outcomes in mathematics episodes. Additionally, mathematics activities, particularly in primary



settings, were more likely to involve written tasks and recording. However as indicated below, there were examples of episodes that incorporated problem based learning with scope for children's agency.

3.2.3 Selected Episodes: Opportunities for inquiry and creativity in learning and teaching

The *Selected Episodes* provide examples of the full range of learning activities identified as associated with inquiry and creativity. The different learning activities were evidenced in a variety of contexts as illustrated below.

Questioning: Across the episodes analysed in the Country Reports, children's questions provided important starting points and motivation for inquiry, emerging at different stages in classroom activities. In some episodes children were invited to come up with their own questions for investigation at the start of a new topic or activity (see for example *GR Ice Balloons* or *UK(EN) Starting Points*). This provided children with opportunities to influence the direction of future activities and in addition gave the teacher insights into their developing thinking. Often however, questions surfaced during activities. In preschool episodes involving child-initiated play, questions were often implicit in children's actions as they explored materials, equipment and phenomena. This is suggested for example in *UK(NI) Gloop* by Ryan's use of different tools in exploring a mixture of cornflour and water. In other instances children posed their own questions to investigate, building on earlier challenges set by the teacher. For example in *PT Sun and Distance* children raised new questions prompted by earlier explorations of the relative sizes of the Sun and the Earth and the distances between them such as "If the Sun was room size, what would be the Earth's size?" In *FI Ways to Count*, following exploration of different ways of using equipment to solve mathematical problems, one child asked "How can you count up to 18 with fingers? I don't have so many fingers". This question was set as a problem to discuss in pairs and alternative solutions were shared with the whole class.

More generally an important issue was not just whether children were encouraged to raise questions, but how far they were given opportunities to find ways to answer them. This depended for example on whether teachers recognised the potential in child-initiated play or had scope to build on children's questions in planning for subsequent sessions. In some of the cases associated with the *Selected Episodes* there was evidence of ways in which teachers capitalised on children's persistent interests and questions. For example in relation to *UK(SC) Forest School*, the child Ian's active interest in living things had been recorded in his class profile and was fostered by centre staff as was evident in this episode. In *UK(SC) Day and Night* the teacher Petra built on the questions children had raised at the start of the project. Class projects in this setting were regularly recorded in class floor books that tracked the progress of projects over time using photographs of activities and displays and examples of children's work and comments. They provided rich evidence of children's questions and ideas, the range of investigations undertaken and what children had learnt. This reminded children of their experiences and drew their attention to the processes involved in inquiry for example how their questions had led to investigations or how records of observations they had made informed conclusions.

Designing or planning investigations – Episodes recorded across the consortium provided many examples of opportunities for children’s decision making in designing or planning investigations. In a number of instances children were set challenges or problems to be solved, and were asked for example to select suitable materials, decide on an appropriate strategy and to justify the approaches adopted. For example in *FR Ice Cream Sticks*, children had to devise their own strategies to count a large number of ice cream sticks. Children were encouraged to suggest solutions, listen to alternative ideas and then to decide which was the most appropriate strategy and why. In *DE Water Inquiry*, children were challenged to come up with their own experiment to demonstrate that ice and steam both come from water. They were asked to document their planning through writing or drawing in a ‘scientists’ sheet’. In *RO Ice Investigations* children were set the challenge of helping a hungry squirrel to get an acorn out of an ice cube. Children were shown a range of materials and asked to work in groups to come up with a solution. In *UK(EN) Shapes* children were given the challenge of finding a shape that had more than six faces. In other episodes there was no set outcome and children undertook broader explorations of particular phenomena and events. For example in *BE Colouring* children investigated dyeing cotton cloth using natural materials. Children were able to select a rich range of resources and equipment from both inside and outside the classroom and to explore how long to leave the cloth in the dye solution. In *MT Counting Caterpillars*, children were able to use the segments of a ‘counting caterpillar’ in different ways to find different pairs of number combinations to make up different number totals. Notable features of such episodes included the provision of a variety of materials, dialogue and collaboration in groups and teacher scaffolding to support reflection and reasoning.

Observing and using equipment – The case studies across the consortium included many examples of opportunities for children to make observations both inside and outside the classroom and to consider factors that might affect their observations. For example in *UK(EN) Buttons*, children were encouraged to observe what happened when they held a chocolate button in their hand for a short period of time. In making walls in episode *BE Sand Box* children observed the effects of using different materials for the bricks, varying the proportions of sand and water to make mortar and placing and balancing the bricks in different ways. In *UK(SC) Forest School* children made observations of the weather and of ice on the pond. In a number of instances children were able to use equipment to enhance their observations and aid comparisons. For example in *UK(SC) Forest School* the child was able to use a magnifier to look closely at samples of ice. Children often used non-standard or standard measures to support their explorations or investigations. For example in *MT Feet* children used a variety of resources to try out different ways of measuring their feet. In *RO Measuring Volumes* children used a variety of containers to measure the volume of water samples. In *FI Melting Snow* children measured the volumes of snow and water using litres and decilitres.

Making connections – Making connections played an important role in children’s learning across the episodes reported, connections between areas of learning, connections with prior experiences and connections between actions and effects as illustrated by the examples of *Selected Episodes* that follow. In *BE Carpenter Corner*, the children integrated measurement and the use of mathematical vocabulary into their design and making activities. In *PT Swing Game* a child made links to his/her

grandmother's pendulum clock in making a swing game to investigate factors that make a good swing. In *UK(NI) Gingerbread Man Raft*, children drew on their prior knowledge of materials in designing a raft for the Gingerbread Man to cross the river. Furthermore, one child drew on real life experiences to extend the activity by choosing materials to cover the Gingerbread Man to stop him from getting wet. The explorations of living things in the schoolyard in *MT Minibeasts* triggered connections to previous experiences of ants and to prior knowledge about the life cycle of a butterfly. In *GR Bee-bot* children demonstrated growing abilities to make connections between the buttons they pressed and the movement of the Bee-Bot as they tackled the challenge of programming the Bee-bot to get to the treasure. In these episodes there were examples of children making their own connections as teachers stood back, observed and gave children space to come up with their own ideas and make mistakes. However based on their observations, teachers also stepped in to support and extend learning. In the episode *BE Carpenter Corner*, the teacher noted the child's initiative to use measurement and then stepped in to encourage and support him in using a meter rule. In *GR Bee-bot* the teacher noted that the children were having problems with distinguishing left and right. He intervened to support children in remembering which was right and which was left and also drew attention to the fact that if someone is facing you, their right is your left (and vice versa).

Explaining evidence – Although social dimensions had been identified as under-represented in both the policy and teacher surveys (D3.2 and D3.3), there were examples across the cases in the Country Reports of children explaining evidence, often prompted by interactions with other children or the teacher, or by the need to justify conclusions in presenting ideas and findings to the whole class. In *FR Share*, children worked in a group with a teaching assistant sharing sweets made from salt dough. Children were able to explain whether they thought the sweets had been shared fairly, justifying their responses based on their observations of whether each child had the same number. In *DE Building Blocks* children were able to explain to the teacher why they thought their 'Leaning tower of Pisa' kept falling down drawing attention to particular observations, communicating using gesture as well as oral commentary. In *UK(EN) Fruit Café* children were given a set of papers, each paper showed a set of coins (7 x 1p, 3 x 5p and 5 x 2p) and children had to decide which set of coins they would choose and why. Children were able to offer reasons for their choices making reference to the number of coins and/or their value. In *RO Float and Sink* the children investigated which materials would be best to help rescue an ant that has fallen into a creek. Each group was asked to present their findings to the class. The teacher here played an important role in prompting children to justify their conclusions with reference to the evidence collected during their inquiries.

Communicating explanations – There were varied opportunities across the episodes for children to communicate explanations, mainly through dialogue with others (in common with explaining evidence), but also through written recording. In some instances the nature of the task itself led to communication of explanations within groups. For example, in *PT Wolf, Sheep, Cabbage* children were asked to find ways to move a wolf, a sheep and a cabbage in a boat across the water to the opposite shore so that none of them were eaten up in the process. As children worked in groups to come up with possible solutions, they explained their suggestions to others, drawing on their knowledge of food chains. In a number of episodes, class discussion provided important opportunities for children to

discuss explanations. For example in *UK(EN) Habitat*, children were asked to design a habitat that would provide camouflage for an animal. At the start of the session the children were shown three paintings of animals in different settings and asked to express their views about whether the animals were well camouflaged and how the artist might have achieved this effect. At different points during the session children engaged in peer assessment of the habitats they had designed for their animals, explaining the features they felt were successful and offering suggestions for improvement. At the end of episode *FR Magnet*, the teacher supported children in coming to shared categorisation of objects according to whether they were attracted to the magnet or not, drawing out children's suggestions and explanations.

The *Selected Episodes* also illustrate the value of varied forms of communication and representation in supporting learning and the important opportunities this can offer for dialogue with peers and adults. (See for example: *FI Multiplication Story*, *GR Measuring tables* and *UK(EN) Counting Minibeasts*.) In *Counting Minibeasts* children represented their ideas using physical materials and in writing, but it was the dialogue with the teacher that provided insights into their thinking and explanations. In *Multiplication Story* the children were asked to compose multiplication stories linked to the features of a tree and to record them in drawing and/or writing. In *Measuring Tables* children worked in teams to record instructions (measurements) for the carpenter who would be making new tables for the classroom. Again discussion about children's recording, in this case with the whole class, provided important further insights into the explanations underpinning children's recording.

Challenges

As suggested across this section, time limitations were reported as the major issue that affected the range of learning activities offered to children, in particular time for children to develop and follow up ideas and questions. Partners indicated that in some instances the school timetable, or lack of flexibility in planning requirements, meant that it was not always possible for teachers to capitalise on the creative potential in activities or children's responses. Teacher factors also played a key role in determining the scope for children's decision making. The most effective episodes, in relation to fostering creativity in science and mathematics were built on careful observation of children's responses and sensitive intervention, with questioning to build on and extend their inquiries. (This is discussed in subsequent sessions on scaffolding and the role of teacher assessment). Too much teacher direction, often based on a concern to meet curriculum requirements, restricted scope for inquiry and creativity.

3.3 Pedagogy

3.3.1 Factors identified across episodes

Overall features

Factors associated with creative teaching were well represented across the episodes reported by partners. Almost all factors (previously identified in D3.1 *List of Factors*), were identified in at least half

of the episodes. The exceptions were *play* and *diverse forms of expression*. These two factors featured in just under half the episodes. As discussed in sections 2.4.3 Limitations, the relatively low representation of play may have been in part a product of limitations of time and resources to capture the changing dynamics of free flow activity, particularly in preschool settings. The factors most strongly represented in the episodes were *scaffolding*, *collaboration* and *problem solving and agency*.

Differences between preschool and school

Some differences were noted between preschool and school settings across the consortium. The role of play and motivation and affect featured much more strongly in preschool pedagogy. There was also greater incidence in preschool episodes of promoting dialogue, encouraging children's questioning and fostering reflection and reasoning. No differences were suggested in relation to other factors associated with creativity.

Differences between science and mathematics

No strong differences were noted between mathematics and science in terms of the factors associated with opportunities for creativity and inquiry. Although there was some slight indication of greater focus on collaboration, dialogue and expression in mathematics and more scaffolding and questioning in science. The analysis of episodes across the consortium suggested that factors associated with creativity in teaching were more strongly represented in activities integrating science and mathematics. Episodes integrating science and mathematics were more common in early years settings. Countries with policies reflecting child centred perspectives on early learning such as Belgium, Finland and Germany had the greatest proportion of episodes integrating science and mathematics.

3.3.2 Themes and issues identified in the Country Reports

Overall features

As indicated in section 3.1 Aims and Objectives, there was evidence from case studies across the consortium of the influence of school policy and teachers' views of learning on the pedagogical approaches observed during fieldwork. For example teachers referred to child-centred experiential perspectives associated with Reggio Emilia, Froebel, Montessori and Laevers or to training in inquiry based learning, in explaining their emphasis on play, the processes of learning and on children's agency. Opportunities for *children's exploration* and for *dialogue and collaboration* were important features of episodes across both preschool and primary settings. In line with findings from the *First Survey of School Practice* (D3.3) partners indicated that promoting *children's motivation and interest* was given high priority in approaches adopted, particularly in preschool, and in many episodes, teachers' own enthusiasm played a significant role in fostering children's engagement. Strategies to promote motivation such as *use of stories*, connections to children's *prior experiences* and to *everyday life* were often employed. However partners noted very limited use of *drama or history* and as suggested earlier, the employment of *approaches integrating science and mathematics* varied considerably across countries. 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. Furthermore, the research indicates that the role of varied forms of representation in learning could be more widely recognised. Fieldwork indicated the value of dialogue with children about their recording, and the potential of representation and expression, not just for recording outcomes, but for fostering reflection and reasoning processes. For example time for children to represent experiences in the classroom often prompted discussion with peers and adults and further questioning. In many instances interviews with children about their work (such as written recording, drawings, models) provided rich insights into their thinking and learning processes. As discussed below, commentary in the Country Reports underlined the importance of teachers standing back to allow children opportunities to explore and make their own decisions. However, it also drew attention to the potential of sensitive responsive scaffolding to support independence and extend learning. Finally across the dimensions issues of space and time and the constraints of curriculum requirements and teachers' planning come through strongly in the Country Reports as factors affecting pedagogical approaches observed and limiting potential for inquiry and creativity.

Differences between preschool and school

Commentary in the Country Reports drew attention to the greater evidence of pedagogical approaches associated with creativity and inquiry in preschool settings. This included for example reference to a stronger emphasis on play and the use of games, the more widespread employment of drama and role-play and more generally greater space and time for child-initiated inquiry. There was more evidence of teacher initiated and teacher led activity in primary settings and although digital technologies were more widely used, this was mainly by the teacher.

Differences science and mathematics

The Country Reports from most countries identified no strong differences between science and mathematics pedagogy. In some countries partners commented on a tendency for more inquiry based pedagogy in science, accompanied by a greater focus on opportunities for children to express their ideas.

3.3.3 Selected Episodes: Opportunities for inquiry and creativity in learning and teaching

The *Selected Episodes* included varied examples of pedagogical approaches that fostered creativity and inquiry in both preschool and primary settings.

Play and exploration – In the preschool settings described in *BE Sand Box* and *UK(NI) Gloop*, staff provided rich materials and equipment. Children were given time and space to explore, to observe how materials behaved, try out equipment and pursue their own ideas and interests, on their own or alongside other children. Adults observed. At times they asked questions, but children determined the direction of inquiry. In *UK(NI) Gingerbread Man Raft* and *UK(EN) Café* there were also opportunities for play and exploration but teacher had a greater role in structuring and setting the purpose for activities. The Fruit Café described in *UK(EN) Fruit Café* was based around the daily provision in the

class of snacks of fruit or vegetables and a drink for children. They ran the café themselves each day with the support of a teaching assistant. However teacher led, whole class activities related to money and counting, and teacher involvement in setting the menu of prices played important roles in establishing practices and in supporting children's independent application of mathematical knowledge and skills in the café context. The context for the *UK(NI) Gingerbread Man Raft* episode was the story of a Gingerbread Man. The teacher's aim for the activity was for children to explore the properties of materials to see which would be most suitable to make a boat for the Gingerbread Man to cross the river. Children were able to select materials from round the classroom and develop their own designs. As in *BE Sand Box* and *UK(NI) Gloop* adults visited the children occasionally to observe, encourage and extend exploration.

There were fewer examples of exploration in the primary episodes. Where they were included they were often designed to offer important opportunities for children to become familiar with specific phenomena or processes. For example In *UK(EN) Sound* children were provided with a variety of resources to explore different ways of making sound. The range of exploratory activities associated with the episode *UK(EN) Balancing Pens* were planned to introduce a range of skills and ideas associated with measurement. Children were able to select their own resources and ways of working and were encouraged to develop and reflect on their own ideas.

Motivation and affect – Teachers observed across both primary and preschool phases employed a variety of approaches to foster children's motivation and positive attitudes to science and mathematics. Often as in *DE Building Blocks*, teachers planned activities building on observations of children's interests, in this case their interests in Block Play (noted often across the consortium). Links with stories provided a motivating context in number of episodes. As already indicated in *RO Float and Sink* and *UK(EN) Gingerbread Man Raft* children explored which materials would be best suited to carry the story characters across the water. In *FR Share* the children shared sweets between the pigs from a familiar story and in *FI Multiplication Story* children were asked to write their own stories. Making connections to everyday life also helped to promote interest and engagement. The problems posed in *DE Fermi Questions* and *GR Measuring Tables* were related to real world phenomena taken from the children's school environment. In addition in *GR Measuring Tables* there was a clear purpose and audience for their investigations. Across the episodes there were illustrations of the ways in which activities in the outdoor environment helped to foster both positive attitudes to science and to the environment as shown in *MT Minibeasts* and *UK(SC) Forest School*. Teachers' own interest and enthusiasm also played a key role in promoting interest and motivation as was evident in *UK(SC) Day and Night*.

Role of dialogue and collaboration – In the great majority of episodes recorded in the Country Reports children worked in pairs or in small groups. This offered opportunities for children to articulate ideas in solving problems as illustrated in *UK(EN) Balancing Pens*, negotiate ways of working as shown in *GR Bee-Bot* or as in *BE Colouring* to support their peers and speculate what might happen. Class discussion also played an important role, particularly in primary settings, in encouraging sharing of experiences, reflection and reasoning. For example in *RO Ice* children debated materials they would need to get the acorn out the ice so that the squirrel Scrat could survive. In *FI Ways to Count* and *FR*

Ice Cream Sticks class discussion provided a forum for sharing and evaluating children's alternative strategies in solving counting problems.

Problem solving and agency – As indicated in the discussion of *Learning Activities*, the Country Reports included many episodes in which teachers provided varied opportunities for children's problem solving and agency, often with some guidance from the teacher. In a few episodes, mostly in preschool, the focus and direction for inquiry was initiated by children, prompted by the rich environment for exploration both inside and outside the classroom. See for example *BE Carpenter Corner*, *UK(NI) Gloop* and *UK(SC) Forest School*. In others, teachers supported children in raising questions to be investigated as illustrated in *GR Ice Balloons*. However in many episodes, such as *DE Fermi questions*, *DE Water Inquiry*, *PT Swinging rope game*, *RO Float and Sink* and *UK(EN) Habitat* the teacher set the initial question or problem to be tackled. In all these episodes children were involved in selecting materials and deciding on their approach to the problem or investigation with varied levels of guidance. In *DE Fermi Questions*, the teacher largely observed and gave occasional advice, whereas in *RO Float and Sink* for example, the teacher supported the children in suggesting ideas, drawing on their previous experience and knowledge. Children were given varied levels of guidance in relation to the recording and reporting of investigations (in *GR Ice Balloons* and *RO Float and Sink* recording frameworks were provided by the teacher). Teacher guidance was most evident in encouraging reflection, reasoning and the evaluation of ideas, through dialogue with individuals, groups or the whole class as illustrated for example in *RO Float and Sink* or *UK(EN) Habitat*. There were very few examples of a structured approach to inquiry or problem solving.

Questioning and curiosity – In the cases reported across the consortium teachers underlined the importance of promoting children's questioning and curiosity. The Selected Episodes illustrate the potential of materials such as sand, water and cornflour to foster curiosity (see for example *BE Sand Box*, *GR Ice Balloons*, *UKNI Gloop*). Teachers also used stories, poems and paintings to provide a context to stimulate imagination and provoke ideas and questions as illustrated for example by *RO Float and Sink*, *UK(EN) Buttons* or *UK(EN) Habitat*. Episodes set in the outdoor environment provided many examples of the ways in which engagement with living things and natural materials can foster interest (see for example *MT Minibeasts*, *UK(SC) Forest School*). In addition there were episodes in which teachers provided explicit encouragement of questioning, such as *GR Ice Balloons* or *UK(EN) Starting Points*. Questions were valued and utilised as starting points for inquiry and for problem solving, they often led to the generation of alternative ideas and strategies.

Diverse forms of expression – The overview of factors represented in the episodes reported across the consortium and commentary in the Country Reports both indicate that this is an aspect of pedagogy that could be explored and developed further in teacher education. The *Selected Episodes* illustrate the value of different ways of representing and expressing ideas in fostering learning processes and giving insights into children's thinking. Across the episodes children conveyed their thinking through actions, talk and varied forms of recording and representation. In preschool settings in particular children's actions often conveyed their questions and thinking (see for example *BE Sand Box* or *UK(NI) Gloop*). Across both phases talk played a key role in children's expression of their ideas. However, recording and representation using different materials also offered valuable and varied opportunities

for children to communicate and to reflect on their learning. In *PT Sun Distance* the different approaches to representing the relative sizes of the Sun and Earth and the distances between them fostered interest and questions and helped children to gain an appreciation of proportion and distance. In *DE Fermi Questions*, *UK(SC) Day and Night* and *UK(EN) Counting Minibeasts*, children were given scope to represent their ideas in their own ways. During the processes of representing what they had learned about the solar system in *UK(SC) Day and Night*, children talked about their growing understanding with peers. In explaining their recording they gave insights into their developing knowledge and interests. In *UK(EN) Counting Minibeasts*, children's use of materials to represent their counting processes and their written records gave evidence of their strategies and thinking. This episode also highlighted the insights to be gained through discussion with children about their recording. In *PT Wolf, Sheep Cabbage* children were encouraged to model and test their approaches to the problem using both paper and computer simulation. As indicated below, this helped in generating and evaluating alternative ideas and strategies and fostered creativity.

Reflection and reasoning – There were many examples in episodes across the consortium of ways in which teachers encouraged reflection and reasoning, in particular the evaluation of alternative ideas. In a number of episodes children were encouraged to explain and reflect on ideas and strategies as they worked in groups as illustrated for example in *DE Fermi questions*, *PT Wolf Sheep and Cabbage*, and *UK(EN) Balancing Pens*. Often teachers stimulated class discussion of alternative ideas and strategies. For example, in *FR Magnet* the teacher promoted class discussion about how to record the categorisation of a pair of scissors made of both magnetic and non-magnetic material. In *MT Counting Caterpillars*, children were invited to reflect on their thinking as they shared their counting strategies with their peers. In *RO Measuring Volumes*, teacher questioning played a key role in fostering reasoning from observations to inform conclusions about which vessels held more water. In *UK(EN) Fruit Café*, the teacher called on different pairs of children to explain their reasoning about which set of coins they would choose. (They had to choose between three sets of coins that included different numbers of coins of different values).

Scaffolding – As suggested throughout the discussion of factors associated with pedagogy, in many episodes sensitive and responsive scaffolding by teachers played a key role in fostering children's inquiry and creativity. In a number of episodes teachers provided starting points and resources and stood back to allow children to pursue investigations and problem solving in their own ways. In some instances the resources themselves influenced the direction of investigations. For example in *BE Colouring* the teacher provided an instruction card for extracting the dye from natural materials, the inclusion of scissors with metal blades and plastic handles in *FR Magnet* was designed to foster debate about categorisation, and the prices set in *UK(EN) Fruit Café* were chosen to provide appropriate challenge. Teachers stepped in at different stages in activities to foster independence and extend learning. For example teachers used questioning in the early stages of investigation to support children in thinking about what materials they might use (for example *RO Float and Sink*) or which strategies they might employ (for example *MT Counting Caterpillars*). During investigations teachers also used questioning to encourage prediction and focus observation (*FI Melting Snow*) or support collaboration and communication (*DE Building Blocks*). Teacher questioning also played a key role in



many episodes in reflecting on outcomes (*GR Measuring Tables*). In some instances teachers introduced particular skills (for example using a saw and measuring in *BE Carpenter Corner*), or knowledge (associated with money and counting in *UKEN Fruit Café*), to support independent application during child directed activities.

Challenges

As highlighted in the discussion of learning activities restrictions of staffing, space, timetables and the curriculum limited the pedagogical approaches adopted, particularly in the primary age phase. Opportunities for inquiry and creativity were also influenced by the extent to which teachers recognised and valued the creative potential in children's actions, talk and representations of their learning. This relies on careful observation and listening (as emphasised in the section on assessment below) as well as an awareness of the nature of creativity in early science and mathematics. The Country Reports indicated that teachers in a number of settings indicated they had gained new insights into young children's creative capabilities through involvement in fieldwork and the opportunities this provided for reflection with both researchers and children. This has important implications for the teacher education materials to be developed in Work Package 5. Developing awareness of features of creativity in early science and mathematics will be an important priority. In more specific terms, the findings suggested that opportunities for playful exploration could be extended in the primary age phase and that use could be made of more diverse forms of expression and representation, including the use of ICT to support learning processes.

3.4 Assessment

3.4.1 Factors identified across episodes

Overall features

The episodes recorded across the consortium provided limited evidence of the range of assessment practices adopted, as discussed below. Formative assessment approaches were noted in over two thirds of the episodes. In about a quarter of cases this was associated with the collection of a variety of evidence. Few episodes included examples of summative assessment or of peer or self-assessment.

Differences between preschool and school

Some differences were noted between preschool and primary episodes. Assessment featured more strongly in the primary episodes. In particular there was greater evidence of the explicit use of formative assessment and of a range of evidence in primary settings.

Differences between science and mathematics

Analysis of the factors recorded across the episodes indicated little difference in the assessment approaches evidenced in science and mathematics episodes. However there was greater evidence of both formative and summative assessment in episodes integrating science and mathematics. These episodes also used a wider range of evidence and showed greater involvement of children in





assessment processes. (As in previous sections it is important to note however that the number of episodes integrating science and mathematics was small.)

3.4.2 Themes and issues identified in the Country Reports

Overall features

It was noted in a number of Country Reports that fieldwork provided fairly limited evidence of teachers' assessment practices. Partners suggested that an important contributing factor is the nature of assessment practices. Assessment practices in many settings were informal and not always visible to the outside researcher only present for a limited time. However, findings from fieldwork and commentary in the Country Reports suggested that *formative* on-going assessment is valued and recognised as important in partner countries. *Observation and questioning* were strategies most commonly reported. Partners suggested that teachers considered *cognitive, social and affective* dimensions of learning in making assessments, but that creativity or *creative dispositions* were very rarely the explicit focus of assessment or evaluation.

Differences between preschool and school

The Country Reports noted a number of differences between assessment practices in preschool and primary settings. In a number of countries, preschool cases provided evidence of a more holistic approach to assessment with greater attention to affective factors such as children's interest and enjoyment, and to the processes of learning. Partners also commented on greater evidence of multimodal approaches to assessment such as informal observation of children's actions, listening to children, or use of photographs, and greater use of assessment to inform learning and teaching processes. More generous staffing levels and more limited regulations concerning assessment often made this more possible in preschool settings. In a number of countries partners also commented that pressures associated with curriculum requirements, accountability, testing and parental concerns about children's attainment resulted in greater focus on summative assessment and monitoring of outcomes in the primary school settings.

Differences between science and mathematics

Country Reports indicated that in preschool there was little difference in the assessment approaches adopted in science and mathematics. However in primary schools, assessment in mathematics was often given greater priority and there was more evidence of the use of formal approaches such as exercises and tests in mathematics with a greater emphasis on summative processes. Partners also commented that this contributed to narrowing the focus of *assessment* in mathematics, in particular there was limited focus on mathematical processes, and a tendency to neglect assessment in science. However, the examples of episodes reported indicate that this does not necessarily result in a narrowing of the *focus in teaching* or in attention given to inquiry and creativity.



3.4.3 Selected Episodes: Opportunities for inquiry and creativity in learning and teaching

Although in general, evidence of assessment was limited, the *Selected Episodes* include a range of examples of *formative assessment* being used to inform both planning and teacher intervention. For example in *GR Ice Balloons* and *UK(EN) Starting Point* teachers elicited children's questions at the start of a project and built on this assessment information to gain insights into children's ideas and interests in order to plan subsequent sessions. The activities involved in episodes *FI Melting Snow* and *UK(EN) Buttons* were planned to address difficulties children had experienced in previous sessions. Examples were noted where assessment information informed teachers' actions. For example the teacher's observations of the children's actions in *BE Sandbox* prompted her intervention to support their skills in using the saw and in measuring. In dialogue with children in *FI Melting Snow* the teacher's questions about the volumes of water and melting snow built on her on-going assessment of children's responses. In *DE Water Inquiry* the teacher's questioning was prompted by children's recording and designed to encourage them to clarify their 'Scientists' sheets'. In a few episodes there was evidence of children's involvement in assessment. In *BE Sand Box* children self-assessed and learnt from each other about how best to mix sand and water. In *UK(EN) Sound* children self-assessed their confidence in explaining how sound is made to another group. In the episode *UK(EN) Habitat* children engaged in peer assessment and feedback at different points during the session. Finally in *UK(SC) Forest School* the child reflected on his learning during his visit to Forest School that day. The photographs he had taken with his teacher, with his commentary, were included in his individual profile. Alongside teachers' assessment practices, in a number of episodes, researchers' dialogue with children about their experiences or their recording (for example in *UK(SC) Day and Night*), also provided useful assessment information. As indicated in the discussion of *Diverse forms of expression* above, findings from both formal and informal interviews with children underlined the value and importance of gaining children's own insights into their learning.

Challenges

The episodes reported across the consortium provided limited evidence of assessment practices. While in some settings assessment practices were well developed, in general partners identified the need for more strategic and explicit use of assessment to enhance learning and teaching. As in previous phases of the *Creative Little Scientists* project, partners highlighted the need for greater guidance in relation to assessment approaches, particularly in science. They noted in particular the importance of using a variety of assessment strategies in the early years, for example the need for active listening, close observation and a focus on children's capabilities not just on limitations in their knowledge and skills. In most episodes children worked in groups and partners noted the challenges of assessing group work. Partners also commented that greater use could be made of assessment information to evaluate and improve task design, curriculum and teaching approaches. Finally experiences during fieldwork also underlined the need for greater focus on children's active involvement in assessment processes and the value of dialogue with children to gain insights into their learning. In a number of settings across the consortium, photographs and children's recording provided useful starting points for discussion. In a number of episodes partners noted potential for

further inquiries based on children's ideas and questions. However capitalising on children's emerging interests relies not just on opportunities to observe and recognise this potential, but the need for effective recording and communication systems and for flexibility so that this can feed into future planning. Examples of such systems were noted in the case studies associated with *UK(SC) Forest School* and *UK(SC) Day and Night*.

3.5 Materials and resources

3.5.1 Factors identified across episodes

Overall features

There was considerable variation in how far the different factors related to materials were represented in the selected episodes. The *provision of a rich physical environment* for exploration featured most strongly and was recorded by partners in almost three quarters of episodes). An environment to *foster creativity, sufficient space, a variety of resources* and *sufficient human resources* were noted in about half the episodes. However there was more limited evidence of the use of *informal resources* or *ICT* (identified in around a quarter of the episodes) and only a small minority of episodes involved *outdoor resources*. In almost all instances teachers designed their own learning experiences. The vast majority of episodes indicated very limited or no reliance on textbooks or published schemes.

Differences between preschool and school

Factors related to materials were more strongly represented in preschool settings – in particular in relation to materials to support exploration and creativity and in the use of informal resources. There were substantially more examples of use of ICT in primary school (included in almost half the episodes). Little difference was noted between preschool and primary settings in terms of the variety of resources made available to support learning, or the degree of reliance on textbooks and published resources.

Differences between science and mathematics

The provision of a rich physical environment featured more strongly in episodes involving science (both science episodes and episodes integrating science and mathematics). Resources to foster creativity and sufficient space were also identified in the large majority of episodes integrating science and mathematics. Overall the use of outdoor resources was limited, but this was particularly marked in relation to mathematics (only noted in 3 episodes). There were no substantial differences in the frequency of factors related to the variety of resources or human resources. A slightly greater proportion of mathematics episodes were based on textbooks or published resources.

3.5.2 Themes and issues identified in the Country Reports

Overall features

The Country Reports across the consortium highlighted the important role of materials in fostering creativity and inquiry in the episodes observed during fieldwork. Teachers in many settings prioritised the *provision of a rich physical environment*, with a diversity of attractive and interactive resources to foster motivation and gain children's interest. Exploration of natural materials such as sand and water and construction with wooden blocks featured strongly in preschool settings. Partners noted widespread use of everyday and household materials in science and mathematics investigations. This helped to demonstrate the relevance of activities in making links with children's home lives and prior knowledge and experience. Partners underlined the importance of *access to a variety of materials and equipment* to allow opportunities for children to make choices and the value of teacher provision of additional materials, based on observation, to extend and support learning. The *use of resources in the outdoor environment* was more common in preschools and primary schools close to the natural environment. In some settings children had open access to the outdoor environment within the school grounds. Partners commented that school philosophy and organisation had a strong influence on the opportunities afforded for exploration of outdoor materials. Despite the winter weather, (which may have restricted the range of outdoor activities observed during fieldwork), in a number of episodes teachers took good advantage of the opportunities afforded to explore the properties of snow and ice (as can be seen in the *Selected Episodes*).

Other resources that featured strongly in Country Reports were books and photographs to provide contexts, prompts and support for inquiry. Episodes in both preschool and primary settings included examples of use of ICT, although partners indicated that use of ICT by *children* was fairly limited. While there was evidence of the use of published resources in some settings, partners suggested that in most instances teachers made some adaptations to materials to suit their own local contexts.

Two further factors related to materials highlighted in the Country Reports were *space and levels of staffing*. Partners suggested these factors had a considerable impact on the scope for inquiry and creativity in learning and teaching. They noted in particular that in preschool settings there were often extensive outdoor play areas and room indoors for different workshop areas. In addition staffing ratios were often more generous. This made it possible to offer and support a wider range of activities.

Differences between preschool and school

As indicated above, some common differences between the two phases of education were noted. Partners commented in particular on the extensive classroom space and easy access to playgrounds and outdoor areas just beyond the classroom, found in many preschool settings. In primary settings access to outdoor resources was more often associated with excursions such as field visits or trips to botanical gardens. Although there were some primary schools where wildlife gardens or allotments had been established, and good use was made of opportunities to explore materials or forces and movement in the playground. Use and development of the school grounds to support inquiry and creativity would be a valuable area for further professional development. They also highlighted the

often more generous staffing levels in preschools that offered opportunities for more varied ways of working.

Differences between science and mathematics

Partners drew attention to some differences between science and mathematics episodes with reference to resources. The mathematics episodes featured greater use of formal equipment such as measuring equipment or structured apparatus. In science episodes children were more likely to be working with everyday materials. It was noted that very few mathematics episodes included use of the outdoor environment.

3.5.3 Selected Episodes: Opportunities for inquiry and creativity in learning and teaching

The *Selected Episodes* include a rich range of examples of the importance of materials in affording opportunities for creativity in learning and teaching, in making choices and exploring different approaches.

Rich physical environment for exploration - In a number of episodes children had opportunities to explore materials to find different approaches to solving problems. For example in *BE Sandbox* children used sand, water, bricks and stones to explore how to make a strong wall and in *UK(NI) Gingerbread Man Raft* children had space to explore different ways of making a raft for the Gingerbread Man. In *DE Building Blocks* and *UK(EN) Shapes* children were challenged to manipulate construction materials to make new shapes and structures. In *PT Sun Distance* the children used different materials to explore and represent the relative sizes of and distances between the Sun and the Earth.

Variety of resources - Provision of a variety of resources was important in enabling children to make their own choices. For example In *BE Colouring* children had access to a variety of natural materials and equipment in investigating the processes involved in dyeing cloth. In *GR Ice Balloons* and *RO Float and Sink* children were able to select from a range of materials in investigating ice and finding out which materials would float. In *MT Feet* the teacher provided a variety of equipment for measuring and *UK(NI) Gloop* children had access to a range of tools that could be used in exploring characteristics of the mixture of cornflour and water. In *FR Magnet* children explored which materials were magnetic. Here the variety of resources provided by the teacher played a key role in setting the challenge of categorising objects made of more than one material.

Outdoor resources - Use was made of outdoor resources in a number of episodes. Children's explorations of snow and ice in *FI Melting Snow* and *UK(SC) Forest School* and of living things in *MT Minibeasts* drew on resources in the natural environment. Teachers also provided equipment to support their explorations including magnifiers and measuring equipment. In *BE Colouring* and *DE Water Inquiry* children were free to make use of resources in the school environment both inside and out.

Informal resources – Opportunities for children to select and use informal resources to support their explorations and investigations could be seen in a number of episodes for example *BE Sand Box*, *GE Fermi Questions*, *GR Ice Balloons* and *UK(NI) Gloop*.

Sufficient space – Sufficient space to explore was significant in a number of the *Selected Episodes* for example in *PT Sun Distance* children had sufficient space to model distances between the sun and the earth. In *PT Swinging Rope game* children needed space to try out different approaches to making the swinging rope game. In *UK(EN) Counting Minibeasts* children had sufficient space on the carpet to display their approaches to counting and allow comparisons in approach.

ICT and digital technologies - Although the use of ICT was not extensive across the episodes reported, the *Selected Episodes* include examples of varied use of ICT by both teachers and children. In *MT Counting Caterpillars* the teacher used the interactive whiteboard to share and try out different strategies for organising the caterpillar's segments to solve number problems. In *UK(EN) Habitat*, a visualiser was used to share children's work, providing opportunities for peer assessment and reflection on learning. In *UK(SC) Day and Night* the teacher used an ipad app to share and discuss images of the Earth, Sun and Moon and a model of the solar system. In all these instances use of ICT was motivating and provided opportunities for sharing ideas and experiences across the class. Children's use of ICT in the selected episodes was more limited. In *PT Wolf, Sheep, Cabbage* and *UK(SC) Forest School* children used ICT to support their investigations. In *PT Wolf, Sheep, Cabbage* children used the computer to model and verify their approach to the problem. Children used digital photography to record their experiences in *UK(SC) Forest School*. This provided important opportunities for further discussion and reflection back in school. In *GR Bee-bot* the children had to work together solve the problem of programming a floor robot to reach some treasure. This proved a motivating context for planning and making connections between the buttons on the robot and its movement.

In relation to the other factors associated with materials, identified as significant in D3.1 in fostering inquiry and creativity, partners reported *sufficient human resources* and more limited *reliance on policy documents* in the *Selected Episodes*.

Challenges

Partners highlighted a number of issues in relation to materials that reflect earlier comments in relation to Learning Activities and Pedagogy, for example issues of time and staffing levels, limited use of the outdoor environment and of ICT. In some countries partners also commented on the lack of physical resources in some settings and the need for more up to date teaching and guidance materials to support teachers in developing activities to foster inquiry and creativity.



3.6 Grouping

3.6.1 Factors identified across episodes

Overall features

The Country Reports included few episodes involving either multi-grade teaching or ability grouping. Working in small group settings was a feature of around three quarters of the episodes reported. Class sizes varied. Class sizes of between 20 and 30 children were most common, reported in around half the episodes. Around a fifth of episodes were based in classes of 30 or just over 30 children and a further fifth in classes of between 10 and 20 children. In a few instances there were smaller class sizes of lower than 10 children associated with rural settings. There were also some preschool settings where the overall class size was very large, between 50 and 60. But in these instances, several teachers worked with the children across a large space both indoors and out, often divided into distinct zones of activity.

Differences between preschool and school

No differences were noted between phases in relation to multi-grade teaching. More primary episodes included ability grouping. There were very few examples of ability grouping reported in preschool. Greater use of small group work was noted in preschool but was a very common practice in episodes across both phases.

Differences between science and mathematics

No differences were noted between science and mathematics episodes in relation to the incidence of multi-grade teaching. Ability grouping was used more often in episodes involving mathematics (in about a quarter of the mathematics episodes). Small group work featured in around three quarters of all science and mathematics episodes. In episodes integrating science and mathematics (more of which were in preschool) just over half the episodes involved small group work. This may reflect in part the more informal and flexible grouping arrangements associated with free flow exploratory activities in preschool settings, often integrating several areas of learning.

3.6.2 Themes and issues identified in the Country Reports

Overall features

As indicated above, Country Reports across the consortium indicated that working in groups was a common practice in both science and mathematics and across both preschool and primary settings. Mixed ability grouping was the most common arrangement, allowing opportunities for dialogue and collaboration as illustrated above in relation to 3.3 Pedagogy. However partners highlighted the teaching skills needed in the management of group activities, for example in designing suitable tasks, in supporting the allocation of roles and in assessing group work. The episodes indicated varied approaches to the organisation of working groups. Teacher structured groups were more common in primary settings with children often choosing play partners in the preschool phase. Group sizes also



varied. In some episodes the focus was on pair work, in others children collaborated in larger groupings.

Fieldwork also provided evidence of both whole class and individual work. Whole class groupings were common in both preschool and primary, for example for introducing activities or sharing and reflecting on experiences. Individual work tended to be more common in mathematics in primary school or in preschool where young children selected their own context and focus for activity.

Only a few countries reported episodes involving multi-grade teaching, but in reporting these episodes partners noted the value of multi-grade teaching in fostering peer learning and support.

Differences between preschool and school

There was limited commentary in the Country Reports on differences between the grouping strategies adopted in preschool and school settings. Where commentary was included, partners noted the larger group sizes and the greater use of whole class groupings in primary school.

Differences between science and mathematics

Reflecting the overview of factors associated with groupings, partners noted the greater use of ability grouping and individual work in mathematics episodes.

3.6.3 Selected Episodes: Opportunities for inquiry and creativity in learning and teaching

Examples of opportunities that group work provides for supporting inquiry and creativity are illustrated above in the section in 3.3.3 under Pedagogy and related to *dialogue and collaboration*.

Challenges

The Country Reports included reflections by partners on the challenges of managing group work, including giving sufficient time for group work activities. A number of partners considered that this would be a valuable focus for further professional development. Partners also noted the impact of class size and staffing levels on the effectiveness of group work. It is difficult for teachers to support and monitor group work on their own.

3.7 Location

Themes and issues related to location have been addressed above in 3.5 Materials and resources (factors associated with outdoor learning and informal learning materials). Examples of opportunities for creativity and inquiry in learning and teaching related to Location are provided here. Partners were asked to identify whether episodes took place *outdoors* or *indoors* or *both outdoors and indoors*. They were also asked to classify the approaches as *formal* (initiated by the teacher in school settings), *non-formal* (initiated by the teacher but associated with non-formal settings such as a visit to a museum or Forest School) or *informal* (such as child-initiated or child chosen free play or learning within day to day routines or the playground) (Eshach, 2007).

Below is a brief summary of findings from the factor grids and any additional issues raised in the Country Reports.

3.7.1 Factors identified across episodes

Overall features

The majority of episodes observed during fieldwork and included in the Country Reports took place indoors and involved formal approaches to learning initiated and framed by the teachers. It is likely that this reflects in part the limitations of fieldwork processes considered in 2.4.2 Limitations associated with the time of year (Winter) and the limited time frame and human resources available for fieldwork. In particular the small number of visits to each setting made it very difficult to observe educational visits (non-formal learning).

Differences between preschool and school

No substantial difference was noted in the use of outdoor learning between preschool and school, but the preschool episodes included a greater number of examples of informal approaches associated with child-initiated play.

Differences between science and mathematics

In most cases little difference was also identified between the science and mathematics episodes in terms of location. A slightly higher proportion of science episodes took place outdoors and involved informal learning approaches. (There were only three examples of mathematics episodes involving outdoor learning).

3.7.2 Themes and issues identified in the Country Reports

Overall features

Although the episodes included limited examples of outdoor learning, fieldwork provided opportunities for researchers to talk with teachers more generally about their use of the environment beyond the classroom. As indicated above in discussing materials, some partners commented on the impact of *school location*. Some of the countryside schools included in the research were able to offer rich opportunities to foster links with nature and understanding of the environment (for example *FI Melting Snow*). However there were urban settings also that organised visits to local wildlife areas on a regular basis (for example *UK(SC) Forest School*). In addition some settings were developing environmental areas within the school grounds.

In some preschool settings *outdoor activities* were common. Children had free access to outdoor areas and in a few instances planning for provision in the outdoor areas was given high priority. In primary settings teachers indicated that activities in the school grounds were less frequent, although as indicated earlier in 3.5 Materials and resources, the episodes included examples of children's use of resources and space within the wider school environment. Teachers suggested that outdoor learning

was mainly associated with trips for example to the zoo or museums. Limited use was reported of the immediate local environment for learning such as buildings, shops or streets.

Differences between preschool and school

Partners commented that provision of space and staffing in preschool settings contributed to greater use of outdoor areas, with children more free to move between indoors and out. This also afforded greater opportunities for children to engage in different activities simultaneously in different workshop areas. In primary settings, movement was more restricted and a common whole class focus often observed. As suggested above, discussions with teachers indicated that non-formal learning associated with visits to a variety of educational establishments were more usual in primary settings.

Differences between mathematics and science

As suggested in discussion of 3.5 Materials and resources, partners in some countries commented on the greater use of the outdoors for science. However in other countries little difference was noted between the subjects.

3.7.3 Selected Episodes: Opportunities for inquiry and creativity in learning and teaching

While few in number, the *Selected Episodes* provide examples of the exciting potential for learning outdoors in all weathers (for example *FI Melting Snow*, *UK(SC) Forest School*) and the added scope for inquiry offered by more flexible use of the wider school environment (for example *BE Colouring*, *GE Water Inquiry*, or *PT Swing Game*). Although a number of preschool case studies in the Country Reports document the nature of the rich outdoor provision in the contextual information provided about each setting, the episodes themselves under-represent the opportunities such provision can offer. Factors associated with location (the use of outdoor learning and non-formal and informal approaches) would be valuable areas for further research in the future.

Challenges

Partners in a number of countries noted that staffing levels and health and safety regulations restrict use of outdoor learning opportunities. They also considered that further training would be valuable for teachers in relation to the planning and organisation of school visits but also in developing their own school environment.

3.8 Time

3.8.1 Factors identified across episodes

Overall features

Partners judged that there was an allocation of sufficient time in just over half the episodes.

Differences between preschool and school

Similar proportions of preschool and school episodes were judged to offer sufficient time.



Differences between science and mathematics

Some difference was noted between episodes focusing just on science and those featuring mathematics (either as a single subject or combined with science). In a greater percentage of science episodes partners judged that further time was needed.

3.8.2 Themes and issues identified in the Country Reports

Overall features

As suggested in earlier sections, issues of time were raised frequently in different sections of the Country Reports. Partners noted the influence of policy and school timetables on the allocation of time and the extent to which teachers felt able to be flexible and respond to children's ideas. In a number of countries it was noted that subjects, teaching hours and lesson times are more likely to be laid down in primary settings, whereas in the preschool phase there are more limited requirements. This can afford greater time for example for children to explore and try out ideas and revisit ideas in different contexts. Teachers have greater scope for flexibility to respond to the unexpected. A further concern in a number of countries was the more limited time allocated to science than mathematics. As highlighted in the review of policy requirements across the partnership in D3.2 *Report on Mapping and Comparing Reported Practices* this may have been a consequence of more detailed policy requirements, in particular assessment regulations in mathematics.

Differences between preschool and school

As suggested above, partners indicated the more flexible use of time in preschool, giving children opportunities in particular for following their own inquiries over time and revisiting ideas and experiences and teachers the scope to respond to children's interests and unexpected events.

Differences between science and mathematics

Fieldwork indicated that in a number of countries there was more often a set time for mathematics and greater time allocation in comparison to science.



3.8.3 Selected episodes: Opportunities for inquiry and creativity in learning and teaching

A number of the *Selected Episodes* illustrate the value of children having time to explore, make mistakes, or examine different aspects of a phenomenon or problem for example as in *BE Sand Box UK(NI) Gloop*, or *PT Swing Game*. Other episodes formed part of on-going projects that developed over long periods. *UK(EN) Fruit Café* made use of daily activity to develop mathematics and increasing independence; combining snack time and doing it every day allowed it to embed and for children to become confident in the process. In the class associated with *UK(SC) Day and Night* the children contributed to the questions to be addressed within the project on Earth in Space, following these up over a series of sessions and recording their findings in a class floor book. The preschool settings associated with *FI Melting Snow* and *UK(SC) Forest School* went repeatedly to the same environment. Children had opportunities to become familiar with the surroundings, see change over time and follow up interests.

Challenges

As noted above partners noted a number of common challenges associated with school timetables and policy requirements that are difficult for teachers to tackle on their own. As suggested in later sections planning and support at the school level can help in generating more time for inquiry and creativity.

3.9 Content

Partners were asked to comment on whether science and mathematics were treated as separate subjects that were planned separately or whether teaching approaches observed integrated mathematics and science. They were also asked to indicate the level of detail in teachers' planning.

3.9.1 Factors identified across episodes

Overall features

A small majority of the episodes focused on a single subject (either science or mathematics) and included no elements of integration of science and mathematics (either planned or incidental). Around a fifth of the episodes included planned integration of science and mathematics and just short of a further fifth some incidental links between the subjects. Partners indicated varied detail in planning for the episodes observed, with a fairly even distribution between high, medium and low levels of detail in planning.

Differences between preschool and school

In terms of the integration of science and mathematics in planning and teaching, more of the preschool episodes included some integration of the two subjects, although in almost half there was still no evidence of integration. In both preschool and primary episodes the levels of detail in planning varied but a smaller proportion of the primary episodes showed low levels of detail in planning.

Differences between science and mathematics

A greater proportion of the mathematics episodes focused on a single subject, mathematics (about two thirds of the episodes). The examples of integration between science and mathematics in mathematics episodes also tended to be incidental. There was greater incidence of detailed planning for science episodes and lowest for those integrating science and mathematics.

3.9.2 Themes and issues from the Country Reports

Themes and issues raised in the Country Reports in relation to content are included in the following section of the Report, 3.10 *Enabling factors or barriers at the contextual level: 3.10.3 Policy Factors.*

3.10 Enabling factors or barriers at the contextual level

The case studies provided in the Country Reports included varied school contexts for learning and teaching and suggested a range of factors at the contextual level that can influence the opportunities for inquiry and creativity. Reference was made to school and teacher factors but also to the influence of policy on practices observed in classrooms during fieldwork. These are outlined below, illustrated by examples from the case studies associated with the *Selected Episodes.*

3.10.1 Whole School

Evidence from fieldwork processes, in particular school documentation and interviews with staff, highlighted factors at a whole school level that can contribute to a climate that has the potential to foster inquiry and creativity in science and mathematics. These are outlined below.

Whole school philosophy and context

In a number of schools, practices were informed by explicit perspectives on early childhood education, supported by the school leadership and reflected in school practice. For example the approaches adopted in *BE Carpenter Corner* were influenced by the emphasis on experiential learning associated with Ferre Laevers. Approaches adopted in *UK(NI) Gloop* were informed by commitment to the Reggio Emilia philosophy. The school associated with *UK(SC) Forest School* reflected a strong commitment to Froebelian principles. In these three settings there was a strong emphasis on child-initiated exploration of a rich environment. Practices adopted by the teacher in *PT Wolf, Sheep, Cabbage* reflect the importance given to the development of the whole person in accordance with the school's Christian ethos. The value and attention given to children's ideas in the classroom associated with *UK(SC) Day and Night* illustrate the school's status as a Rights Respecting School (an award recognising success in putting the United Nations Convention on the Rights of the Child at the heart of a school). Other important whole school factors highlighted by partners included the extent to which teachers were given freedom to explore new experiences and strategies and the commitment of school leadership to continuing professional development. In particular in contexts where there is no strong focus on accountability, it was noted science can be neglected if it is not valued by the school and by teachers. (This was not found to be the case with mathematics).



Team work

Teachers in a number of schools across the consortium referred explicitly to the important role of team work in enabling them to try out new ideas and reflect on practice. The teacher in *BE Carpenter Corner* had been team teaching with a colleague since the previous year and both commented on how much they had gained from this experience. The teacher in *UK(EN) Balancing Pens* collaborated with the teacher in a parallel class exploring ways of integrating play-based activities into practice in her primary classroom. The school associated with *UK(EN) Fruit Café* and *UK(EN) Sound* had a science committee involving staff at all levels and children to plan and review science provision and discuss new initiatives. Team working was also a feature of the settings associated with *GR Bee-bot* and *UK(SC) Forest School*. Teachers in both settings were encouraged to try out new activities and approaches could modify their plans according to the children's needs and interests. However it was also noted in some Country Reports that team work could act as a barrier in instances where teachers were constrained to keep in line with a parallel class or school policy frameworks without regard to children's progress.

Differences between preschool and school

No marked differences were noted between preschool and school settings in terms of many whole school factors. However in preschool more than one staff member per class is more common. This provides greater opportunities as well as requirements for teamwork.

Differences between science and mathematics

There was no strong indication in the Country Reports of differences at whole school level between science and mathematics.

Barriers

The Country Reports referred to a range of barriers at whole school level that had an impact on the scope for creativity and inquiry in classroom settings. Most notable were issues associated with constraints of the timetable and the organisation and provision of space, resources and staffing, as illustrated in the previous sections of this report. Partners noted the need for schools to be committed to the importance of science education in the early years. (This was not the case for mathematics that generally has a more secure place in the curriculum). Lack of understanding of the concept of creativity and lack of explicit planning for inquiry and creativity highlighted in previous sections restricted opportunities for creativity in learning and teaching. Partners also noted that expectations of parents and concerns about attainment and academic results can act as barriers. A number of the schools associated with the *Selected Episodes* (for example *BE Carpenter Corner* and *UK(SC) Day and Night*) planned regular communication, events and workshops to encourage parental involvement and promote understanding of inquiry based approaches to learning in science and mathematics.



3.10.2 Teacher factors

The sample of 71 teachers included 4 male and 67 female teachers of varied age and experience as shown in Table 5 below. It is notable that there is strong representation in the sample of experienced teachers.

Table 5: Background of the teachers who participated in fieldwork N=71

Age in years	Under 25	25-29	30-39	40-49	50-59	60+	Do not know
% of teachers	1	30	21	25	14	0	8

Years in teaching	0-5 years	5-10 years	11-20 years	20+ years
% of teachers	23	21	32	24

All apart from two (who were in the process of training to be teachers) were qualified teachers. In some instances partners had information about the teachers' roles in their schools and their recent participation in professional development. Some had roles of responsibility in their settings for example 17 were curriculum coordinators in mathematics or science, 7 were headteachers or deputy headteachers and at least 20 were involved in teacher education. A substantial number of the teachers (42) had been recently involved in courses of professional development in science and mathematics. It should be noted that the teachers volunteered to participate in the study and were therefore more likely to be enthusiastic and confident about science and mathematics than the teachers in general in partner countries. Whether they were teachers who perceived they taught creatively or were keen to develop such teaching is not known.

The Country Reports provided examples of teacher factors that can influence opportunities for creativity and inquiry in early science and mathematics education highlighting in particular opportunities for continued professional development and teachers' perspectives on learning and teaching in science and mathematics.

Influence of teachers' perspectives on learning and teaching

As indicated in section 3.1 Aims and Objectives, teachers' perspectives on learning had an important influence on opportunities for inquiry and creativity in the classrooms observed during fieldwork. The Country Reports underlined the need also for teacher flexibility to respond to children's ideas and interests and the need for teacher confidence to respond to the unexpected. Here school climate and opportunities for professional development played important roles in supporting teachers. Many partners also noted that while many of the teachers were committed in general terms to promoting creativity, they were often unsure what this might mean in the context of science and mathematics.

Opportunities for professional development

The cases associated with a number of the selected episodes highlighted the positive influence of involvement in research projects and further professional development on teachers' practices and confidence in fostering inquiry and creativity in their classrooms (as illustrated by the examples above). For example the teachers associated with *BE Carpenter Corner*, *BE Colouring* and *BE Sand Box* were all involved in a professional development community focusing on child-centred education. A number of teachers had participated in national and international projects and initiatives associated with IBSE, reflected in the approaches adopted in *DE Fermi Questions*, *RO Float and Sink* and *RO Measuring Volumes*. Others had received training in approaches to environmental education associated with Forest Schools such as the teacher in *UK(SC) Forest School*. The teacher involved in *UK(EN) Balancing Pens* was involved in a local authority network exploring ways to incorporate play-based approaches in early primary practice.

Differences between preschool and school

No strong differences in perspectives and attitudes between preschool and early primary school teachers were identified in the Country Reports. However some partners noted differences in the qualifications and initial training of teachers in preschool and early primary school, reflecting findings from *D3.2 Report of Mapping and Comparing Recorded Practices*. In particular they noted the more limited training and qualifications of preschool teachers.

Differences between science and mathematics

No general differences across the consortium were identified in teacher perspectives or opportunities for training in science and mathematics, although a number of teachers reported that they were more confident in one subject or the other. However as indicated in later sections, some differences were noted concerning the time and opportunity for science teaching in some classrooms and in relation to specific factors related to pedagogy and assessment as indicated in earlier sections.

Opportunities for creative teaching and learning

As suggested above and in previous sections of this report, the case studies include many examples of teachers' commitment and enthusiasm in providing motivating contexts for children's learning, their willingness to collaborate with others and their openness to new ideas. These characteristics contributed to the rich opportunities for creative teaching and learning as exemplified in the *Selected Episodes*.

Barriers

Partners reported that teachers' lack of confidence and background subject knowledge acted as a barrier in some contexts. The Country Reports identified a range of issues where teachers felt they needed further support, including for example: classroom management and organisation needed to support inquiry based and creative approaches; the challenges presented in implementing cross-curricular approaches – in particular in identifying the science or mathematics content and potential in thematic work, and the need for better teacher preparation to build on children's questions and comments..



3.10.3 Policy context

The Country Reports provided a varied picture of the influence of the policy on opportunities for inquiry and creativity in early science and mathematics, reflecting findings from D3.2 *Report on Mapping and Comparing Recorded Practices*. A number of key features of the policy context were identified in partner commentary as outlined below.

Scope for local control of curriculum and pedagogy

As reported in D3.2 *Report on Mapping and Comparing Reported Practices*, policy in some countries, in particular in relation to the preschool phase of education, provides room for differences in content and approach to meet local circumstances. General guidance is provided in relation to the provision of a broad core curriculum, with no high stakes focus on outcomes. In preschools teachers often have freedom to work with diverse topics and are less confined by assessment requirements. In primary schools, aims and subject content are often more closely defined and in mathematics there are often specific requirements for summative assessment and accountability that can impact on practice. Partners commented however that in both phases schools and teachers have some scope to make decisions about teaching approaches as illustrated in the range of episodes included in the Country Reports.

Support in policy for inquiry-based and creative approaches to learning and teaching

While the Country Reports identified constraints associated with policy requirements, they also noted the encouragement of IBSE and scientific literacy, references to creative dispositions and the promotion of creativity in the policy documentation of most, though not all, partner countries. The range of episodes reported across the different policy contexts in partner countries illustrate ways in which teachers can take advantage of the scope for teacher decision making to promote inquiry and creativity in their classrooms. However as highlighted in D3.2, partners indicated that further guidance is needed to support teachers in making the most of these opportunities, and as outlined above school support and access to continuing professional development are also vital.

Differences between preschool and school

As indicated above, a number of Country Reports gave some evidence of more holistic approaches to learning promoted in policy in relation to the preschool phase and greater opportunities for flexibility to respond to children's ideas and interests in preschool settings. There was generally a greater focus on specific curriculum and assessment requirements in primary schools.

Differences between science and mathematics

Many of the Country Reports made reference to more specific expectations of curriculum and pedagogy and greater use of formal assessment in mathematics. They also noted that this could result in a neglect of science in curriculum provision.





Barriers

Partners noted a number of barriers associated with policy requirements and accountability associated with curriculum and assessment as suggested above. Pressures of accountability and inspection of teacher performance in some countries had an impact on teachers' confidence and willingness to take risks with unfamiliar approaches to learning and teaching. The strong focus in many countries on language, literacy and mathematics in the early years of education can reduce the time and attention given to science, although science offers rich contexts for the development of skills in language, literacy and mathematics. While there were indications of some support for creative approaches to learning and teaching in policy, as suggested above, this was often at a very general level with limited explicit exemplification and guidance in policy about what this might involve in early science and mathematics.



4. Conclusions

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

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

4.1 Approaches used in the teaching, learning and assessment of science and mathematics in early years: opportunities for inquiry and creativity

As in previous sections of this report, conclusions in relation to teaching, learning and assessment approaches are presented in terms of the *pedagogical interactions* observed during fieldwork alongside evidence of teachers' *pedagogical framing* of activities and wider *contextual factors* that influenced the approaches adopted. They also make reference to the dimensions and factors identified as important in nurturing creativity in science and mathematics in the early years (as listed in Table 1).

4.1.1 Pedagogical interaction

Learning activities

Learning activities observed during fieldwork offered considerable potential for inquiry and creativity in learning in the opportunities they provided for the *generation and evaluation of ideas and strategies*. *Observing and making connections* featured in most episodes. Although *questioning, planning, gathering evidence (using equipment), explaining evidence* and *communicating explanations* received more limited attention, they were still evident in more than half the episodes and were more strongly represented in primary settings. Findings indicated the important contribution of rich, motivating contexts in *generating* ideas, questions and interests, but also the need for teacher sensitivity to features of inquiry and emerging ideas implicit in young children's explorations, as well as for time and teacher flexibility to build on these. They also commented on the key contribution of discussion and teacher questioning in fostering the social dimensions of inquiry associated with communicating and justifying explanations based on evidence, the other key feature of creativity in early science and mathematics related to the *evaluation* of ideas and strategies. Partners commented on the greater scope for child-initiated activity and creative engagement in preschool settings, although this was not always recognised by teachers, and similarly on the tendency for pressures of time and curriculum requirements to limit opportunities for children's creativity and inquiry in primary settings.



Pedagogy

The episodes reported provided many examples of each of the teaching approaches identified in D2.2 *Conceptual Framework* as associated with both creative teaching and IBSE (the synergies). With the exceptions of *play* and the promotion of *varied forms of expression* there were examples of each of the other factors in at least half of the episodes reported in both preschool and primary settings. Those that featured most strongly were *collaboration, problem solving and agency and scaffolding*. Opportunities for children's agency varied. In preschool there was greater scope for child-initiated inquiry, but even where the teacher set the focus, as was more common in primary settings, there were opportunities for children's decision making with varied levels of guidance from the teacher. Strong examples of creative teaching were associated with experiential learning in preschool and an explicit focus on IBSE/PBL in primary school. *Reflection and reasoning* was more strongly represented in the episodes that might have been anticipated from the policy and teacher surveys (in Work Package 3), fostered by rich examples of *dialogue and collaboration* offered by the extensive use of group work in both phases of education. Varied forms of *teacher scaffolding* were evident in the episodes reported through the choice of materials, teacher questioning or the introduction of particular skills or equipment to enhance inquiry. The potential of sensitive responsive scaffolding to support independence and extend inquiry was underlined (both when to intervene and when to stand back). Providing motivating contexts for learning was a strong feature of many episodes, particularly in preschool, linked for example to everyday life, stories and poems or children's interests and questions. However it was noted (as in the teacher and policy surveys associated with Work Package 3) that there were very few examples of the use of drama or history to prompt inquiry or a creative response. Play was the factor that featured least in primary settings. The value of opportunities for play and exploration in the primary age phase could be more widely appreciated, in generating ideas and questions and a feel for phenomena. Findings also suggested that the roles of varied forms of representation and the *processes* of representation (not just the product) in developing children's thinking need greater recognition, including the role of ICT.

Assessment

Findings from fieldwork confirmed the picture gained from the policy and teacher surveys carried out in Work Package 3, that policy and practice in relation to assessment is underdeveloped. Assessment approaches were generally informal and formative based on observation and teacher questioning. Episodes provided examples of ways in which teachers built on assessment information to inform their interventions and planning for future sessions. However partners noted that in some instances potential for inquiry based on young children's interests and questions or implicit in children's actions was not recognised. There was limited evidence of the involvement of children in assessment, although interviews with children conducted during fieldwork indicated their capabilities to reflect on their learning and gave teachers new insights into their learning processes. There was also limited evidence of summative assessment. Some differences were noted between practices in preschool and primary school settings. In preschool settings there was evidence of a more holistic approach to assessment involving cognitive, social and affective factors, drawing on varied forms of evidence such



as gesture, talk, children's recording or visual images. In a number of preschool settings children's profiles provided a valuable record of progress. In some cases children actively contributed to the selection of material, offering opportunities for reflection on learning. More generous staffing levels in preschool often made this more possible than in primary settings. In primary school there was greater focus on summative assessment, particularly in mathematics, where the use of more formal approaches to assessment such as standard tasks and tests was noted.

Materials and resources

A common feature of the episodes recorded was the provision of a rich, motivating physical environment for exploration, making good use of everyday and household materials and natural resources. Children's access to a variety of resources played an important role in fostering inquiry and creativity, although this was mostly implicit in teachers' planning for provision. The episodes provided limited evidence of children's use of ICT to support learning in science and mathematics. There were also few examples also of episodes involving the use of outdoor resources, however as noted in 2.4.3 Limitations as field work was conducted during the winter period, this might have been expected. Here differences were noted between preschool and primary settings. In a number of preschool settings, children had free access to outdoor areas and the overall provision of space and staffing levels were more generous. This provided greater scope for practical exploration fostering children's creativity in generating and pursuing ideas for investigation. Teachers in most settings designed their own learning experiences. Only a small proportion of episodes (although more common in mathematics) relied on textbooks or published schemes.

4.1.2 Pedagogical framing

Aims

Findings from fieldwork across both preschool and primary settings reflected a strong focus on social and affective factors of learning. Scientific and mathematical content, the development of process skills, fostering IBSE/PBL and the promotion of creative dispositions also featured in the majority of episodes. The episodes reported also illustrated ways in which aims associated with IBSE/PBL were closely interconnected with the promotion of social and affective factors important in engaging children in inquiry and the development of skills and understandings in early science and mathematics through their inquiry processes. Explicit focus on the nature of science was limited, reflecting findings from the policy and teacher surveys in Work Package 3. However opportunities for discussion of the nature of science were indicated in a number of episodes, particularly in reflecting on the outcomes of explorations or investigations in early primary episodes. No substantial differences were noted between the aims of science and mathematics episodes. Partners noted that the aims of activities were often not made explicit and where aims were explicit they rarely featured a focus on creativity. Partners also commented on the important influence of teachers' wider perspectives on learning and teaching, and their views of the nature of science and mathematics on the aims explicit or implicit in the activities observed. They also noted that the integration of cognitive, social and affective aims



common in many episodes reflected the holistic approach to early years education set out in policy in many partner countries.

Grouping

Class sizes varied considerably with class sizes of 20-30 being most common. Small group work was a common feature of practice in the episodes reported, in some cases informal child-chosen groupings (more common in preschool) and in others groupings structured by the teacher (more common in primary school). The episodes provided rich examples of the potential of small group work for fostering dialogue, collaboration and peer learning. Use was also made of whole class discussion to share experiences and reflect on findings from investigations.

Location

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

Time

The influence of school timetables and curriculum requirements on teachers' approaches was highlighted in many Country Reports. More flexible timetabling and a more holistic approach to learning and teaching commonly associated with preschool settings allowed teacher greater flexibility to follow children's interests over time and to revisit experiences, and make provision for children to encounter ideas in a range of different contexts. The challenge here was often less one of time but of recognising and building on children's emerging interests, skills and ideas. In primary settings, specific teaching hours and times were more likely to be laid down. This presented challenges associated with following up on children's ideas, responding to the unexpected or making connections between experiences. The episodes provided useful examples of ways of building on children's ideas and questions over time and fostering reflection across a class project or scheme of work. These would provide useful starting points for discussing ways of making best use of time. As outlined in Work Package 3, a further difference noted by partners, particularly in primary settings was the greater time allocation for mathematics in comparison with science. However this was also often associated with restrictions associated with specific requirements in terms of subject content. As outlined below science was more often presented as part of wider area of learning. This offered greater scope for flexibility and making connections, but there were also dangers of neglect of science if not prioritised by schools or teachers.





Content

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

4.1.3 Wider contextual factors

School

The cases studies illustrated ways in which factors at school level can contribute to a climate that has the potential to foster creativity in learning and teaching in early science and mathematics. They include influence of the whole school approach to learning and teaching on teachers' scope for creativity and the value of team work in giving teachers confidence and encouragement to share and try out new ideas. The case studies also indicated ways in which school organisation of resources, space, staffing and timetabling can support, or act as a barrier, to creativity and inquiry both in teaching and learning. Findings indicated that preschool settings often had more generous space, resources and staffing with greater scope for flexibility to allow time to follow children's ideas and interests. Finally, partners emphasised the need for schools to value the place and contribution of science in the curriculum to ensure potential for science learning is capitalised on in preschool and not neglected in primary settings.

Teacher

Findings highlighted the important influence of teachers' perspectives on learning and teaching and opportunities for professional development on the approaches adopted in the classroom and the scope afforded for creativity and inquiry. The teachers associated with strongest episodes were often able to articulate their views of learning and teaching informed for example by child-centred, experiential perspectives, or explicit reference to inquiry based learning. However few teachers indicated they had considered the nature of creative teaching and learning or how this might be reflected in early science and mathematics. In a number of episodes teachers indicated that they were adopting teaching approaches they had learnt about and tried out on courses of professional development. The courses had provided inspiration and confidence, for example to take on exploratory or investigative approaches or find out about children's ideas. However in other cases, while teachers were sympathetic to approaches associated with inquiry and creativity, they felt they needed further guidance on teaching strategies to foster creativity and stronger subject knowledge in science and mathematics to recognise and respond to children's ideas and thinking.



Policy

Finally findings suggested a varied picture of the influence of policy on opportunities for inquiry and creativity reflecting findings from D3.2 *Report on Mapping and Comparing Recorded Practices*. Policy in many of the partner countries advocates inquiry-based approaches and in a number of instances there are general references to the importance of creativity in learning and teaching. This provides important support for teachers and schools concerned to foster inquiry and creativity in early science and mathematics. However, curriculum and assessment requirements, and space and time at school level can constrain teaching approaches, particularly in primary settings. The support of the whole school and teacher professional development are important, as outlined above, in enabling teachers to take advantage of the scope for inquiry and creativity in their particular policy contexts. The *Selected Episodes* provide inspiring examples of the potential for creativity and inquiry within a range of different school and policy contexts.

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

Fieldwork provided rich evidence of the varied ways in which approaches to learning, teaching and assessment fostered skills, attitudes and understanding associated with inquiry and creativity in early mathematics and science. It also provided strong illustrations of young children's capabilities and interests in science and mathematics as discussed in D2.2 Appendix 1 *Review of science and mathematics education in preschool and early years of primary school*. Across the episodes there were many examples of children *observing* and *making connections* for example with prior learning or between experiences. Opportunities for children's *questioning* were also present but not always recognised or built upon. There was greater evidence of children's engagement in the social dimensions of inquiry, *explaining evidence* and *communicating explanations* than might have been expected from the policy and teacher surveys, often prompted by dialogue with peers and adults. Explicit examples of children's developing *understanding of the nature of science* were limited but starting points for the development of understanding of the nature of science was indicated in a number of episodes, in children's reflections on learning in classroom discussion or in interviews with researchers. Children's inquiry skills and understandings noted in episodes were interconnected with evidence of a number of creative attributes. For example children's *motivation, curiosity* and *abilities to come up with something new* were evidenced in raising questions and in their active pursuit of explorations and investigations. The episodes reported offered many examples of children's *sense of initiative* and *growing abilities to collaborate* in deciding what to do in carrying out investigations. Children showed *imagination, ability to make connections and thinking skills* in offering explanations.

How do teachers perceive their role in doing so?

The case studies provided in the Country Reports included background information about the teachers involved. They also summarised key features of the teachers' perspectives on learning and teaching gained from interviews to discuss the episodes observed. This provided some indication of teachers'



views of their roles in fostering children's learning interest and motivation in science and mathematics. In a number of instances teachers indicated that this was not something that they had considered previously. Approaches they adopted had mostly been implicit and that fieldwork processes had prompted reflection on the nature of inquiry and creativity in early mathematics and science and how this might be fostered. Key themes highlighted by partners in their case studies are emphasised here. Further details are provided in the Country Reports. A more comprehensive analysis of the original interview data from across the partnership is planned for the future.

Teachers gave varied responses and emphasised different aspects of the role of the teacher. Connections can be identified to the features of pedagogy associated with creative and inquiry-based approaches, the synergies, outlined in the *Conceptual Framework* (D2.2). Most teachers made reference to the importance of encouraging and supporting young children's engagement in early years science and mathematics as an important starting point for learning. No other feature of teachers' views was highlighted by a majority of teachers. Other aspects of the role of the teacher that gained the greatest attention (mentioned by more than ten of the 74 teachers) included an emphasis on fostering motivation and collaboration and providing a rich environment with space and time for exploration and problem-based learning, reflecting findings from the teacher survey. Another key role identified was the role of the teacher in encouraging reflection and making connections to promote children's conceptual understanding and application of ideas in varied settings. A number of teachers also underlined the important roles of careful listening and observing in supporting learning (linked to the key role of assessment). Other themes mentioned (by at least five teachers) were the importance of child-initiated investigation, the key role of teacher questioning, the need for varied forms of expression and the importance of collective processes of discussion, review and evaluation linked to notions of citizenship. However limited explicit reference was made to the role of creativity or features of inquiry in science and mathematics.



5. Implications

Findings from the case studies examined in the Country Reports suggest a number of implications for teacher education, for policy development and for further research as outlined in the sections below.

5.1 Teacher education

Implications for teacher education are outlined below in relation to the factors identified in D3.1 *List of Factors* as associated with opportunities for inquiry and creativity in early years science and mathematics.

5.1.1 Contextual factors

Whole school factors

The case studies across partner countries illustrated the importance of the ethos of the school in fostering opportunities for inquiry and creativity in teaching and learning. In a number of instances teachers referred to the value given in their schools to team working with colleagues and ways in which this encouraged teachers to discuss and try out new ideas. Organisation at a whole school level also played an important role in facilitating inquiry and creativity for example: flexibility in timetabling to allow response to children's ideas and interests or unexpected events, organisation of classrooms and furniture to allow space for varied forms of activity; investment in the wider school environment (spaces outside the classroom), in the school grounds and the organisation of procedures, equipment and staffing to enable regular use of the wider environment for learning. These themes are reflected in the suggestions for teacher education outlined below, in particular in relation to *Teacher Factors, Location, Time and Content*. This suggests the value of whole school in-service training to support the development of policy at school level to support creativity and inquiry in early science and mathematics.

Teacher factors

The cases highlighted the important influence also of teachers' perspectives (both implicit and explicit) on their practices in the classroom. This underlines the importance of encouraging teachers to reflect on the bases for their practice, to examine their own views of learning and teaching and what it means to be a 'good teacher', and factors that have influenced them. This suggests that teacher education in the following areas would be valuable:

- *Nature of inquiry and links to nature of science.*
- *Awareness of range of teaching and learning approaches and strategies - including formal, non-formal and informal approaches and knowledge of different types of inquiry and their purposes (including open, guided and structured approaches).*
- *Nature of creativity – including awareness of distinctions between features of creative teaching and creative learning.*

- *Reflection on ways in which teachers' conceptions influence their practice.*

5.1.2 Pedagogical framing

Aims and objectives

In a number of preschool episodes the aims of science or mathematics experiences were not stated but implicit in the learning and teaching processes observed. In primary school stated aims for activities were more common, often related to specific curriculum requirements or guidance in national or local policy, rather than a broader view of the rationale and aims for science education. Furthermore concern was expressed in a number of Country Reports about the limited time allocated to science in school timetables. This suggests that teacher education should include consideration of:

- *The purposes of science and mathematics education.*
- *The rationale for the place of science and mathematics in the early years curriculum.*

Location

The episodes recorded across partner countries included some rich examples of use of the outdoor environment, both the school grounds and the wider environment beyond the school. However there was considerable variation in the opportunities for outdoor learning provided across settings, suggesting the following areas for development through teacher education, building on the strong practices recorded in the Country Reports:

- *Making use of varied settings for learning - including flexible use of the environment both indoors and out.*
- *Developing the school grounds and the outdoor classroom in preschool settings.*
- *Managing visits to the outdoor and wider environment beyond the school.*
- *Strategies at whole school level to support outdoor learning including: staffing, equipment, health and safety, liaison with parents, building progression in experience across the school.*

Grouping

Episodes from across the Country Reports illustrate a variety of approaches to the use of group work and the potential of group work to support children's inquiry processes and creative thinking. However a number of teachers commented on the difficulties associated with organising and managing group work, in picking up on issues and questions raised during group work processes and with assessing children in the context of group work. This suggests that it would be valuable to explore:

- *Value of collaboration for inquiry and creative thinking*
- *Different ways of organising group work – ways of grouping children, task design and teaching strategies to promote collaboration.*
- *Effective strategies for sharing ideas and discussions from different groups (the teacher cannot be with every group and may miss key issues and questions).*
- *Assessment of group work.*

Time and Content

A number of teachers across partner countries commented that they found restrictions of time a major issue, especially in primary school settings. In particular teachers underlined the need for time for extended engagement with an area of study, and for building on children's ideas and events in the world around them. Themes that could be explored in teacher education include:

- *Approaches to timetabling to allow space for cross-curricular project work and child- initiated exploration.*
- *Ways of building flexibility into planning to take advantage of unexpected events, children's interests and questions.*
- *Building connections across the curriculum – examining of different kinds of connections and their potential contributions to inquiry and creativity.*
- *Ways of working with curriculum and policy expectations to allow time for children's inquiries.*
- *Strategies both formal and informal for supporting extended engagement with an area of study and progression in learning.*

5.1.3 Pedagogical interaction

The Country Reports offered a range of suggestions regarding priorities for teacher education in relation to the dimensions associated with pedagogical interactions. They build on the potential for inquiry and creativity shown in the episodes recorded, but also suggest issues for teachers to explore in considering how opportunities for inquiry and creativity in learning and teaching might be extended further in everyday classroom practice.

Learning activities

The episodes across the Country Reports include a range of examples of the different learning activities associated with inquiry (as illustrated in the selection included in the Appendices to this report). However they suggest also that there is further scope for extending opportunities for children's agency and creativity in learning, for example in capitalising on children's ideas for further inquiry, in fostering decision making during inquiry processes and in sharing, evaluating and reflecting on outcomes. Areas to be explored through teacher education could include:

- *Ways in which everyday learning activities can be opened up to allow greater opportunities for children's decision making in inquiry and problem solving and scope for creativity.*
- *The key roles of children's questioning and ideas (both implicit and explicit).*
- *Strategies for eliciting and building on children's questions and ideas during inquiry processes (before, during and after explorations and investigations).*
- *Ways of fostering children's agency in inquiry and problem solving – in particular the importance of children making their own connections between questions, planning and evaluating evidence.*
- *Different kinds and purposes of inquiry and problem solving and the varied opportunities they offer for creativity.*

Pedagogy – Role of the Teacher

Play and exploration

The preschool episodes across partner countries provided a number of rich examples of play and exploration – in particular when they led to sustained or extended inquiries. However, researchers across the partnership commented that it was often difficult, within the limitations of the resources available for fieldwork, to pick up on child-initiated play and follow its development over time. It is by its nature unpredictable and spasmodic, and developments may occur over several weeks of periods of short engagement with particular materials or phenomena. In a number of preschool settings however, children's persistent interests and engagements were recorded by staff in children's profiles, with comments on how they might be further fostered or extended. In primary settings far fewer opportunities for play and exploration were identified but there were instances of children developing their own explorations beyond the original task set by the teacher. Building on these observations from fieldwork processes issues to be explored in teacher education could include:

- *Ways of making the most of opportunities for child-initiated play – including strategies for picking up on children's ideas, interests and questions; ways of evaluating provision for free flow play in preschool settings; recognising and capitalising on the potential of children's explorations beyond the teacher's original intentions.*
- *The value of play and exploration in science and mathematics across the primary school in fostering inquiry and creativity – for example in familiarisation with phenomena and events prompting questions, eliciting ideas, providing opportunities for exploration of alternative strategies.*
- *Ways of building in opportunities for play and exploration in science and mathematics learning and teaching in primary school.*

Motivation and affect

Across the range of cases and episodes included across the Country Reports teachers emphasised the importance of engaging children's interests and curiosity and promoting motivation in mathematics and science. This reflects findings from D3.3 *First Survey of School Practice* that indicated that teachers gave high priority to social and affective factors in their aims for early science and mathematics. The episodes provide useful examples that could be used in teacher education to examine the role of affective factors in engaging the children including:

- *A range of approaches for provoking interest and motivation, such as stories, poems, songs, drama, puppets, games.*
- *Strategies for making and building on real life connections and applications.*

Dialogue and collaboration

Across the episodes recorded in both preschool and primary settings there were a number of examples of dialogue and collaboration between children that fostered problem solving and reasoning. Issues associated with the more formal organisation of group work more common in

primary settings have been outlined in the section above on grouping. In preschool settings arrangements were generally more informal with shifts backwards and forwards over time between individual work, children working alongside each other and collaboration. This suggests the following areas for consideration in teacher education:

- *Recognising varied patterns of collaboration in preschool settings, shifting between individual and collaborative activity over time*
- *Awareness of ways in which resources and teacher intervention can help foster collaboration.*

Problem Solving and Agency

The section above on *Learning Activities* considers issues associated with fostering learning activities associated with inquiry and problem solving. Implications for teacher education are outlined in particular related to opening up opportunities for children's agency.

Teacher questioning to support inquiry and creativity

The episodes across the Country Reports highlight the key roles of teacher questioning in fostering inquiry and encouraging reflection and reasoning. The Conceptual Framework (D2.2) highlighted the importance of teacher questioning in scaffolding children's inquiries and the different kinds of questions that might be productive in fostering children's independence and extending thinking. Fieldwork processes provided varied examples of both productive questioning and opportunities that were missed to extend learning. Furthermore the episodes recorded suggest that more could be done to foster children's questioning. In a few episodes, mostly in preschool, the focus and direction for inquiry was initiated by children, or teachers supported children in raising questions to be investigated. However in many episodes the teacher set the initial question or problem to be tackled.

Key themes to be explored through teacher education include:

- *Different forms of questioning, what forms of questioning are most productive at what points and why.*
- *Using questioning to encourage children's reflections, explanations and forms of expression.*
- *Ways of encouraging children's own questions, including those that are investigable.*
- *Giving the children time to formulate their responses or come up with new questions.*
- *Teacher scaffolding through questioning, judging the timing and nature of questioning to foster independence and extend inquiry.*

Forms of representation and expression

The Country Reports included examples of episodes in both science and mathematics where children were able to represent and express their ideas in their own ways – however this practice was not widespread. Children's representations in these instances also offered valuable contexts for dialogue about their ideas and thinking. The focus in recording can often be on the product, rather than the process of recording, and the opportunities it can provide for children to explore ideas and reflect on learning. It was evident that where teachers left open how ideas might be recorded this helped to free children's imaginative responses. Issues to be explored through teacher education could include:

- *Ways of capturing each stage of the learning process through varied forms of recording.*
- *Exploring and valuing different forms of representing and expressing ideas.*
- *Highlighting the purpose of recording and selecting appropriate approaches for desired purposes.*
- *The role of recording and discussion to support reflection and reasoning processes.*
- *Ways of promoting reflection and discussion.*

Scaffolding

The *Conceptual Framework* (D2.2) underlined the significant role of teacher scaffolding in fostering children's creativity and independence in inquiry and problem solving but also the complexities of the issues involved in judging when to intervene and stand forward and when to stand back. This relates to both designing learning activities and teacher questioning discussed above. In the episodes reported in the Country Reports teachers showed varied awareness of their roles in scaffolding children's curiosity and creativity. The episodes provide a variety of examples that could be used in teacher education to discuss a range of issues including:

- *Teacher scaffolding in science and mathematics teaching to support creativity.*
- *Establishing open ended learning activities.*
- *Recognising moments to stand back in order to observe, listen and build from the children's interests or to step forward to extend inquiries.*
- *Intervening with appropriate questioning to support inquiry.*

Informal learning

Fieldwork processes provided some indications of opportunities for informal learning in science and mathematics for example within day to day routines or child-initiated games and other activities in school classrooms or outdoor play areas. In some instances teachers or children made connections to children's informal learning at home or in the wider environment. This would be a valuable area for further research. Themes that might be explored through teacher education include:

- *Recognising and building on opportunities for informal learning within the school environment.*
- *Ways of eliciting and building on children's informal learning outside school.*

Assessment

Across all phases of the project, assessment has emerged as a key area for development. While varied forms of assessment were employed across the episodes to inform teachers' views of children's progress, ways in which assessment information was used to inform learning and teaching was often implicit and there were limited examples of children's involvement in peer and self-assessment. Themes to be explored through teacher education could include:

- *Different assessment strategies and forms of evidence that could be used in early science and mathematics.*
- *Importance of listening to children, their interests and questions.*

- *Involvement of children in assessment processes, for example dialogue and feedback on progress; integration peer and self-assessment into teaching and learning processes.*
- *Using assessment information explicitly to inform both teaching and longer term planning.*
- *Using individual or class records of activities in science and mathematics to foster reflection on learning.*
- *Assessing group work.*
- *Use of children's portfolios for assessment.*

Materials and resources

The provision of rich resources was noted in many of the episodes, however the children's use of resources was rarely the focus of teacher observation and discussion and in the case of digital technology this was rarely used by the children themselves. The episodes provide useful examples of observations of children's interactions with materials during free flow play that could inform more explicit approach to the provision and planning of resources. Issues to be explored through teacher education could include:

- *Recognising the potential in everyday materials.*
- *Organisation of materials in the classroom and school environment both indoors and out to support independent inquiry and creativity.*
- *Ways in which the organisation and nature of resources can both constrain and extend children's explorations.*
- *The importance of observing children's use of resources to gain insights into their developing explorations and thinking.*
- *Strategies for developing and extending teachers' own classroom resources.*
- *Evaluating ICT resources - awareness of the potential of children's use of ICT to support creativity and inquiry, but also the limitations and challenges.*
- *Knowledge of natural resources and issues in the local environment, organisation of materials and equipment to support investigations in the wider environment.*

Pedagogical approaches in teacher training

A number of teachers involved in the fieldwork across partner countries felt they had gained a great deal from participation in the *Creative Little Scientists* research project. In particular they indicated that the approaches and instruments employed during fieldwork provided valuable starting points for discussion and reflection. Aspects of the fieldwork that might be used in teacher training include:

- *Taking video recording or photographs of classroom sessions to support reflection.*
- *Using the framework of factors for analysis of teaching and learning processes.*
- *Selecting examples of episodes to illustrate and examine critically opportunities for creativity and inquiry in learning and teaching.*

5.2 Policy

The Country Reports highlighted a number of key areas for attention in policy related to teacher education, curriculum and assessment, guidance on learning and teaching approaches and provision of classroom resources to support early science and mathematics.

5.2.1 Teacher education

The previous section provides detailed recommendations for the content of teacher education programmes. Here the focus is on broad considerations that might inform the development of policy in relation to the provision for teacher education across partner countries.

Importance of opportunities for ongoing professional development

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.

Training for inquiry and creativity in early science and mathematics

The Country Reports identified detailed priorities for teacher education to support inquiry and creativity in early science and mathematics as outlined in section 5.1 Teacher Education above. Key implications for policy in relation to teacher education include:

- The need for 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.
- 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.
- Importance of training for teachers 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.

Training for subject leaders in science and mathematics

A number of Country Reports highlighted the importance of training for subject leaders in science and mathematics to promote inquiry and creativity across the school, and to support colleagues in fostering inquiry and creativity in their classrooms. Recommended content for subject leaders included:

- Examination of the aims and purposes of science and mathematics education.
- Approaches to learning, teaching and assessment to support inquiry and creativity.
- Strategies for developing whole school policy.



Cases studies in a number of countries illustrated the value of collaborative approaches in providing a supportive climate for implementation of new practices in the classroom and the development of policy across the school.

Training for teacher educators

The Conceptual Framework for the project (D2.2) indicated that qualifications and training for teacher educators varied considerably across the partnership. The recommendations above have implications for the training of teacher educators to ensure they have the understanding and skills to provide the kinds of ongoing professional development required to foster inquiry and creativity in science and mathematics. The principles and materials developed in Work Package 5 *Directions for Teacher Training* will provide valuable starting points for sharing and developing practices in teacher education.

Role of policy initiatives and research projects in supporting development of practice

Finally the Country Reports provided examples of ways in which involvement in policy initiatives (related for example to children's health or environmental education), research projects or curriculum development networks in the wider education community can play an important role in raising the profile of science and mathematics in the early years school and teacher development. Greater recognition could be given in policy at national, local and school levels of the potential value of such opportunities for networking and sharing of practice in supporting inquiry and creativity in early science and mathematics.

5.2.2 Curriculum and assessment

The different phases of the project associated with the policy and teacher surveys (Work Package 3) and the fieldwork in schools (Work Package 4) 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. Important implications for policy highlighted across the project include the:

- *Need for coherence in policy between the aims of science and mathematics education and curriculum and assessment requirements.*
- *Importance of sufficient space and time in the curriculum for problem solving and inquiry and to study areas in depth.*





- *Need to give greater value and attention to formative assessment including dialogue between children and teachers to identify ways forward for both learning and teaching.*
- *Importance of on-going development of 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.*
- *Importance of 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.*

5.2.3 Policy guidance on learning and teaching approaches to support inquiry and creativity in early science and mathematics

A further theme that emerged across all phases of the *Creative Little Scientists* project is the need for further guidance for teachers in translating aspirations to foster inquiry and creativity into classroom practices. Commentary across the Country Reports suggests that guidance should include:

- *The important roles of play-based approaches, child-initiated activity and practical investigation in both preschool and early primary school.*
- *More detailed attention to key features of problem solving and inquiry based learning and teaching.*
- *Explanation and illustration of the nature of creativity in learning and teaching in early years science and mathematics.*
- *The importance of 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.*

5.2.4 Resources

Across the Country Reports 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.*
- *Development of the whole school environment, in particular the outdoor environment.*

5.3 Future research

Experiences during fieldwork and the subsequent analysis of data suggested a number of important areas for future research. Limitations of time on the project restricted opportunities to seek out practices that do not take place on a daily basis, or to investigate aspects of learning that require close





observation over time. Further investigation would be valuable to gain insights into the following factors and issues:

- The role of free flow play in fostering inquiry and creativity over time.
- Opportunities for outdoor learning in the wider school environment.
- The contribution of informal and non-formal approaches to young children's learning in science and mathematics.
- The potential of children's use of ICT to enhance inquiry and creativity.
- The role of representation in varied modes in fostering young children's reflection and reasoning;
- Opportunities for exploring the nature of science with young children;
- The contribution of peer and self assessment to the development of creative dispositions in early science and mathematics.

Partners collected a rich range of data during fieldwork, beyond that directly associated with the episodes reported, including detailed interviews with teachers and children and a wide range of photographs of play activities and of school and classroom environments. This offers considerable scope for further analysis.





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APPENDICES

Appendix 1: Key factors illustrated in the Selected Episodes

	Country	Episode	Phase	Subject	Learning Activities	Pedagogy	Other factors
01	Belgium	Carpenter Corner	PreSch	Maths	LA: Plan LA: Connect	P: Scaff P: Agency	A: Self M: Explor M: Variet
02	Belgium	Colouring	PreSch	Science	LA: Plan LA: Expl	P: Scaff P:Collab	M: Variet M: Explor M: Outd
03	Belgium	Sand Box	PreSch	Integrate	LA: Obs LA: Equip	P: Play P: Agency	M: Explor A: Form
04	Finland	Melting Snow	PreSch	Integrate	LA: Equip LA: Obs	P: Scaff	G: SmallG A: Form M: Outd
05	Finland	Multiplication Story	Sch	Maths	LA: Comm LA: Connect	P: Affect P: Collab P: Agency	A: Peer/self M: Cr
06	Finland	Ways to Count	Sch	Maths	LA: Equip LA: Quest LA: Comm	P: Dialog P: Scaff P: Agency P: Express	A: Form A: Summ
07	France	Ice Cream Sticks	Sch	Maths	LA: Plan LA: Expl	P: Dialog P: R&R	
08	France	Magnet	PreSch	Science	LA: Comm	P: R&R	M: Variet
09	France	Share	PreSch	Maths	LA: Comm LA: Expl	P: Affect P: Scaff	M: Human
10	Germany	Building Blocks	PreSch	Integrate	LA: Plan LA: Comm	P: Play P: Affect P: Scaff	M: Explor

11	Germany	Fermi Questions	Sch	Integrate	LA: Plan	P: Affect P: Agency	L: Out/Indoors A: Form
12	Germany	Water Inquiry	Sch	Science	LA: Plan LA: Comm	P: Affect P: Agency P: Scaff	M: Outdoor M: Explor
13	Greece	Measuring Tables	PreSch	Maths	LA: Plan LA: Equip LA: Connect LA: Expl LA: Comm	P: Affect P: Agency P: Collab P: R and R P: Scaff	M: Explor.
14	Greece	Ice Balloons	PreSch	Science	LA: Ques LA: Plan LA: Comm LA: Equip	P: Agency P: Ques P: R and R	M: Explor. M: Variet
15	Greece	Bee-Bot	Sch	Integrate	LA: Plan LA: Obs LA: Connect	P: Affect P: Collab P: R and R P: Scaff	M: ICT
16	Malta	Counting Caterpillars	Sch	Maths	LA: Plan LA: Comm	P: R and R	M: ICT
17	Malta	Feet	PreSch	Maths	LA: Equip LA: Obs LA: Comm	P: Affect P: Dialog	M: Variet
18	Malta	Minibeasts	Sch	Integrate	LA: Obs LA: Comm	P: Affect	M: Outd
19	Portugal	Sun Distance	PreSch	Science	LA: Obs LA: Quest	P: Express P: R and R	M: Space M: Variet
20	Portugal	Swinging Game - Rope	PreSch	Science	LA: Plan LA: Connect LA: Obs LA: Expl	P: Agency	M: Space M: Explor
21	Portugal	Wolf, Sheep, Cabbage	Sch	Maths	LA: Plan LA: Comm	P: R and R P: Express	G: Small G

22	Romania	Float or Sink	PreSch	Science	LA: Plan LA: Obs LA: Comm LA: Expl	P: Agency P: R and R	M: Variet G: SmallG
23	Romania	Ice	Sch	Science	LA: Plan LA: Connect LA: Comm	P: Collab P: Agency	G: SmallG M: Variet M: Explor
24	Romania	Measuring Volumes (Non-Standardised Units)	PreSch	Integrate	LA: Equip LA: Obs LA: Comm	P: R and R	M: Explor M: Variet
25	UK	Balancing Pen	Sch	Maths	LA: Equip LA: Obs LA: Quest LA: Expl	P: Collab	A: Form M: Variet
26	UK	Buttons	PreSch	Science	LA: Connect LA: Expl LA: Obs	P: Scaff P: Affect	A: Form
27	UK	Cafe	PreSch	Maths	LA: Exp	P: Affect P: Play	Ti: Suffic M: Human M: Variet
28	UK	Counting Minibeasts	PreSch	Maths	LA: Plan LA: Comm	P: Express P: Agency P: Scaff P: R&R	M: Space
29	UK	Habitat	Sch	Science	LA: Connect LA: Comm	P: Affect P: Agency	A: Peer M: ICT
30	UK	Shapes	Sch	Maths	LA: Plan	P: Scaff P: Collab P: Agency P: Affect	M: Explor A: Summ

31	UK	Sound	Sch	Science	LA: Obs LA: Comm	P: Dialog P: Collab P: Express	A: Form A: Peer/Self M: Explor
32	UK	Starting Point	Sch	Science	LA: Quest	P: Quest	A: Form
33	UK	Gloop	PreSch	Science	LA: Ques LA: Obs LA: Equip	P: Play P: Affect P: Quest P: Agency P: Scaff	M: Explor M: Inf
34	UK	Raft	PreSch	Science	LA: Obs LA: Equip LA: Quest	P: Play P: Affect P: Agency P: R&R	M: Variet
35	UK	Day and Night	Sch	Science	LA: Quest	P: Affect P: Express	M: Variet M: ICT
36	UK	Forest School	PreSch	Science	LA: Connect LA: Obs	P: Quest P: Play	M: Outd A: Self M: Variet

Appendix 2: Summary of Factors identified across all episodes

	All episodes n = 218	Preschool episodes n = 115	Primary episodes n = 103	Science episodes n = 122	Mathematics episodes n = 71	Science & mathematics episodes n = 25
Factors associated with inquiry and creativity	% all episodes	% preschool episodes	% school episodes	% science episodes	% mathematics episodes	% episodes integrating mathematics and science
PEDAGOGICAL INTERACTION						
Learning Activ.						
LA: Ques	59	63	53	63	49	54
LA: Plan	52	48	57	48	56	54
LA: Obs	77	82	72	83	61	77
LA: Equip	57	57	56	60	51	46
LA: Connect	68	64	72	74	57	65
LA: Expl	54	50	58	50	51	65
LA: Comm	65	59	71	61	65	69
Pedagogy						
P: Play	48	62	32	48	44	54
P: Affect	59	68	49	58	54	65
P: Collab	68	66	70	61	71	81
P: Dialog	57	63	51	52	61	62
P: Agency	64	62	67	59	65	73
P: Ques	52	59	45	56	46	42
P: Express	47	45	50	41	51	54
P: R and R	52	55	49	48	54	54
P: Scaff	72	71	73	72	64	81
Assessment						
A: Form	68	63	75	67	67	77
A: summ	17	12	21	15	14	31
A: Strat	9	8	10	10	7	8
A: Evid	24	18	31	18	26	35

A: Peer / self	20	20	20	15	24	27
Materials						
M: Explor	71	77	64	75	61	69
M: Cr	47	51	43	48	39	58
M: Space	50	57	45	48	44	69
M: Outd	16	19	14	21	4	23
M: Inf	29	34	23	34	22	19
M:ICT	28	13	44	31	22	27
M: Variet	45	48	43	44	44	50
M: Human	44	48	40	45	44	35
M: Pol	88	93	83	92	78	89
PEDAGOGICAL FRAMING						
Aims & Obj						
AO: KnSc	54	52	55	63	40	35
AO: UndSI	22	22	23	29	11	19
AO: ScProcSkills	50	49	52	62	29	42
AO: IBSE/PBL	47	46	48	48	40	54
AO: Social	71	72	69	69	71	65
AO: Affect	65	68	61	65	61	62
AO: Creative	50	49	50	47	47	62
Location						
L: Outdoor	8	10	6	9	3	12
L: Indoor	88	85	90	74	21	0
L: Both	4	4	4	0	0	10
L: Formal	75	61	83	71	68	81
L: Non-Formal	7	8	3	4	3	8
L: Informal	18	20	14	22	15	7
L: Grp	72	73	72	75	69	69

Grouping						
G: MG	11	12	9	12	11	15
G: Abil	11	7	17	9	25	30
G: SmallG	77	77	78	75	69	69
G: No	n/a	n/a	n/a	n/a	n/a	n/a
Time						
Ti: Suffic	56	57	54	45	72	62
Content						
C: Sci/M Sep	55	37	66	52	68	19
C: Detail (High)	37	31	43	47	28	19
C: Detail (Medium)	36	36	36	31	43	38
C: Detail (Low)	27	33	19	23	28	42
C: Sci/M Integ (Planned)	21	28	15	16	6	92
C: Sci/M Integ (Incidental)	17	16	17	17	19	4
C: Sci/M Integ (None)	62	47	58	68	72	4
C: Core	44	56	30	49	32	50

Appendix 3: Selected Episodes

Episode: BE Carpenter Corner	Setting: PreSch
Subject: Mathematics	Age Group: 4-6 years old
Key factors:	Teacher: Maaike
Learning activities: Planning investigations / Making connections	
Pedagogy: Teacher scaffolding / Role of problem solving and agency	
Contextual Factors: Self assessment / Rich physical environment for exploration / Variety of resources	

Aims

This activity took place on the first day of a new atelier (workshop) cycle. Maaike wanted to observe the children to get to know what were their interests and talents. They had to choose which materials to use, what they wanted to explore and what they would like to design and make in the 'Carpenter Corner'.

Analysis of key features

The Carpenter Corner had a **very rich physical environment** with a special work bench and with real carpentry tools; several saws, nails, pincers, hammers, and wooden materials were made available. The children could also go outside the classroom to bring in other materials. Maaike stressed the importance of using real materials to design and inquire. The children could select the materials they wanted to use by themselves, so, **ownership and agency** was very much stimulated.

Two children chose to work in the Carpenter Corner. One of the children was a four year old girl; she belonged to the (morning) class group of Maaike and Sarah (who team teaches with Maaike). The other child was a five year old boy. For him everything was new as it was his first time in this atelier and this classroom. Maaike encouraged the children to work with their peers and children who were confident with an activity were expected to teach those who were less competent.

During the episode the two children **planned to make a house**. First they had to learn how to saw the wood. Maaike showed the children how to use the saw and explained that they always had to use the saw when other people were present for safety reasons. To use the saw, the wood had to be placed in a clamp to hold it still. The girl opened the clamp on the work bench and, when asked by the teacher if their box would now fit in, **the children decided to measure** their box. The boy **initiated this use of mathematical skills** himself and found a folding ruler (meter) to measure their box. He made careful marks with a pen to make his measurements accurate.

The initiative of the children was encouraged tremendously; the children were allowed to work with all materials in the Carpenter Corner. Instructions were only given for safety reasons. The different materials stimulated the imagination and the creative thinking of the children. By asking questions, the teacher also **stimulated the children's reasoning and problem solving skills**.

Opportunities for inquiry and creativity

The resources looked exciting and appealing as the carpenter corner looked just like the work area of an adult carpenter. The children were able to work freely in this area – probably unlike any previous experiences, if such equipment was used in their homes. **The children were fascinated by the different tools** in the corner and enjoyed playing with them before they started making anything. **Playing with the various tools helped them to make their own choices** about what materials to use and how to make their own design.

Children were able to **make connections** with other subject areas. Some children **integrated artistic skills with their design whilst others adopted a more scientific/mathematical approach** using measurement skills in the making of their product.

Children led their own activities and the teacher only intervened to show them how to use a new piece of equipment or to promote the children's reflection and evaluation of what they were doing.

The children were engaged in **self-assessment** as they all had to evaluate what they had made themselves. No child's creation was copied as the designs came from the children themselves. They evaluated what they had made and also the processes they followed.

ILLUSTRATIVE EXTRACTS FROM DATA

Rich variety of resources/ Agency – children solving problems themselves

The children could choose from a wide variety of resources in the Carpenter Corner. Child 1, who had never worked in this corner before, had a very good idea to transport the wooden materials.

Child 1: *Can I use that big bucket?*

Teacher: *Why do you need a bucket?*

Child 1: *I would like to transport the wooden materials in it, because otherwise I can get a splinter in my finger.*



Working with peers to encourage agency

Peer tutoring was encouraged by placing older children with younger children.



Both children worked together to build a house.

The 4 year old girl, however, did not know exactly what to do; the teacher said to the 5 year boy: *"Could you explain it?"*

The boy answered and showed what had to be done.

In this activity the boy was the designer and the girl liked to be doing things. Later, the boy continued to work on this house whilst the girl made lots more smaller houses.

Children encouraged to assess what they are doing

Although there were instructions from the teacher, children were also stimulated to reflect on what they were doing.

The boy suggested they needed to saw a window in their house. The teacher showed the boy and the girl how they must clamp wooden box in the workbench in order to cut it safely. They needed to turn the lever, so that the work bench opened. The girl started turning the lever, the teacher asked several times, *"Does the box already fit in the workbench?"* Each time it was measured by the girl and the boy.



Making connections – linking mathematics and science

Child 1 wanted to measure the wooden box. He recognized the need for accurate measurements.

Child 1: *I'm going to have a look with the meter (ruler).*

Teacher: *Yes, you can measure it.*

Child 1 finds a fold meter (folding ruler) in one of the bins and he unfolds the meter. He kneels on the ground.

Child 1: *I'm going to look how long this measures.* (He measures the wooden box.)

Child 1: *That's not going.*

Teacher: *Is it not good?*

Child 1: *I have to have a pen.* (He draws a line on the wooden box.)

Teacher: *Child 2 is it already OK?*

Child 2: *No.*

Teacher: *Maybe Child 1 has to put there a line too, such as here.*

The teacher showed the other measurement that was done by Child 1.



Episode: BE Colouring	Setting: PreSch
Subject: Science	Age Group: 5-6 years old
Key factors:	Teacher: Lies
Learning activities: Planning investigations / Explaining evidence	
Pedagogy: Teacher scaffolding / Collaboration	
Contextual Factors: Variety of resources / Rich physical environment for exploration / Use of outdoors	

Aims

The goal of the teacher (Lies) was to engage the children in extracting dyes from a range of natural materials, to identify factors that affect the dyeing process (e.g time and temperature of the water) and for the children to engage in collaboration and autonomous learning.

Analysis of key features

The activity was part of a bigger project about American Indians that the children had chosen to do. The children found out that some American Indians use natural dyes to colour their clothes, so the children first explored how to dye cotton fabric and later on they made their own clothes.

This episode focuses on four girls who chose to work in the corner where they were dyeing pieces of cotton fabric with dyes from natural products. On the table were **a rich variety of materials, such as oranges, grass, herbs, coffee, tea (also rose hip tea), funnels, sieves (in different sizes), cutting boards, scissors, cups and knives**. The children were also allowed to go **outside to collect more natural materials** if they wanted to do so.

To **scaffold the children's technique for extracting the dye** the children were given an instruction card with pictures showing how they have to handle the natural materials and how to separate these materials from the coloured water to extract the dye. **Lies only interacted when necessary or when the girls explicitly asked for her help**. The children were given the freedom to select the materials themselves and two of the girls **decided to go outside** to collect more grass and mud for their investigation.

Although the children had an instruction card to guide them, **they were allowed to plan their own investigations**, for example, they had to **choose which sieve to use by investigating** which size was most successful at separating the materials from the water. Indeed, one child chose not to sieve her coloured water at all. They could also **choose how long to leave the cotton fabric in the water** and one girl left her cotton fabric longer in the water and **she noticed the colour deepened the longer it was in the dye**.

The children worked together giving each other instructions about how to follow technique of making the dyes and how to do so safely when handling warm water. They took turns in stirring the water and **discussed how much**

orange peel to add and how small the pieces of peel needed to be to get a deeper colour of dye. The children were not sure what colour the dye will be with some of the materials: *"I'm curious what colour this is going to be"* one girl said to her partner. *"I'm also curious"* was the reply but they were confident to predict that the curry powder would be yellow.

In order to bring in an even wider range of natural materials, the teacher decided **to go outside to the park** with the children after playtime so they could find more natural materials in the park.

At the end of the activity the children had a class discussion where Lies asked Girl 3 questions to scaffold her explanation of why she decided to leave her fabric in the rose hip tea dye longer - *"because it hasn't enough colour"*.

Opportunities for inquiry and creativity

Although the children were given support with the instruction sheet they were still in control of planning their own investigations. By following their own ideas **they were curious about the results and were very motivated to explore further**. This curiosity was demonstrated by the girls who went outside to collect other materials, which were not present on the table, such as grass and mud.

Providing a range of materials stimulated another girl's interest and **she carried out her own investigation** in which she chose to explore what would happen if she added several different natural materials to the water rather than just one.

The teacher's role was one of facilitator and to provide support when the children needed advice. The interactions between the teacher and the children were short and focused on questions that promoted the children to reflect on their ideas. Thus, the children **were able to make their own decisions** as could be seen by one girl who left the materials in the water and did not separate them from the water before adding her cotton fabric to be dyed.

By supportive questioning the teacher also enabled the children to provide **their own explanations** of their evidence.

ILLUSTRATIVE EXTRACTS FROM DATA

Providing a rich variety of resources



The children had lots of different materials from which to extract dye and a wide range of equipment from which to choose. They could also go outside to choose other natural materials to use to dye their fabrics.

Child 1: *We went for more grass.*

Child 2 (who stayed in the classroom): *You may pour water in your cup.*

Child 4 (who also stayed in the classroom): *If you want to bring in the new grass, you first have to put this grass in your cup. And if you want to have water in your cup, then you have to ask her (she means Child 3).*

Children collaborating



Child 2: *I cut it with a knife. It has to be little pieces.*

Child 4: *Like this* (She showed a piece to Child 2.)

Child 2: *A little more warm water.*

Child 4: *There is some in the measuring cup.*

Child 2 took it and Child 4 held the cup with her hands. However, Child 4 did not want Child 2 to add too much additional water, so she pushed the measuring cup away.

Scaffolding the dyeing technique

Child 1: *Teacher, may we do it in little pieces?*

She showed how she did the pieces in the cup before her.

Teacher: *You may do it. Look, you can see here what the child is doing.*

And the teacher pointed to the pictures on the instruction card.



The children talk to each other about their techniques and ideas

Child 1 was still cutting up the materials with her tongue sticking out of her mouth concentrating hard. Child 3 was saying "Little pieces" to her.

Child 1 to Child 3: *But my fingers are almost broken.* (They, however, continue to cut up the material even further.)

Child 1: *I'm curious what colour this is going to be.*

Child 2: *I'm also curious.*

Child 1 to Child 2: *With you, it will turn yellow.* (Child 2 is working with the curry powder.)

Episode: BE Sand Box	Setting: PreSch
Subject: Integrated	Age Group: 3 years old
Key factors:	Teacher: Katrien
Learning activities: Gathering evidence (through observation) / Gathering evidence (using equipment)	
Pedagogy: Role of play and exploration / Role of problem solving and agency	
Contextual Factors: Rich physical environment for exploration / Formative assessment	

Aims

During this activity the children had to build something using the materials provided by the teacher. The children decided what they wanted to build after playing with the resources provided and they could choose whether to work individually or with others.

Analysis of key features

This episode was situated in a theme about stones. In the sand corner the teacher had placed **materials to build with, including real bricks**. They also had unfamiliar **specialist tools to help with the building process** such as plaster trowels and spirit levels, as well as the familiar bucket and spades.

First, the two children worked separately in order to make their own wall. However, after some time they started working together to build one wall and they shared the tasks required to prepare their materials. The teacher guided the process by asking the children what they had done or what had happened. When, at the end of the activity, the wall fell down, the teacher (Katrien) interacted with the children to discuss the reasons why the wall fell down.

In this activity the learning process of the children was characterised by the ownership of the children, who were learning by doing and **by observing the effects of their actions**. For example, when Child 2 was pouring out the water to mix with the sand she noticed that the sand was not mixing enough with such a great amount of water and so she poured some of the water out of her bucket. Child 1 **observed this effect** and only put a little bit of water on the sand in his bucket, indicating that he had **used the evidence** from his partner's mixture to make decisions about his own mixture.

The **self regulated learning and construction of their play** was also enhanced by the space they got from the teacher, for example, the teacher was present in the classroom observing the children, but she gave them more than 10 minutes before she came to interact with them. When she did interact, the main focus was on appreciating what the children were doing and on supporting them to go on to a next step. **The teacher offered learning opportunities** just by making the suggestion to place the bricks next to each other, to offer new possibilities in the play of the children. Katrien scaffolded her questions to

help the children reflect critically on their work in order to promote their conceptual understanding.

At the end of the activity Katrien took time to assess what the children had done and to ask the class a new question. She asked them to look at the walls of the school building when they are playing outside to see if the bricks are laid in the same pattern as they had used when making their wall (i.e. one on top of the other). All children in the class were involved in the discussion, thus, what was learned by a few children could be shared with all the others. During the sand box activity the children learned a lot about the effects of combining sand and water, and how to use this combination to **solve the problem** of how to fix bricks together in order to build a wall successfully.

During their **play they also came across different strategies** to balance their bricks, and the importance of placing them in a balanced way. They also got the opportunity of using different materials in order to construct their wall.

To find evidence that their walls were level the children used spirit levels to measure whether the bricks they had placed in their wall were level.

Opportunities for inquiry and creativity

In this episode the children were working very independently and had **to make their own decisions** about what materials to use and how to prepare them; they **made their own plans** about what to build and whether to work on their own or with other children. Building a wall **presented the children with problems** of how to stick the bricks together and the best way to place the bricks.

The materials the children could use provided a rich set of resources as they included real bricks rather than toy bricks and special technical tools that they did not know how to use at first. **Playing with these tools helped the children work out how** to use them in the building process.

The activity presented them with several problems and they were given the **opportunity to solve these problems themselves**. This episode also contained opportunities for **collaboration between children** as they played, they watched what each other did and they made decisions based on **their observations and evidence** of the impact of what other children were doing.

ILLUSTRATIVE EXTRACTS FROM DATA

Interaction with the resources – at the beginning separately and then together



The children have different starting points concerning the content of the activity.

Child 1 is filling the bucket with a shovel until it's completely full.

Child 2 is filling the bucket until it's semi-full.

Later they worked together:

Child 2: *I have to make some more mortar.*

Teacher: *Why?*

Child 2: *To help Child 1 with the building.*

Child 2: *I need more water then.*

Child 1: *I also want some more water.*

The teacher let them go and fill their beakers with water.

Child 2 is adding some more water to her bucket.

Child 1 is adding water to his bucket filled with sand.

Child 2: *We need 2 more bricks!*

Child 1: *I will make them.*

Child 2: *I will place some sand.*

Children's self assessment and learning from each other

The children, who were learning by doing, observed the effects of each other's actions and changed their actions accordingly. Child 1 watched Child 2 pouring the water into her bucket and she noticed that the sand was not mixing enough with that amount of water:

Child 2 puts some more water in her bucket and starts stirring again. After a while she notices there is too much water and she pours out some water.

Child 1 assesses that only a small amount of water is required and so puts a little bit of water on the sand in the bucket.

Children's play – observing effects of their actions

The wall the children had been building fell down.

Child 1 continued to prepare his brick ready to keep on building.

Child 2 tried to rebuild the fallen wall by replacing the bricks up on each other, but she failed to lift them up to be able to place them up on each other. After a few tries, she placed one brick on top of the two bricks next to her side of bricks. Then she grabbed the stone below and placed that one on top of that side of the wall.



Child 1 is finished with preparing his brick and looks at the actions of Child 2. Child 2 is trying to place her two resting bricks on top of the tower, but she doesn't succeed. She seeks help from Child 1.

Child 2: *Child 1, can you make this?*

Child 1 grabs the bricks and places them one by one on top of the wall.

Child 1: *Please!*

Child 2: *I will place some more wet sand on top, so the next one will be fixed in a proper way.*

Teacher scaffolding – questions for the children

Teacher: *Oh, look what happens? (She lets the stone loose and they fall).*

Teacher: *How is this possible?*

Child 2: *Because it wobbles. (...) I will take some wet sand.*

Teacher: *Can you place the sand on the brick?*

Child 2 places the sand on top of the brick.

Teacher: *Can you make it completely flat?*

Child 1 hands over the plaster trowel. Child 2 makes it flat with the plaster trowel.

Teacher: *Can you place the next brick on it now?*

Child 2 is placing the brick on top of it.

Teacher: *Can you use your spirit level to see if the bricks are in balance?*

Child 2 places the spirit level on the bricks and sees they are balanced.

Episode: FI Melting Snow	Setting: PreSch
Subject: Science	Age Group: 5-6 years old
Key factors:	Teacher: Mary
Learning activities: Gathering evidence (using equipment) / Gathering evidence (through observation)	
Pedagogy: Teacher scaffolding	
Contextual factors: Small grouping / Formative assessment / Outdoor resources	

Aims

The aim of the activity was for children to observe states of water and know what happens to snow when heated. This experimental activity was typical of the sort used in which the children learn to plan an experiment. They also learned how to estimate and conduct the experiment, observe the changes during the experiment (follow the process of boiling) as well as becoming familiar with scientific concepts such as melting, boiling, heating, evaporation, liquid and solid.

Analysis of key features

In this learning activity the children studied snow and the states of water. They were set a problem-based activity; what happens when snow is heated? The children collected snow using various measures, through these they also learned measurements e.g. 1 litre, ½ litre, 3 decilitres. Because the camping cooker was used for heating the snow, for safety reasons the activity was partly in the form of a demonstration; the teacher was strongly involved in the activity and asked questions about the phenomena observed.

The teacher asked for volunteers to participate in the activity and provided materials. The children worked independently but followed the teacher's guidelines. The children worked in small groups of 5 or 6 and each had individual responsibilities to a) collect snow b) follow the experiment, including observation and discussion with the teacher and c) mark down the results of the experiment. The teacher conducted the experiment twice with two different groups of children.

The teacher lit a fire in the camping cooker outside the classroom and asked the children to use **containers of different shapes**, but all with a volume of one litre, to collect snow. Once the children had collected the snow, the teacher poured the snow from one of the children's containers into a bowl on the cooker.

The teacher used **questioning to scaffold** children's **predictions** about what would happen to the snow and to focus their **observations** e.g. *"What do you think, how much water will we have when the snow has melted?"*, *"What you can see here?"* (pointing at the steam). Later, the teacher poured the water from the melted snow back into the original container, and asked the children to observe if there was more or less water than there had been snow.

When working with the second group, the teacher asked the children to compress the snow when they were filling up their containers. When the snow they had collected had melted, she asked the children whether they would have more or less water than the first group.

Once the experiment had been conducted, the children were asked to **record individually what they learned by making a drawing** on a blue piece of paper, which featured images of two containers. Children were to colour with white chalk one container full of snow and to indicate the amount of water that was observed as a result of the experiment in the other container.

Several **formative assessment** strategies were used during the session and there were signs of learning assessment. The teacher provided feedback during the whole-group discussion and asked questions, observed the children's activities and shared reflections with them. She also collected the children's drawings to evaluate their understanding. Reflection together with the children, and the teacher's questions e.g. *"How do you know that we have 1 litre of water here?"* also provided an arena for self-evaluation.

Opportunities for inquiry and creativity

Children's **inquiry skills** were fostered as they were tasked to find out about what happens when snow is heated by **making predictions and gathering evidence using observation and measuring equipment**. Children were supported in trying to solve the problem, follow the change of state of water and discover the reasons for it. **Teacher scaffolding** and involvement varied across the episode as she was guiding the approach to the activity, encouraged children to articulate and reflect on their observations and drew attention to concepts and processes associated with changes in state.

ILLUSTRATIVE EXTRACTS FROM DATA

Teacher questioning to scaffold discussion with the children about their observations and measurements



Snow is melting in the camping cooker.

Teacher: *What do you think, how much water will we have when the snow has melted?*

Children: *More / Less.*

Teacher: *What you can see here? (pointing to the steam)*

Children: *Steam.*

Snow has melted into water. The teacher pours water back onto the dish.

Teacher: *What do you think now: Is there more or less water than when there was snow?*

Children: *Less*

Teacher: *Could you tell me how much there is approximately?*

Children: *There are 3 litres, there is ½ litre, there is 1 litre.*

After discussion they agree that there's about half a litre of water.

Teacher: *How much snow did we have?*

Children: *One litre.*

Teacher: *So when water is in the form of snow it needs more space.*

Making a drawing to record learning



Children were asked to **record individually what they learned by making a drawing** on a blue piece of paper, which featured images of two containers. Children were to colour with white chalk one container full of snow and to indicate the amount of water that was observed when it had melted in the other container.

Episode: FI Multiplication Story	Setting: Sch
Subject: Mathematics	Age Group: 7-8 years old
Key factors:	Teacher: Helen
Learning activities: Communicating explanation / Making connections	
Pedagogy: Affect / Collaboration / Children's agency	
Contextual factors: Peer/self assessment / Materials that foster creativity	

In generating multiplication problems and stories relating to children's everyday experiences children **made connections** between mathematical concepts and learning in the classroom and mathematical patterns and relationships in the living world outside. The task aroused children's **curiosity** as they were **motivated** to explore more **connections** between school mathematics and mathematics beyond their classroom.

Aims

The aim of the activity was for children to learn about multiplication through story making. The teacher (Helen) told the observer that in an earlier lesson they had made up this kind of story using the same paper form, so the approach was already familiar to the children. She said that it is important to use different kinds of examples so that children understand that they can use any sorts of objects or things in the stories.

Analysis of key features

Helen, the teacher, started the lesson by drawing a tree with three branches on the blackboard. With the whole class, Helen discussed how to make multiplication questions from the drawing she had made. She then went on to draw two apples on each branch, and subsequently two leaves on each apple. Again, the children were encouraged to create multiplication questions from the additional details she had drawn.

Right after the whole group discussion the children **worked in pairs** to collaborate in creating their own multiplication stories and questions as well as in recording them on a worksheet. The worksheet provided space for children to record their multiplication stories in diverse ways, ranging from graphically and numerically to using words, highlighting how Helen valued **diverse forms of expression**. The teacher observed and scaffolded, using questioning to prompt children to articulate their questions and ideas.

At the end of the lesson the children told their stories to the whole class. This encouraged children to **communicate and explain** their ideas, and to share and discuss different possibilities for mathematical stories linked to the apple tree. The stories created in the activity supported the children's understanding of multiplication. The mathematical operations were discussed and the children learned how to create and solve mathematical word problems.

The children were also encouraged to engage in **self-assessment** by writing their feedback at the bottom of the worksheet.

Opportunities for inquiry and creativity

The activity of writing their own stories encouraged the children's **imagination** and **creative thinking** skills, and working in pairs motivated them and provided an opportunity for **engagement and agency**. Questioning was a crucial part of collaboration with the teacher, and dialogue was fostered in peer interaction.

ILLUSTRATIVE EXTRACTS FROM DATA

Teacher questioning to scaffold children's ideas, questions and story making

The teacher asked questions about the tree, and several children answered:

Teacher: *I have drawn a tree on the chalkboard. How many branches are there? / Think what kind of multiplication you could make from this tree?*

Teacher: *What kind of tree is this? / What kind of multiplication could you make from apples and branches?*

Teacher: *What do you see on the apple? / How many leaves are there on one apple? / What kind of multiplication can you now make?*

The teacher then drew two leaves on each apple, and the children and Helen counted the leaves together.

Teacher: *Come up with a short story which includes the branches and the apples.*

Child 1: *There was one tree with three branches. There were two apples on every branch.*

Teacher: *So what is your question?*

Child 1: *How many apples are there in the tree?*

Teacher: *Once before, we have made a multiplication story together. Now you can make new ones in pairs and in small groups.*

Teacher modelling an example, connecting the mathematical concept of multiplication to children's everyday experiences



Valuing diverse forms of expression and encouraging self-assessment.

The worksheet provided space for children to record their multiplication stories in diverse ways.

At the bottom of the worksheet, children were also asked to provide their feedback of the task, providing an opportunity for them to engage in self-assessment

Work sheet for multiplication stories

Kertolaskun tarinapaperi

1. Mark down your mathematical operation
1. Merkitse lasku. $5 \cdot 3 = 15$
2. Draw your multiplication story here.
2. Piirrä lasku haluamallasi tavalla (esim. ympyröillä tai viivoilla)
3. Present your multiplication sum here.
3. Merkitse sama yhteenlaskuna.
 $3 + 3 + 3 + 3 = 15$
4. Please, create a story. Draw a picture about your story.
4. Keksi laskusta tarina. Piirrä laskutarinaan so.
5. Please write your multiplication story.
5. Kirjoita laskutarina.
Olika kerran 5 lasta. Jokainen lapsi sai 3 paitaa. Kuinkamonta paitaa on yhteensä?

How did you feel about making multiplication stories?
Miltä laskutarinan tekeminen tuntui? Ympyröi 😊 😐 😞 Please, explain.
Perustele: Kiva kun sai piirtää.

Episode: FI Ways to count	Setting: Sch
Subject: Mathematics	Age Group: 7-8 year old
Key factors:	Teacher: Rachel
Learning activities: Gathering evidence (using equipment) / Questioning / Communicating explanations	
Pedagogy: Dialogue / Teacher scaffolding / Role of problem solving and agency / Diverse forms of expression valued	
Contextual factors: Formative assessment / Summative assessment	

Aims

The aim of the activity was for children to use a range of physical objects to solve subtraction problems.

Analysis of key features

Rachel, the teacher, had noted that several of her children found a particular subtraction problem in a recent test difficult. The problem in question was "What number is 4 numbers smaller than 18?". Rachel used the recent **summative assessment** information about her children to help inform the lesson from which this episode is drawn.

Rachel provided her children with **a range of physical materials and equipment**, such as beads ("pearls") and rulers, as well as reminding them that they could also use their fingers to help solve the problem too. Whilst specific materials and equipment, and the problem were provided by the teacher, the children themselves had an opportunity to **select resources** and **plan** how the equipment and materials would be used. **Diverse forms of expression** were fostered in encouraging children to present their methods in their own ways.

Children were **encouraged to work in pairs** and each pair had their own set of materials and equipment. The children had to try to solve the problem and then teach their approach to others.

During the plenary, children were expected to take turns to **present their solutions** to the rest of the class. This provided Rachel with opportunities for **formative assessment**. Once the children presented their methods, Rachel set additional problems for the children.

Throughout the classroom activity and plenary discussion, Rachel asked children a range of **questions to scaffold** children's use of resources to solve the problem. Examples of her questions and children's responses are included in the illustrative extracts from the data that follow.

Opportunities for inquiry and creativity

A range of creative dispositions was fostered in this lesson. For example, by turning a closed mathematical question (i.e. "What number is 4 numbers smaller than 18?") into a relatively open-ended investigation of different strategies to

answer the question provided opportunities for children to select materials and approaches, and children's **problem solving skills** were reinforced.

Some of the suggested 'tools' (e.g. children's own fingers) aroused children's **curiosity** and **motivation to solve the problem**, as can be seen from one of the children's questions: "How can you count up to 18 with fingers? I don't have so many fingers."

As previously mentioned, whilst specific materials and equipment were provided by the teacher, the children themselves had the opportunity to plan how the equipment and materials would be used, promoting their **sense of initiative** and **creative thinking skills**. This was particularly the case when Rachel's scaffolding questioning was used to extend the children's creative thinking. For example, as can be seen in the following extracts from the data, two children who had proposed to solve the problem of 18-4 using their twenty fingers, were challenged by the teacher to think of a way to solve the problem if there was only one child, and hence only ten fingers to work with. Their solution of keeping ten in their head and only using their ten fingers to work out the difference between the remaining 8 and 4 was relatively innovative in their context.

ILLUSTRATIVE EXTRACTS FROM DATA

Materials and learning tools, such as rulers, fingers and beads ("pearls") offer different approaches to solving problems



Children's questioning valued by the teacher

Child 1: *How can you count up to 18 with fingers? I don't have so many fingers.*
Teacher: *That's a good question. Let's see if we can soon find a solution to your problem.*

Children take turns to share and explain their methods with the rest of the class.



Teacher scaffolding encouraged children's creative solutions.

The girl and the boy showed their solution with their fingers.

Teacher: *What problem do you have if you don't have a friend with you? / How can you count with fingers if you're alone?*

Teacher tells them that they have a correct solution and the class applauds.

Child 2: *I will reduce 4 from 8.*

Teacher: *Ok, so what number you keep in your head?*

Child 2: *Number 10.*

Teacher: *After you have counted with fingers the units, you add that 10 from your head. Great! You all found a correct way!*

Episode: FR Ice Cream Sticks	Setting: Sch
Subject: Mathematics	Age Group: 7-8 years old
Key factors:	Teacher: Nani
Learning activities: Planning investigations / Explaining evidence	
Pedagogy: Dialogue / Reflection and reasoning encouraged	
Contextual factors: Small group/ Use of physical resources	

Aims

The aim of the activity was to encourage children to devise strategies to count systematically a large number of objects, and promote understanding of place value - the transition between units to tens, then the transition between tens to hundreds, and the transition between hundreds to thousands. According to the teacher Nani, it is an interesting activity for children who have difficulties because they can focus their attention on units and tens and for gifted children because they can focus their attention on bigger numbers such as hundreds and thousands. To construct collectively a new tool (the sticks organised in groups of 10, 100, 1000), for children to understand numbers' composition.

Analysis of key features

The lesson started with Nani, the class teacher, showing a large number of ice cream sticks to the children. One of them asked excitedly if she had eaten all of the ice cream herself. Building on the children's excitement and interest in the ice cream sticks, she asked the children to estimate how many sticks there were altogether, and later to devise their own counting strategy. Strategies of various levels of efficiency were proposed to her e.g. by counting in twos, tens and twenties, and discussed as a whole class. Then, in pairs at tables, the children manipulated and ordered the sticks in various ways to find out how many there were.

The strategy of the teacher was to build up the activity step by step through collective discussions. The teacher scaffolded and helped to organize democratic discussion and decision making. She explained during the interview with the researcher the importance of the 'democratic' dimension of this activity. It was quite clear to children that democratic decision making is the way to do their daily activities (**Child Sh:** "The children on the tables, if they agree..."). According to Nani, this kind of lesson can be proposed to the class only when this approach to classroom functioning is accepted and acquired by the children.

Moreover, one of the important aspects of Nani's pedagogy is to encourage children to **explain their own views**, or understanding. Indeed, she argues that if teachers cut down children's explanations, they may stop children's learning. For example in this episode, a child initially suggests counting the ice cream sticks in twos. It is an interesting idea, but it was not the one that Nani was expecting (every ten is more appropriate for her goal). Nevertheless, because in her approach the best solution is decided collectively, she does not make any comment on this specific solution.

Furthermore, she encourages collaborative work between gifted children and children with difficulties by placing them together for specific purposes (for example: **Teacher:** "Child Au could you come to work with Child Ma?").

It was noticed that children developed greater understanding of number through the activity. They recognised that the grouping strategies adopted were not just useful for representing the number of ice cream sticks. These forms of representation were useful generally for counting faster (e.g. 'hundred is easier'). Through this activity they managed to decompose big numbers.

In another part of the lesson, the children devised interesting approaches for future activities. They replaced a big pile of ice cream sticks by a clear and simple organization of the ice cream sticks. More precisely, they organized them into different kind of groups: 10 units were held together through elastic string, 10 groups of 10 units were placed into plastic bags, and 10 plastic bags were placed into an aquarium. This material follows children for their entire school years. In the future, the teacher will send them to the ice cream sticks corner to solve any difficulty with number problems.

Opportunities for inquiry and creativity

Creativity was fostered here at each step in the progression of the workshop. The children had to find by themselves the best strategy to count the large number of ice cream sticks. The teacher's role was mainly to choreograph the discussion, to stress important ideas, and to ask children to make choices between different strategies. Children had to reason, to find solutions, but also to listen other suggestions and to decide democratically which solution was the most appropriated and why.

According to Nani "this approach suits entirely with the idea of the curriculum to help children to become citizens". Furthermore, the presence of a challenge, counting such a large number of ice cream sticks, enhanced children's curiosity and motivation. Finally, collaboration and dialogue constituted key aspects of the process, and regular discussion of progress with the entire class allowed them to succeed.

ILLUSTRATIVE EXTRACTS FROM DATA

Teacher's engaging introduction to the problem

Child A: *You have eaten all of them?* (He is talking about the ice cream sticks)

Teacher: *Yes, I've eaten all of them, can you imagine it? According to you, how many are they?*

Children: *100, 2.000 ... More than 100 ...*

Teacher: *That is what I want to know, how many ice cream have I eaten?*

Children were encouraged to explore the materials and to plan their own counting strategy



Opportunities for children's reasoning

Teacher: *Does everybody count every 10? Does someone count every two? Child D, why do you count every ten at all?*

Children: *Because it goes faster!*

(...)

Teacher: *Wait, wait, and listen, there is another idea which is arriving, listen, then we will choose the best idea, the easiest way to count. Child D you say that we have to make ...?*

Child D: *Hundreds.*

(...)

Teacher: *So do we make packets of 100? Or (...) the other idea is that we take all the units on the tables to make tens. So what do we do?*

Child E: *If you count all the tens on the table you can forget some ... when hundred is easier.*

Learning environment where children were encouraged to listen to others' ideas and make a collective decision

Teacher: *Hey children, 10 seconds of attention. Child C has said that after we will count and see how many ice cream sticks there are.*

Child A: *Yes, but we have to agree on something.*

Teacher: *We have to agree on something. And, we have to be able to check. If you say to me "there are 48", I have to be able to check that there are 48!*

Child B: *We will count them again!*

Teacher: *Again?!*

Child C: *The children on the tables, if they agree, will count every 10, when they will have the correct number and we can do 10, 20, 30 and it doesn't take a lot of time, and we will be able to know the number.*

Episode: FR Magnet attraction or not **Setting:** PreSch
Subject: Science **Age Group** mixed age 3-4 and 5-6 years old **Teacher** Ivette
Key factors:
Learning activities: Communicating communication
Pedagogy: Reflection and reasoning encouraged
Contextual factors: Variety of materials

Aims

The teacher's goal was to enable children to categorize objects depending on their attraction or not by magnets.

Analysis of key features

This episode involved the children exploring whether some given objects are attracted to a magnet or not. **Included in the objects were pairs of scissors which were made out of iron and plastic**, so part of the scissors were magnetic and part of them were not magnetic.

The activity was initiated by the teacher and involved children working in small groups (n=5-6) testing the objects and then as a whole group (n=13) for the discussion of their findings and the **formation of a collective statement** about the magnetic properties of materials.

In the small group activities the teacher discussed the children's discoveries with them and helped them sort out their categories - 'Magnetic' and 'Non-magnetic'. The teacher emphasised the importance of children testing their objects during the first phase **in order to have evidence to be able to justify their own decisions** about the magnetic properties of the objects.

In the next phase of this episode the children **worked together as a whole group to share their findings and to come to a common conceptualisation about magnets and magnetic materials**. During this sharing and conceptualisation phase, the teacher asked the children to test objects again if necessary so they were sure of their categorisation of the magnetic properties of the objects. The discussion **fostered the children's ability to express themselves and to listen to the others**. Some children placed the scissors in the 'Magnetic' category and some placed them in the 'Non-magnetic' category.

The teacher used a large sheet of paper and drew two columns to record the children's results; one column for the magnetic objects and one for the non-magnetic objects. The children tested the magnetic properties of the objects again, **one at a time together and a common categorisation was created**.

During the collective discussion, **the teacher supported the children to explain their own ideas**. In pre-school, language difficulties are frequent and children can find explaining their ideas a barrier to communication. For example, one child tried to say that iron objects are attracted by magnet. In French 'iron'

(fer) is similar in sound to 'green' (vert) which is similar in sound and spelling to 'glass' (verre). At first the teacher did not understand the child's explanation due to his enunciation difficulties. **However, although it would have been possible to guess what the child meant, the teacher showed him a glass and asked: 'Do you mean glass ('verre')?'** The child thought about the question and says 'No, I mean iron ('fer')' and showed the iron part of the scissors to the class.

The category in which to place the scissors confused the children as anomalous results for the scissors had been recorded depending on which part of the scissors had been tested with the magnet. None of the children said that the scissors could go in both categories but at the end of the workshop a girl proposed a solution to the problem of the scissors' categorisation, she suggested that they could be placed 'on the line' between both categories.

Opportunities for inquiry and creativity

By letting the **children make their own categorisation** in small groups and then to **foster a collective categorization as a whole group** allows children to construct their own understanding to contribute to a collective discussion. They were able to make adjustments following a discussion to their original decisions. This way of processing ideas supports children forming their own concepts of magnet's properties rather than just being told the properties by their teacher. In suggesting a way to categorise the scissors the girl showed **creativity in offering a solution**, fostering **new understanding** that an object might belong in more than one category linked to the different materials from which it is made.

Providing **resources which create cognitive challenge** e.g. the scissors helps promote collaborative discussions as the children have to resolve the dilemma of the anomalous results.

By allowing children to use different forms of expression and **supporting them to make their own explanations** rather than making assumptions about what they are intending to say, values children's contributions to the collaborative construction of ideas.

ILLUSTRATIVE EXTRACTS FROM DATA

Testing familiar objects to see if they are magnetic or not
The teacher discusses children's discoveries



Teacher: So, I have a look on what you have done... the red container. The red containers are all at the same place, the green are also together. Nobody has said to me "I don't know...". You did know, it sticks or it don't. Child Ax told me the scissors sticks (Teacher takes the scissors). Ah! They are in the box where it doesn't stick!

Child B: I've tried and it didn't stick!

Teacher: Ah... Ah... Ah.... Come Child Ax, we will try, if we don't know (Teacher is sitting, near her is Child Ax). I've heard many children who said the name of the object... No? Don't you know the object's name?

Children: No.

Teacher: Child Fé you told it! Child Ma?

Child Ma: A magnet.

Teacher: Yes! Magnet! I've heard many children who have said it!

Children share their findings: The problem of the scissors



Teacher: We can place it in both containers ... So why in a side, it sticks and not on the other side? Yes, the red, what do you want to say Child Ca?

Child Ca: The red, because it is scissors.

Teacher: Yes, it is scissors you are right, Child Ma?

Child Ma: Because it is big.

Teacher: Because it's big. Child Ax?

Child Ax: It doesn't stick because it only sticks on the green.

Teacher: On the...? (in French, glass, green, and iron have close spelling)

Child Ax: Only on green, as green... you know, green.

Teacher: Wait, are you talking to me about glass. (Teacher shows to the child a pot in glass).

Child Ax: Yes, (Child Ax scrubs his head) no, in iron. (Child Ax shows the iron part of the scissors).

The teacher proposes collective categorisation of the objects
Solving the problem of the scissors



Finally the question of the scissors is still confusing children.

A creative solution is proposed by one of the children. The solution might be to place scissors on the line of the paper sheet.

Teacher: Yes, it doesn't stick on the orange side! Child Ax, do you remember that? Looks, on this side it sticks and on this side it doesn't. (Teacher tries with the magnet on both sides of the scissors). Where will we place the scissors? (Child Ax shows the column where it doesn't stick).

Child Ca: We will stick it on the line!

Teacher: Come and show me, that is a good idea. How do you place it? Show me.

Child Ca places the scissors on the line, the iron part on the stick column and the plastic part in the column where objects do not stick on the magnet.

Teacher: That is a great idea, Child Ca!

Episode: FR Share	Setting: PreSch
Subject: Mathematics	Age Group: 4-5 years old
Key factors:	Teacher: Sandy
Learning activities: Explaining evidence / Communicating explanations	
Pedagogy: Role of motivation and affect / Teacher scaffolding	
Contextual factors: Human resources	

Aims

For the children to explore and discuss their own strategies to share a handful of sweets into three equal portions.

Analysis of key features

The activity from which this episode is drawn formed part of a classical topic in division, and was based around the familiar story of the Three Pigs. This activity therefore embraced the different domains of literacy and mathematics. The activity had been initiated by the teaching assistant (TA) a week ago in small-group activities at a table to investigate children's capabilities and strategies in sharing money equally among the three pigs, using cardboard counters.

This time, sweets had to be shared among the three pigs: Henry, Raphael and Christopher. The TA had enhanced the complexity of the task, as she said *"I wanted to see if they have really understood fair sharing"*. To do that, she provided children with a handful of sweets (using salt dough) and not a number that was a multiple of three as she did the last time (as when children are provided with a number, which is multiple of three, it is easier because there are no remainders.) With handfuls of varied numbers of sweets, the children encounter problems. For example, they can have 2 sweets left and cannot share them among the three pigs. While children are expected to encounter difficulties, the TA emphasised no failures because *"we do it again and again, with the help of the other children. It seems important that children can go until the end of their strategy"*.

At the start of the lesson, the TA and the small group of children discussed what 'equally' means. It was noted that each child knew clearly what share meant, but the notion of 'equality' was more difficult for them. Indeed, acquisition of the notion of sharing equally constituted the central goal of the TA's activity.

Additionally, the TA also made the strategic decision to use sweets made of salt dough of different colours instead of cardboard counters **to make the activity more attractive for children**. This also prompted new ideas from the children. One child proposed that the sweets should be shared equally according to the colour.

During the activity, the children worked together. One of them tried to share equally a handful of the sweets. The others had to look at what was happening and at the end discuss the child's strategy. Each child, in turn, **explored**

his/her own strategy then discussed it. As indicated earlier, the aim of this activity was for the children to explore their own strategies to share a handful of sweets into three equal portions. The children knew how to share, but they encountered difficulties in doing this equally. When children encountered difficulties, the TA did not provide solutions but fostered children's collaboration and own exploration of their strategies.

This mathematical activity provided children with a rich context to develop general skills and dispositions for learning. Through this activity, children acquired knowledge/understanding about mathematical content, they developed mathematical process skills, and capacities to carry out inquiry and problem based approaches. Moreover, creative dispositions were fostered, associated with **exploration of the possibilities and reflection and reasoning**. Finally, the TA was gifted in listening, and in **scaffolding** children and to **foster dialogue and collaboration** between children.

Opportunities for inquiry and creativity

Creativity in teaching might be recognized through the **motivating material used in the activity**, such as the sweets, and pigs' names. Moreover, this activity was linked to a story that was being read at the time in the classroom, but also at school level. These elements encouraged children to engage with the mathematical activity. The TA said she had modified the workshop by using sweets instead of cardboard counters *"because it is more attractive for them"*. Moreover, during the session, she modified the activity where necessary to see if it would help children (e.g. *"try sharing them with your brother"*). This flexibility underlines her close involvement in scaffolding children's progression.

The TA was also creative in her attitude towards **scaffolding children's progress** as she did not guide them toward a particular *sharing* strategy. She let them try, and organized sharing of ideas, explanation and collective checking. At the end of the workshop, most of the children managed to do an equal sharing among the pigs by using different strategies. For example, Child F1 tried to share ten sweets by placing two sweets in each of the three plates initially, then adding one more sweet in each of the plates, leaving out the remainder of one. Child Vi and Child Ro attempted to share 14 sweets equally among the three pigs by placing four sweets in each of the three plates initially before adding one more in two of the three plates, resulting in two plates having five sweets each, and one plate having only four sweets. Through the teacher scaffolding, they then decided to remove the fifth sweet in two of the three plates, so that all plates would have four sweets each.

ILLUSTRATIVE EXTRACTS FROM DATA

Examples of the TA's scaffolding questions and children's explanations

Example 1: The children have a handful of 10 sweets. Child FI shares the sweets firstly two by two. Then, one by one and keeps in his hand the last one.

TA: *So what happens?*

Child FI: *It is not the same!*

TA: *You did place...*

Child FI: *3, 3 and 3*

TA: *And you still have one in your hand... We cannot share this one, so?*

TA: *If I place it here (Henry's plate), does it work?*

Children: *No.*

TA: *If I place it here (Christopher's plate), does it work?*

Children: *No.*

TA: *If I place it here (Raphael's plate), does it work?*

Children: *No.*

TA: *No, no, why? Because, it is not the same number. I put it away. And there, is it just?*

Children: *Yes*

(...)

Example 2 : Another child (Child Vi) tries to share. TA gives him a handful of sweets of 14 sweets. The child places 4 sweets each time in each plate. Two sweets remain at the end. Child Vi shares them between two of the three plates.

TA: *Does every pig have the same number of sweets?*

Children: *No.*

TA: *How many sweets are there? Shall we count them together? (She points out at each sweet at a time).*

Children: (First plate) *1, 2, 3, 4.* (Second plate) *1, 2, 3, 4, 5.*

TA: *Is it the same?*

Children: *No.*

Child Ro (Counts the sweets in the last plate): *1, 2, 3, 4, 5.*

TA: *Which plates have the same number of sweets?*

Children: *Those ones* (They point at the plates where there are 5 sweets each).

TA: *Those plates have 5 sweets each, and there (she points out the remaining plate) there are ...?*

Children: *4* (for the 4 sweets)

TA: *So what can we do?*

(Child Ro picks up a sweet in one of the plates where there are 5 sweets.)

TA: *What have you done, Child Ro?*

Child Ro: *I've removed one.*

TA: *How many sweets there are now?*

Children: *4.*

TA: *Really good! (TA takes the sweet removed from the plate by Child Ro). You have removed one, and there are now ...*

Children: *4* (for the 4 sweets).

TA: *Are there 4 sweets everywhere?*

Children: *Yes.*

TA: *Yes, we will manage I think!*

Example of a child's additional idea for investigation

TA: *So, we will try to share them fairly. That means ... Who can remind me, what does it mean? What will we have to do?*

Child FI: *To provide the same.*

TA: *We will try to provide the same number of sweets in each plate. All right?*

Child Ro: *And the same colour!*

TA: *No, the colour is not important here. We will not take the colour into account! Ok?*

(The child's idea was not taken up by the TA at this point.)

Children working collaboratively



Episode: GE Building Blocks	Setting: PreSch
Subject: Integrated Maths/Science	Age group: 5 years old
Key Factors:	Teacher: Bea
Learning activities: Planning investigations / Communicating explanations	
Pedagogy: Role of play and exploration / Role of motivation and affect / Teacher scaffolding	
Contextual Factors: Rich physical environment for exploration	

Aims

The aim of this activity was to foster communication and reasoning as well as number and spatial sense. Thinking mathematics (problem solving, communication, reasoning) was important as well. The children used science process skills (observing, predicting and describing), and social factors of science learning played an important role too (collaboration and communication).

Analysis of key features

The teachers had observed that the children enjoyed very much **playing with wooden building blocks** (KAPLA). The children often built roads and tracks, but only rarely higher buildings like towers.

Bea (the teacher) initiated an activity for a small group of older children. Using a photograph of a wooden block building as model, the children were supposed to copy it. Inspired by other pictures on the wall, the children decided to build the "Leaning Tower of Pisa" as well.

Bea took two children to the construction corner and presented them with a book with photographs of buildings (these buildings were all made from wooden building blocks). She told the children about her plan of copying one of these buildings together with them. By **letting the children decide** which building to copy, it became a joint project.

To be able to copy the building, the children had to **observe carefully, describe and count**. In the beginning, the children needed more support, and Bea assisted them. The children worked together as a team, and Bea stood back and observed. **Bea got involved only when her help was needed**.

Bea **fostered communication and collaboration**. Child 2 placed a brick in accordance with the model. However, since the brick was difficult to see, Child 1 removed the brick. Bea asked Child 2 "You wanted to place this one, right? You have to discuss that with Child 1, so that she knows what's your plan."

When trying to build the top of the building, the bricks repeatedly fell in. The children tried to find a solution, and **Bea helped them verbalise their ideas** with questions. When the children failed to build the roof of their tower Bea had a go but did not succeed either. The children were laughing and realised that it was a difficult task – even for their teacher.

However, the children continued with their task and finally managed to do it. The children were very happy and proud, and one of them went to get a camera to document their result.

Inspired by photographs of real buildings on the wall, the children decided to build the "Leaning Tower of Pisa". One child took the lead, and Bea helped and **followed the Child 2's instructions, making him feel he was the expert**. Although, it seemed obvious to the teacher that by following the boy's instructions, the tower would not get very high, Bea **did not interrupt** the construction and followed Child 2's plan. When the tower tumbled down, she used the incident **to help the child reflect**.

They started building again, and another child joined them. Bea stood back then, observing the children's work. To be able to solve the problem together, the **children had to observe and predict and to communicate their ideas**. Bea encouraged the children to express themselves clearly and she valued their ideas. The **children seemed proud that they found a solution on their own**.

Opportunities for inquiry and creativity

The children's reasoning skills as well as their connection-making played an important role in this activity. In the second part, where **the children took the lead** and were allowed to build the "Leaning Tower of Pisa", their creative dispositions were fostered. The children were motivated and inspired by using the wooden bricks, which the children like a lot.

The teacher **supported their learning, valued their ideas and helped to overcome difficulties**. As a result, the **children were self-confident and showed initiative**.

ILLUSTRATIVE EXTRACTS FROM DATA

The teacher encourages the children to collaborate and to communicate their ideas (express themselves clearly)



Using a photograph of a wooden block building as model, the children were supposed to copy it. Inspired by pictures on the wall, they then decided to build the "Leaning Tower of Pisa" as well.

Child 2 places a brick in accordance with the model. However, since the brick is difficult to see, Child 1 removes the brick.

Teacher: (to Child 2) *You wanted to place this one, right? You have to discuss that with Child 1, so that she knows what your plan is.*

Child 2 replaces the brick.

Child 1: (indignant) *But first there has to be the wall.*

Teacher: *You have to come to an agreement about what you want to do.*

Children take the lead.

Although it seems obvious that the tower will not get very high this way, the teacher follows the children's plan.

Teacher: *Well, Child 2, now you really have to explain to me how such a Leaning Tower has to be built. I actually have never built one.*

Child 2: *You always have to put one like this and another one like that.* (Child 2 places four bricks in front of her and explains).

Teacher: *You mean always to one side?*

Child 2 nods

Teacher: *And then it won't tumble down?*

Child 2 shakes his head.

(Child 2 and the teacher quickly build the tower which does lean extremely wide to the left. Teacher follows Child 2's instructions. After some while the tower tumbles down and a new plan is made.)

The children's reasoning skills as well as their connection making is supported, and the teacher helps to overcome difficulties.



Teacher: *Even if it sometimes doesn't work, stay patient, wait, and the 10th time it finally works out. But to withdraw as an adult and to really let it happen and if it then works, there is this "aha-experience" which you can often already tell from the posture, the children then sit up "Ha, yes, made it".*

Teacher: *Why does it fall in again and again? What do you think?*

Child 3: *Because there is no space ... for this* (points to the tricky spot).

Teacher: *Yes, it doesn't have enough support there, right? We have to think about something else there.*

Child 3 starts to pile up bricks as a sort of supporting pillar.

Child 3: *We build a tower from below to fix it.*

Child 2 starts to carefully slide bricks in the tower from the side.

Teacher: *Ah, you're adding a supporting step!*

Child 3: *Child 2! Good idea!*

Child 2: *And now it has to be unbuilt a little bit over here!*

Teacher: *What do you mean?*

Child 2: (explains to Child 3) *And here it has to support.*

Child 3: *Yes, I know.*

Teacher: *Now you added a supporting construction. Now it is stable.*

Child 3: *Luckily. At last.*

Episode: GE Fermi Questions Subject: Integrated Maths/Science Key Factors Learning activities: Planning investigations Pedagogy: Role of motivation and affect / Role of problem solving and agency Contextual Factors: Outdoor learning / Formative assessment	Setting: Sch Age group: 7 years old Teacher: Andrea
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Aims

The main objective was to foster the children's problem solving skills (e.g. defining the problem, generating ideas, considering various ways of approaching, selecting and evaluating alternatives) and to encourage the use of different approaches to answer mathematical questions. Dimension analysis and approximation are practised as well.

Analysis of key features

In circle time, the teacher, Andrea, presented a new kind of mathematics activities to her children. In small groups, the children were to solve Fermi problems that were connected to different objects or phenomena (e.g. "How many stones are in this glass?" or "Cut a 1-m string from this ball of wool."). The children were not allowed to count or to use any standard equipment for measurement.

To increase **interaction between children and to foster cooperation**, the children worked in small mixed ability groups of four children. Depending on the activity/question, the children worked in different areas of the school building (e.g. one question was to estimate the height of the school building, and the children went outside on the schoolyard to solve this problem).

The different groups of children started to work on their Fermi tasks. All the tasks referred to either concrete items (e.g. ball of wool, stones in a glass) or to phenomena linked to the children's everyday world (e.g. height of the school building, length of a pitch). The **children were very motivated**, discussed the right method to solve the task and drew on their everyday knowledge to be able to make estimates, e.g. about the length of 1 metre: "I jumped down from a 1m board in the swimming pool on Saturday" (the child shows the distance between board and water surface with his hands); or "I'd say a metre is more or less as long as a leg" (using Child 5's body to demonstrate it). As a team, the children made a guess and then discussed their estimations: **they asked for the other's opinion and found innovative methods** in order to check their estimates.

Andrea walked around in class, observed the children during group work, using **formative ways of assessment** (e.g. "How does a child behave in the group?, What does it contribute to the group work?, How does it interact with others?, How does it approach such a task?", as highlighted in the teacher interview). She occasionally gave advice or answered questions. However, her advice

exclusively referred to the working approach, methods, and relevant question, but never to the solution itself.

Reasoning and reflection as well as metacognition were fostered - at the end, the groups documented their working process by writing down how they had proceeded. Then they presented their work to the other groups of children in circle time.

Opportunities for inquiry and creativity

All the Fermi questions were related to real-world phenomena, taken from the children's (school) environment. This was very engaging, and the children were **curious and motivated to solve** this new - and for them unusual - kind of maths activity. They came up with **many different ideas how to solve** the problem, drawing back on individual experiences as well as on previous knowledge. One group of children even "invented" a new scale: They found out that one of their teachers is exactly 2 metres tall and called this size "1 Mr. X". 1 metre was respectively "1/2 Mr. X"! This scale was then used for example to estimate the height of the classroom or the school building.

The children's **reasoning skills were fostered** as well. The teacher used **scaffolding and encouraged collaboration and dialogue** between the children. The children worked as teams and shared and discussed their ideas to come to a common solution.

ILLUSTRATIVE EXTRACTS FROM DATA

The children communicate and discuss their estimations (based on everyday knowledge) within their group until they reach consensus



The Fermi problem for this group of four children consisted of drawing three lines of different lengths (1 m, 10 cm and 1 cm) on the blackboard without using a tape measure or ruler.

Child 5: *I jumped down from a 1-m-board in the swimming pool on Saturday.* (Shows the distance between board and water surface with his hands).

Child 6: *I'd say a metre is more or less as long as a leg.*

Child 7: *Until here, right? Or till here?* (using Child 5's body to demonstrate it).

Child 5 tries to maintain the distance between his hands while moving them to the blackboard. Holds them close to the board, Child 7 draws a line between Child 5's hands.

Child 7: *T-h-a-t long?*

Child 6: *No. This long*

Child 7: *I don't think that this is one metre.* (laughing)

Child 6: *I don't think that either.*

Child 5: *Right. Much too short.*

Child 6 draws a longer line.

Reasoning and reflection: The children document their working process and do a short presentation to the other groups



Children write down how they had proceeded. Then they present the working process as well as the result to their class members.

Teacher: *And these Fermi question are ideal for that because the children get into interaction and they have to think on their own about questions like: "How can I approach this?", "What am I doing here right now?", "How can we solve such a task?" And they just have to talk to each other a lot and to think about "How does this actually work?" and not only to solve a ready-made maths problem.*

Episode: GE Water Inquiry	Setting: Sch
Subject: Science	Age group: 6 years old
Key Factors:	Teacher: Nadja
Learning activities: Planning investigations / Communicating explanations	
Pedagogy: Role of motivation and affect / Role of problem solving and agency / Teacher scaffolds	
Contextual Factors: Rich physical environment for exploration / Indoor and outdoor resources	

Aims

The children had to plan their own experiments to prove that ice and steam both come from water. They were allowed to use any of the equipment in the room to carry out their experiments. IBSE and creativity were specifically planned for this lesson.

Analysis of key features

This activity took place in the "Science Lab". In circle time at the beginning of the lesson, the teacher Nadja talked with the children about the findings of their previous lesson. The teacher acted as if she did not believe that there was a connection between water, ice and steam. She asked the children to prove there was a relationship between water, ice and steam.

The children had to form hypotheses and **plan and conduct experiments** all by themselves, working with a partner or in small groups. They were allowed to work inside the "Science lab" or to **go outside (in the school yard/garden)** if they wanted to, as the children were free to choose.

Before the children could start their experiments, they had to document their plan by writing down or drawing their ideas and procedures on a prepared "Scientist's sheet". Nadja went around from group to group **asking the children to explain their ideas and plans**. The worksheet seemed to help the children to structure and elaborate their ideas. The children were very excited, **discussed a lot and came up with many different ideas** how to prove that ice and steam come from water.

Ice cubes were then handed out to the children and a water boiler could be used as well, when assisted by an adult.

The children conducted their experiments, using ice cubes and different ways of warming them (e.g. putting them close to the radiator or melting them in their hands). When they realised that the sun was shining, some children asked if they were allowed **to continue their experiments outside in the garden**. Nadja encouraged them to do so and went along with them while the other two adults stayed in the room with the rest of the children.

The children's knowledge and understanding of the connection between the three states of water deepened during this lesson. (e.g. **Interviewer:** "And

what do you need in order to transform ice into water?" **Child:** "You need, for example, a radiator, so you can hold the ice to the radiator. Then it also becomes water." **Interviewer:** "Exactly. Because what comes from the sun and what comes from the radiator?" Children [in unison]: "The heat!"). At the end of the lesson, the children came together and compared their experiments and findings in circle time.

Science process skills and social factors of learning were fostered (open inquiry: predicting, planning and conducting experiments, observing, explaining evidence and communicating explanations) as the children had to devise the experiment themselves. They had to **solve the problem of proving** that both ice and steam come from water.

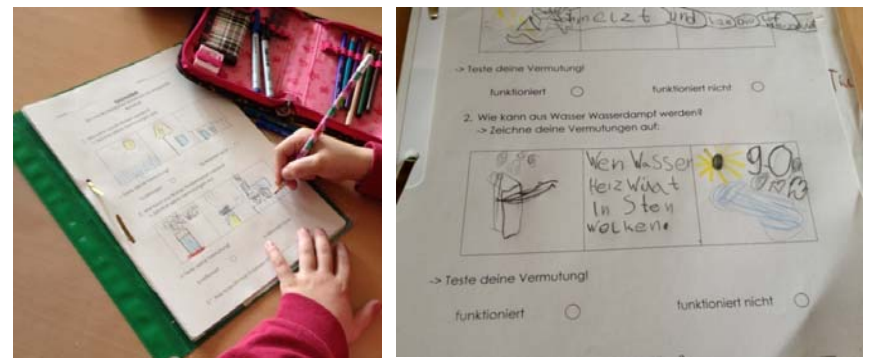
Opportunities for inquiry and creativity

Children were very engaged in this activity and enjoy it a lot to be able to **work independently and even outside the classroom**. They really enjoyed **planning their own investigations** and having the **freedom to make choices**.

The **rich environment** and freedom to try out whatever they wanted (variety of resources, sufficient human resources) motivated them and gave them room for creative approaches. Working together with a partner or in small groups, the children **communicated a lot and brought together many different ideas**. The teacher's real interest in their experiments encouraged them to try out new things.

ILLUSTRATIVE EXTRACTS FROM DATA

The children make connections and plan their own experiments



The children planned their own experiments to prove that ice and steam both come from water. They were allowed to use any of the equipment in the room to carry out their experiments. However, before the children could start their experiments, they had to document their plan by writing down or drawing their ideas and procedures on a prepared “Scientist’s sheet”. They were allowed to work inside the “Science lab” or to go outside (in the school yard/garden).

Teacher: *And what’s this? I don’t really understand that.*

Child 1: *There, the BBQ is set up.*

Teacher: *You put the ice on the grill?*

Child 1: *Noooo...*

Teacher: *I see, sorry. You put water on the grill?*

Child 1: *Yes. And here, on the top, some water is heated up.*

Child 2 (talking to his partner): *Or I draw 100° and then water steams. It could get that hot, though (...). Or 90° (Child 2 remembers the number of degrees from the last lesson and writes a “90°” next to his sentence “When water gets hot clouds arise”).*

Experimenting inside and outside the classroom



When they realised that the sun was shining, some children asked if they were allowed to continue their experiments outside in the garden.

The children enjoy investigating on their own. They find different solutions to make ice cubes melt (inside and outside the classroom).

Interview with children:

Child: *I had fun today!*

Researcher: *So today was the best day in the science lab? Why?*

Child: *Because we were allowed to experiment. Whatever we wanted. We were allowed to try things out outside.*

Child: *Yes today we had to draw and to think about it with our brains and the other time we just had to look and write.*

Interview with the teacher:

Teacher: *The children first had to think about it and to then draw or write their thoughts and then also to try out what they came up with. And I said “You can use everything what we’ve got here in the science lab” (...) And they really came up with amazing ideas.*

Episode: GR Measuring tables **Setting:** PreSch
Subject: Mathematics **Age Group:** 5-6 years old **Teacher:** Mina

Key factors:

Learning activities: Planning investigations / Gathering evidence (using equipment) / Making connections / Explaining evidence / Communicating explanations

Pedagogy: Role of motivation and affect / Children's agency / Collaboration / Fostering reflection and reasoning / Teacher scaffolding

Contextual factors: Valuing potential of physical materials

Aims

The teacher's goals for the lesson were to encourage children to: keep "mathematical notes" as they are working in the classroom using symbols; count in their everyday activities; make estimations and predictions; be able to form and check hypotheses; be able to solve problems (process information, take decisions, come to a result, confirm results) and to foster children's interest and motivation in mathematics using everyday situations and building on their experiences.

Analysis of key features

The episode involved the children taking measurements of their work tables using measuring tools provided by the teacher (a tape measure, a wooden meter, ribbons, spoons, pencils) or any tool of their own conception. The teacher Mina introduced the activity by asking the children to help her in giving the carpenter measurements to create new worktables for the classroom, identical to the current ones. By **setting the activity within a meaningful context**, she wanted children to **make connections between mathematics and their everyday life**. The children **worked in small groups** choosing the measuring tool to use and taking and recording measurements in their group notebooks. They then had to **present and explain their findings to the whole class**. Finally the children **discussed and reflected on the activity**: what problems they faced and how they felt about it.

Once the teams were set up, no further instructions were given. Mina however stressed several times the need to **work collaboratively** to achieve the task. In most teams, one child ended up being in charge of taking the measurements, another two assisting him/her in the task, and one being in charge of recording the measurements in the notebook. Some teams kept these roles throughout the activity, while others rotated them so that all children could get the chance to contribute to all tasks. Mina **emphasised the importance of recording measurements** for the purpose of presenting their findings. She gave them specific instructions about how they should present their findings: to mention the measurement tool used and give the findings for the shape, length, width and height of the table.

In the next phase of this episode the teams **presented and shared their findings**. The teacher **prompted the children to reflect on their findings and collection processes**, continuously reassuring them that it was OK to make mistakes. Two unsuccessful measurements (one team used a ribbon shorter than the table, and one recorded the number of the measurement the wrong way around) were turned into learning opportunities related to **the nature of science inquiry**, such as the need to 'repeat' and 'verify' measurements. During the collective discussion, **she invited children's reflections on what they enjoyed and issues related to collaborative work**, which complemented their more formal accounts on the acquired understandings.

Opportunities for inquiry and creativity

Features of creative teaching were observed during this lesson in the efforts made **to enhance children's attitudes** to mathematics by **connecting mathematical knowledge with everyday life**. Creating a safe environment, where mistakes are accepted and treated as learning opportunities is an integral part of this teacher's practice. Her interest in the affective dimensions of mathematics learning was also evident in her choice of focus for the collective discussion at the end of the lesson, in which she asked the children to evaluate the lesson and suggest way to improve it in this respect. Opportunities for development and demonstration of children's creative dispositions were present in this episode in **fostering collaborative work and inquiry skills**. Issues of collaboration featured highly in children's reflections on the lesson although it is unclear if the children felt that collaborative work assisted them in developing understandings. The teacher encouraged **children's agency** in carrying out the task, by offering minimal directions. She chose a more guided approach when children reported their findings to foster **explanation and reflection and reasoning**. Finally, an important contribution to creative learning in mathematics was the conscious efforts of the teacher to promote understandings **about the nature of inquiry** through **processes of reflection** on their measurements. The skills of reflection *and* reasoning are very important to IBSE, and conceptions of creativity which focus upon the generation and evaluation of ideas. In helping children to develop these skills the teacher skillfully shifted the children's attention from the process to the product and back, exemplifying the importance of both.

ILLUSTRATIVE EXTRACTS FROM DATA

The teacher embeds the task in an everyday life context. She encourages collaboration and fosters children's agency.

Teacher: *A few days ago we said we would like to order a new table from a carpenter. The carpenter rang me and said: Mrs Mina, I will make the table you want. However, you have not given me any instructions. (...) I want you to help me to give instructions to the carpenter. OK? So this is what we are going to do: Every team will go to their table and take its measurements. I will give you notebooks so you can write down your notes. (...) Each team will decide how they are going to take their measurements. We need to provide three measurements to the carpenter: shape, height and width. Last time we said that we can use different tools for measurement (...) To make it easier for you, you need to collaborate. If every one of you wants to keep the tool for himself/herself, the team will not succeed in the task.*



Children share their findings:
Teacher turns children's mistakes into a learning opportunity.

Teacher: *Team 5 used the ribbons to measure the table. What did you measure? The width?*

Child A: *Yes. And the legs.*

Teacher: *(...) Let's see how they managed to measure the table with something different (...) I have never measured anything before in my life.*

Child A: *We start here (end of the ribbon on the ground) and go...*

Teacher: *Wait, you start from here and go where? Here? But, where does our table end (children looking) Mmmm... Isn't it a bit shorter, or longer?*

Child A: *Longer.*

Teacher: *Is it longer? The table or the ribbon? Which is longer?*

Child A: *The table.*

Teacher: *So the ribbon then is ...*

Child A: *shorter*

Teacher: *You needed a little bit more, didn't you?*

All: *Yes we did.*

Teacher: *So, is this the correct measurement for our table then for its width?*

All: *No.*

Teacher: *We have to try again. (Children seem disappointed). It does not matter. (...) When we make an attempt and then we go to check it and it is not right, we try again. Another team had written their measurements the wrong way around - 85 cm instead of 58 cm. She helps them to verify their measurements and then explains their mistake. (...) From what I see, if we give these measurements to the carpenter as they are, he won't know exactly what to do. (...) We thus need to reach a conclusion about the measurements. (...) I will tell you a new word. It's called 've-ri-fi-cation' (...) we will check if the measurements we took are accurate.*

Children reflect about their feelings, collaboration and new understandings



Teacher: *I would like you to say, so that I know what to do next time, so that you like it even more: What from all the things we did today you liked best, impressed you most and helped you? Think about all the steps of the games we used and about the way we worked. Think.*

Child D: *When we measured the tables.*

Teacher: *You liked the measurement of the tables (...) How did you work?*

Child D: *With my team.*

Teacher: *Did you like this process?*

Child D: *Yes.*

Teacher: *Did you agree, disagree? How did you see this?*

Child D: *At the beginning we disagreed a little, but then we agreed.*

Teacher: *At the beginning you disagreed a little, (...) this happens frequently in teams. What did you disagree about? Do you remember?*

Child D: *What we should use to measure.*

Teacher: *Which tool to use for measurement. What did you use?*

Child D: *The ribbon. (...)*

Teacher: *What new thing did you learn, that you did not know before?*

Child A: *I do not know how to describe it.*

Teacher: *(...) Did it have to do with measuring the tables?*

Child A: *That if I do not have a ruler, I can use a ribbon or a meter.*

Episode: GR Ice balloons	Setting: PreSch
Subject: Science	Age Group 5-6 years old
Key factors:	Teacher Sonia
Learning activities: Questioning / Planning an investigation / Gathering evidence (using equipment) / Communicating explanations	
Pedagogy: Fostering questioning and curiosity / Children's agency / reflection and reasoning encouraged	
Contextual factors: Thoughtful use of physical resources / Variety of resources	

Aims

The teacher's objective was for children to study the properties of ice.

Analysis of key features

The episode was part of a series of lessons entitled "Winter". It involved children in teams exploring the properties of ice using ice balloons and a **variety of materials** provided by the teacher (including syringes, paintbrushes, watercolours, dyes, bottle of vinegar and magnifying lenses) as well as other classroom materials selected by the children.

The activity had been **chosen by children** on a previous day, following free play with ice and brainstorming sessions in which they suggested questions and possible investigations. These suggestions had been recorded on flip chart paper and posted on the classroom walls. For the two most popular suggested investigations the children had **drawn their predictions**. This gave the teacher **access to children's previous knowledge and conceptions uninhibited by their language skills**. These predictions were then contrasted with children's drawings of their conclusions at the end of the sequence of lessons on ice.

One of the suggested investigations involved filling balloons with water and placing them in the school's freezer to see what happens. The teacher **had enriched the potential for creative thinking** by adding one balloon that had red dye dissolved in the water, without children knowing. The activity began with the teacher asking the children to think about the materials she had placed on the table and what experiments they could be used for. **She allowed the children time to think about the potential of the materials** before reminding them about their previous suggestions for investigations. They then voted which investigation to carry out. "Playing" with ice balloons was the most popular choice. The teacher brought an ice balloon to each team and **allowed them space and time to follow their questions and interests**. The teacher discussed the children's discoveries, **encouraging them to use different tools and materials in their explorations**. She only addressed the whole class to alert children to thought-provoking observations or suggestions from other teams.

The children then **gathered as a whole group to present their observations and explanations** to Frosty - a snowman doll often used in the classroom as

part of the winter-themed lessons. **Using a doll** motivated the children and fostered a supportive environment, where they felt able to express themselves. Frosty was also a powerful teaching aid for the teacher, who used it **to ask questions and prompt children's discussion of alternative explanations**. One such discussion was about where the liquid in the children's tubs (where the ice balloon had been placed) had come from. The teacher had noted confusion amongst the children about this issue. A number of them maintained that the liquid in their tubs was because they had added watercolours in them, whereas others attributed it to the melting ice. The defenders presented their two **alternative explanations** to Frosty. The whole class then voted on their preferred explanation. The majority view, identifying the watercolours as the cause for the liquid in the tubs, was **questioned by Frosty**. A child who had not spoken before mentioned the cause of 'heat' in support of the 'ice melting' explanation. This resonated with children's previous experiences with ice and led to suggestions for a further exploration - testing whether ice would melt outside the classroom in the cold air - to be done on a subsequent day.

Opportunities for inquiry and creativity

A number of factors important in nurturing creativity can be found in the lesson observed. The teacher fostered children's **questioning and curiosity** through drawing on their interests or questions, as well as making links to the class theme of winter. **Curiosity** was evident in children's observations, questions, and active engagement with the activity. Children worked collaboratively in handling resources and in sharing roles during more complex tasks. The teacher **stood back** and provided limited guidance, allowing children to **work at their own pace**, intervening only rarely to support either their choice of resources or efforts to explain observations. **Explaining and communicating observations** were also points of focus in the teacher's pedagogy. Use of the doll as an audience and voting in case of disagreement, were consistently and efficiently used by her to promote **reflection and reasoning**, discussion of **alternative explanations** and common conceptualisations of the phenomena observed. **Alternative means of expression**, such as children's drawings, were valued and used in an informal way both as part of **diagnostic and summative assessment** of children's ideas.

ILLUSTRATIVE EXTRACTS FROM DATA

Encouraging children's thoughtful use of physical resources
Fostering children's agency in planning the practical activity



T: (...) Will we work with these materials as they are, or should we bring something else that we have been working with all these days?

Child N: We should bring the ice cubes.

Teacher: We should bring the ice cubes and then?

Child N: To see if they have gone bad.

Teacher: Ah, you want to bring the fruits we have put in the ice. (...)

Child E: We should bring the ice and these. To work with the ice and these, to see what would happen if we put these on the ice.

Teacher: So, I hear two ideas. One is of Child N who says that we should bring the fruits and one of Child E who says that we should bring the ice cubes to see what will happen with these materials. (...) (Addressing all the children) Do you remember the ideas expressed by Child N and Child E? Child N please repeat your idea.

Child N: To bring the fruits to see whether they have gone bad.

T: And what is Child E's idea?

Child E: To bring the ice and try out these materials on the ice. That is to go to our tables and put the colours on the paint brushes and try them on the ice.

Teacher: We can do this – a very good idea. What shall we do first? (Children defend the two options and disagree).

Child G: Let's vote. (The children choose the one with the ice balloons.)

Fostering children's questioning and curiosity

Child K: Miss, I see something here. It's like the prickles of a hedgehog.

Teacher: What is the tool that can assist Child K in seeing the inside of the ice?

Child: The magnifying lens.

Teacher: Do you want to go and get the tool that you think will assist you in seeing inside the ice? (...)

Child D: It pricks.

Teacher: Does the ice prick?

Child K: When it breaks it pricks. (...)

Teacher: Does your hand fit inside? Leave your hand for some time inside to see what will happen.

Fostering children's reflection and reasoning using a puppet (Frosty)
Valuing children's ideas



Frosty: It was about time that you gave me voice to speak – I have been sitting over there for so many days.

Frosty: Child D what are you showing me over there?

Child D: We made balloons which turned into ice cubes.
Teacher: We will now tell Frosty what we did and

I, because I am getting old and start forgetting, what should I be doing? (...)

Children: You should write them down. (...)

Teacher: Each team will now tell everybody what they did, how they worked, what they saw, what impressed them, what made them go wow!!! [...]

Child D: We had some balloons and put inside water, which turned into ice cube. (Teacher writes down "We made ice...")

Teacher: Child D. How did you make the ice?

Child: We put some water and turned into ice.

Teacher: We put some water. Where did we put the water?

Child: Inside the bubble.

Teacher: And then?

Child: It turned into water.

Teacher: By itself?

Child 1: Yes. **Child 2:** From water. **Child 3:** From the freezer.

Teacher: We filled the bubble with water, left it lying around and it became ice?

Child 3: From the freezer. (The teacher writes this down.)

Teacher: Anybody else from the same team? Something that you found, that you SAW, that impressed you? (...)

Child M: It impressed me that the water turned green - dark green.

Teacher: Let me now ask you. Where did we get the water from?

Child: We had not added any water.

Teacher: Had we put any water in the tub?

Children: NO.

Teacher: Child G, where did we find the water?

Child G.: From the colour paints. We added some paints.

Other Child: We put the ice, the ice melted a bit, we added the paints, we stirred them up and it happened.

Teacher: So what do you believe that happened? The water came only from the paints, as suggested by one of you, or the ice melted into water and then we added the paints as well? Which do you believe is the most correct idea? Let's vote.

Episode: GR Bee-Bot	Setting: Sch
Subject: Mathematics	Age Group: 6-7 years old
Key factors:	Teacher: Stavros
Learning activities: Planning investigations / Gathering evidence (observing) / Making connections	
Pedagogy: Role of motivation and affect / Children's agency encouraged / Role of dialogue and collaboration / Fostering reflection and reasoning / Teacher scaffolding	
Contextual factors: Confident use of digital technologies	

Aims

The teacher's goals for the lesson were for children to:

- be able to solve simple problems using a step by step approach and acquire basic knowledge about orientation (4 cardinal points);
- understand how the bee-bot rotates and the change in perspective necessary to direct it when it rotates;
- develop mathematical knowledge and skills associated with operations of addition and multiplication.

Analysis of key features

The episode involved the children playing a treasure hunt game devised by the teacher using "Voula" the Bee-Bot. The teacher Stavros introduced the activity, that had been carried out previously in the classroom, by announcing that children would go treasure hunting to help their friend the bee find the treasure in the forest. Stavros **used this context** to introduce the activity and **motivate** the children. An important focus of the lesson was the rules of the game (e.g. "You have to start from the direction of the sun rising. You will put Voula at the first square facing North. In order to reach the treasure you have to make *more* than 4 steps.") and simple instructions that the children had to follow in order to succeed. The instructions **emphasised the importance of children recording their decisions** for the purpose of presenting their findings at the final part of the lesson.

The activity involved children **working in small groups** devising their own strategy to find the hidden treasure. Children in both teams **discussed and reflected on the activity** trying to find the correct path to the treasure. As the children were discussing in their groups, the teacher repeated his instructions and reminded everybody about the **importance of collaboration** in order to complete the task. Even though the teacher emphasised his instructions at the beginning of the lesson, he allowed both teams to discuss and debate their ideas within the group without interfering **allowing children to express themselves - explain their ideas and communicate their explanations to their teammates - as well as to listen to the others**. The teacher's only interference was focused on fostering collaboration and making sure all children understood the value of teamwork.

Both teams faced coordination issues as all children wanted to programme the bee-bot. In order to resolve any disagreements between the children, the teacher advised both teams to assign specific roles to each member. After the roles were assigned, both teams still struggled to find the treasure, mixing up right and left as the Bee-Bot moved on the map. The teacher **identified the issue** and **began a conversation with the children to resolve any misunderstandings**. At the end of the discussion the teacher suggested that it might be easier for the children to move the Bee-Bot while saying right or left depending on where it goes and not where they stand.

The team that carried out the next attempt immediately after the discussion, and following the teacher's advice, managed to find the treasure and win. After one more unsuccessful attempt, which the teacher took the time to explain what went wrong to the losing team, the game was over and the winner was announced.

Opportunities for inquiry and creativity

Arguably, this lesson fostered children's creative dispositions in a number of ways. Given the hands-on nature of the activity children were **excited and motivated** to carry out their tasks. An important aspect of the activity that contributed to children's enthusiasm was the competition element and the reward offered to the first team that reached the treasure chest. As Stavros commented in his interview *"Children especially enjoy similar activities. Whenever we have competition their excitement and interest is sustained throughout the lesson."* Stavros used questioning during his brief discussions after a failed attempt to encourage children to **explain** what they were doing and to foster **dialogue and collaboration**. The treasure hunt activity was focused on developing **problem solving and reasoning skills**, aiming to **establish connections** between the Bee-Bot buttons and the actual movement of the robot, design the route to the target and understand the change in perspective and direction as the robot moved on the board.

Creative approaches to teaching were reflected in particular in setting a motivating and meaningful context for the activities described that allow opportunities for **physical exploration**, and **problem solving**. Stavros was actively interested in children's explorations and shared their own excitement during the entire lesson, **using questioning** as the main method of **eliciting ideas and encouraging reasoning**.

ILLUSTRATIVE EXTRACTS FROM DATA

The teacher presents the task as a competition and sets the rules. He emphasises the importance of collaboration.



Teacher: Today we will use Voula to find the hidden treasure. Voula has been lost in the woods again and she has to find her way to the hidden treasure. Let's make the two groups we always play in and begin. Let's have the two teams present themselves.

(Children seem excited to try and find the treasure.)

Teacher: I have to remind you that only if you collaborate and work together will you be able to succeed. You don't only have to find the solution, you have to record your every attempt.

Children review problem solving processes followed and collaboration after an unsuccessful attempt to find the treasure.

Child A: If you did not press the right button then...

Child Z: But I was the captain of the team, I had to handle the bee.

Child A: Yes, but you need to listen to all of us.

Child E: We need to decide what to do together, we made a mistake and now if they are correct they will win.

Child A: He is doing everything in a hurry.

Child E: No he just wants to press the buttons on the bee.

Child K: It doesn't matter who presses the buttons, it only matters if we win.

Child Z: Let's start again then.

[The children began to plan the path of the bee-bot, but the teacher arrives.]

Teacher: Where do you think you got it mixed up?

Child A: Child K pushed the button to go right, and then Child E said that we should press forward but Child K pushed right again.

Teacher: Did this [the bee cut-out] help you?

All 4 children: Yes it did a little.

Child Z: But we need to fold it so it won't get wrinkles (...)

Teacher: Oh right, now I see. Now what do you have to do to reach the goal?

Child K: We need to work together.



Teacher: You need to listen to what the others are saying. For example Child A and Child K might have two different ideas. You need to discuss both ideas first before making up our minds.

Child A: But Child Z does not hear us and he pushes the buttons himself.

Teacher: Child Z is the captain of team but he needs to listen to everybody. Best way is for all of you to take turns pushing the buttons. Discuss what you

should do now.

Teacher identifies the problem and initiates a discussion.



Teacher: I see that you keep having problems with left and right. Let's see now, which is your writing hand?

(Children lift their arms - all children are right-handed.)

Teacher: Which is your right hand then? Remember, I am the only one who is left-handed here.

All: This is right (right hands are still up).

Teacher: I have observed that instead of saying left and right when moving the

Bee-Bot, you just keep saying "Go this way or that way". This might confuse you. Why don't you try to move the Bee-Bot while saying right or left depending on where it goes and see if that helps you. Right and left do not change for Voula. You have to check where she is looking to figure out if she needs to go right or left. If she is turned backward then what happens? Be careful when that happens. Child D, come here in and stand opposite to me. Which is my right hand?

Child D: This one (points to the left hand).

Teacher: Be careful Child D, when two people are facing each other their right hands are on the opposite side. I will turn around for you to see which one is my right hand. My right hand is on the same side only when we are facing in the same direction.

Episode: MA Counting Caterpillar	Setting: Sch
Subject: Mathematics	Age Group: 7-8 years olds
Key factors:	Teacher: Fleur
Learning activities: Planning investigations; Communicating explanations	
Pedagogy: Reflection and reasoning encouraged	
Contextual factors: Use of ICT	

Aims

This activity focused on a problem solving activity where the children needed to find different combinations of number pairs that all add up to the same total number. The focus for learning can be said to be on the development of cognitive skills and understanding as the teacher aimed at fostering the children's skills and understanding in the manipulation of objects to solve mathematical problems, associated with number bonds.

Analysis of key features

This episode involved the children initially working in the wider class group and then practicing approaches introduced in smaller groups. **The teacher made use of resources such as the interactive whiteboard where the children could practice strategies for solving number problems, and share their reasoning with the class.** She also provided a laminated caterpillar and segments in the shapes of circles that could be stuck on the caterpillar with Velcro to make up various number combinations.

The teacher initiated this activity by asking the children if they could remember the story concerning the number 10. Two children were called out to demonstrate how different pairs of numbers such as 5 and 5 or 4 and 6 add up to 10. They used straws to demonstrate their reasoning and strategy to the class. **The children were not only encouraged to give the correct answers but to communicate their explanations through demonstrating how they achieved their answers.**

The teacher invited another child to work out another example where two pairs of numbers were needed to add up to 4. This time the teacher used the interactive whiteboard and encouraged this child to use an image of a caterpillar and organize its segments in different colours to represent the different number combinations. **The use of ICT stimulated a discussion where the children proposed different strategies to acquire the answer.** The teacher made use of this opportunity through testing out these strategies on the interactive whiteboard. Therefore the interactive whiteboard provided an opportunity to introduce the use of the counting caterpillar for the children to **communicate their reasoning** regarding the task to the class and **to reflect upon their peers' reasoning. This supported their understanding of this activity.** Additional examples were used to reinforce the use of the caterpillar to solve mathematical problems **where the teacher asked questions** about the different parts of the strategy to **foster reflection** about this method.

The group work was introduced after the teacher ensured that the students understood how the caterpillar might be used. Each table was given the laminated caterpillar resources that they could manipulate in their small group. The teacher provided enough **freedom to allow the groups to plan and design their work as they saw fit.** Two groups decided to take off the segment that represented the caterpillar's head. This decision was made after the children **discussed in their small groups** and reflected on the usefulness of the head and collaboratively agreed to do without it. The other groups concentrated on representing the total number with the circular segments and then took off individual segments to come up with the combination of number pairs to make a particular total.

The teacher then redirected the groups to join the class for a class discussion. She encouraged the children to share their strategies with the class in terms of how they came up with the different number pairs. Through **communicating about their planning and reasoning** the children were invited to **reflect on their own thinking** as they shared their strategy with the class. The children could also **reflect upon new ways of working out** this mathematics activity through **listening to their peers' explanations.** To terminate the activity the children were instructed to complete some classwork concerning employing the strategies that they had been practising.

Opportunities for inquiry and creativity

The group work organized by the teacher, **stimulated discussions** amongst the children regarding the ways they should go about this activity. This **freedom and time** afforded for the children to be autonomous provided the students with the space to be creative. This creativity is observed in the different ways they organized their resources and the **different ways they reasoned** out the activity.

Through providing the children with the opportunity to communicate their creative work, the teacher demonstrated that creativity should be embraced. Through acknowledging the **groups' different contributions** the teacher also fostered acceptance of **different methods of going about an activity.** This supported the children in making their own contributions and in making sense of different activities in their own ways.

ILLUSTRATIVE EXTRACTS FROM DATA

The use of ICT to share children's reasoning
Teacher asking questions to promote reflection



Teacher: What are the number pairs for 4? The caterpillar makes 4...careful...start from zero.

Child 1: 0 and 4.

Child 2: No...just 4.

Teacher: Let's see what we have.

Teacher: What happens when we get 3 again?

Children: They are the same.

Teacher: Do we need to do them all over again?

Children: No.

Reflecting about methods to be used in the small groups



Child 1: How are we going to work it out?

Child 2: We need to find numbers, we have number 6.

(The children count six segments on the caterpillar and remove the other segments.)

Child 1: We can start with 1...then count the rest...we need 5.

Creativity observed in the child initiated adaptation to the resource



(The children are a little perplexed as they look at the caterpillar's head)

Child 3: Do we need to count this?

(The children decide to remove the caterpillar's head so that the segments are the only things on the caterpillars' body.)

Episode: MA Feet	Setting: PreSch
Subject: Mathematics	Age Group 4 years olds on average
Teacher Natasha	
Key factors:	
Learning activities: Gathering evidence (using equipment) / Gathering evidence (through observation) / Communicating explanations	
Pedagogy: Role of motivation and affect / Role of dialogue and collaboration	
Contextual factors: Variety of resources	

Aims

The aims of this activity involved further developing the pre-skills needed for measuring, where children learn that length can be measured in different ways through the use of different tools such as measuring tape, paper rulers and blocks. The teacher also aimed at instilling awareness concerning how to use the different tools such as positioning the 0 at the start of the scale on the measuring tape and ruler exactly at one end of the object to be measured.

Analysis of key features

This episode involved the children measuring the length of cardboard cutouts representing the children's own feet that they have prepared on a previous day.

The different measuring tools included blocks, measuring tape, and paper rulers. The children worked together in small groups (n= 4/5) and were encouraged to use these different tools to determine the length of their feet. All the children were already familiar with using these measuring tools as they already had previous experience of measuring the height of objects.

In the first part of the activity the teacher collected the children together in a whole class group and reminded them of a previous activity where they had drawn the outline of their own feet. She engaged the children's attention through selecting a child to draw the outline of her foot. The Learning Support Assistant (LSA) and the researcher were also invited in this initial part of the activity, as two other children were selected to outline the adults' feet whilst the rest of the children observed. This initial exercise **captured the children's attention successfully, fostered motivation and a positive affective response** as the children laughed excitedly and were eager to participate.

Afterwards the teacher distributed the cutouts of the children's feet and the measuring tools to each of the four tables **whilst instructing the children to measure their feet by using the different tools.** The children seemed to prefer using the blocks to measure as they immediately selected this tool. They were proficient in its use since they had already investigated how to use blocks to measure length or height in a previous activity. One of the children **communicated his results to his group** and to the teacher by **explaining that the length of his foot corresponded to 9 blocks.** On observing the children's preference for blocks, the teacher prompted the children to use the other tools. On one table a child took on the teacher's advice and **demonstrated to his group how to use the measuring tape** on his cutout.

The teacher **monitored the group work** and noted that some children were not using the measuring tape or paper ruler correctly. This difficulty was due to the emerging skills of fine motor and eye-hand coordination that the children were still developing and mastering. **Through questioning,** the teacher invited the children to reflect about the correct procedure of measuring that implies starting from 0cm. The students themselves came up with this explanation as one of the children expressed that you need to start from 0cm. The opportunity **to communicate this explanation** redirected this particular student's awareness towards observing the positioning of the tool he was using and adjusting his work in order to follow what he had proposed. This discussion motivated the other children on the same table to investigate the measuring tape and paper ruler and follow the guideline expressed by their peer. The children were counting aloud as they explored with all the different tools.

The group work organized by the teacher provided opportunities for peers to observe each others' work, **to communicate their own explanations and to demonstrate to each other to use the different tools.** The freedom to explore the different tools also contributed to the children's positive attitude towards this activity.

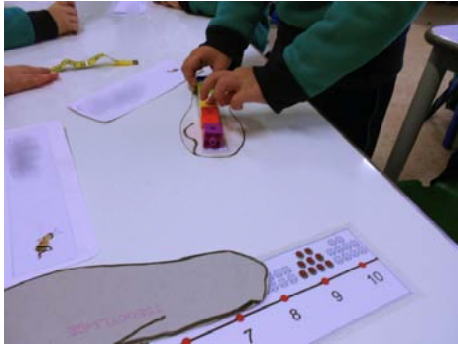
As the activity was coming to an end the teacher redirected the children's attention towards the goal of this activity. She asked the children to think about how they can measure the length of their feet. The children replied that they could use a variety of tools such as blocks, measuring tape and ruler. This indicated that the children had **successfully understood that there are different ways of measuring length.** The teacher also consolidated the children's counting skills by counting numbers all together as a class pointing out that counting is also an important aspect in measuring.

Opportunities for inquiry and creativity

By providing a variety of resources and organizing their exploration within small groups the teacher provided opportunities for children to interact with different measuring tools in different ways. The group setting also enabled children to observe, **communicate and demonstrate to each other** the different ways these tools could be utilized. By **providing questions** were the children where to reflect upon their own work, instead of the correct procedure, the children were encouraged to come up with their own solutions and guidelines.

ILLUSTRATIVE EXTRACTS FROM DATA

Child communicating his results to his peers
The teacher challenges students to use other tools



Child 1: Look it is 9 blocks.

Teacher: Ok now see if you can use these too. (The teacher points to the paper ruler and the measuring tape)

Children communicating and demonstrating the use of different tools



Child 1: You can do it like this (holding the measuring tape against the cutout). He is still not aware that he needs to start from 0cm)

The teacher poses questions to engage the children in reflection and observation
The child communicating and demonstrating the procedure



Teacher: Now look at the numbers on the tape, how do you have to do it?

Child 1: You have to do it from 1.

The teacher consolidating the learning

Teacher: So how can you measure the length of your foot?

Child 1: You can use the blocks.

Child 2: Or the measuring tape or the ruler.

Episode: MA Minibeasts	Setting: Sch
Subject: Integrated Maths/Science	Age Group: 6-7 years olds
Key factors:	Teacher: Lydia
Learning activities: Gathering evidence (through observation) / Communicating explanations	
Pedagogy: Role of motivation and affect	
Contextual factors: Outdoor resources	

Aims

The activity focused on science inquiry. This involved developing and consolidating the children's observation skills whilst enhancing knowledge about and awareness of different types of minibeasts and their habitats. Mathematical concepts were also introduced as the children needed to record their observations through using tables provided in the distributed worksheets.

Analysis of key features

This episode involved the children **exploring the schoolyard** and **observing** the different minibeasts present in their **outdoor surroundings**. A worksheet with a table was distributed to the children so that they could record the minibeasts' characteristics, the number and the habitat. The children worked together in small groups and were left free to explore their environment as they wished.

The teacher initiated the activity by asking the children about their own experiences of nature by **posing the questions** of what they usually find in their gardens at home or in the countryside. **The children were very eager to express themselves and responded positively to the question raised by participating.** After listening to the children's prior experiences, the teacher distributed a worksheet and instructed the children to explore the school's yard and garden and record what minibeasts they encounter.

One group found a pupa stuck to a tree. They excitedly discussed this minibeast and engaged in communicating explanations about the characteristics of the pupa. This encounter **stimulated the children in sharing their previous experiences of the insect, exchanging knowledge** regarding the process of transforming from a caterpillar into a butterfly **and posing questions** regarding this process. The group recorded this observation and moved on to exploring other parts of the yard.

Another group spotted some ants and started counting how many they could see. **This encounter also triggered a discussion about their previous experiences of ants as one of the children described how his mother does not like it when she sees ants in her kitchen.** This group also engaged in **questioning the behaviour of the ants** as they commented about how fast the ants were running and were curious if they are carrying food.

Both these encounters with minibeasts demonstrated how the two groups were very curious and interested about their surroundings. This activity made use of the **children's curiosity to foster positive attitudes towards science**, as the teacher recognised that **the outdoors presents a variety of resources that engage children** in observation, meaning making and sharing of scientific knowledge.

The mathematical concepts introduced in this activity, associated with recording data, were not as easy to grasp for children as the process of observation associated with the scientific inquiry. The researcher assisted the children in recording the minibeasts in their worksheet, as one group was struggling with representing their observations in the tables. The teacher terminated the exploration by directing the children to class. She encouraged the children to **discuss their observations with the whole class.**

Opportunities for inquiry and creativity

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

This exploratory activity organized by the teacher permitted the children to **make connections** to their everyday life making the scientific inquiry and knowledge discussed relevant and meaningful. This was evident as the children communicated about their previous experiences and exchanged knowledge about the minibeasts.

ILLUSTRATIVE EXTRACTS FROM DATA

Communicating explanations about the pupa stuck to the tree



Child 1: *See what this is ...?*

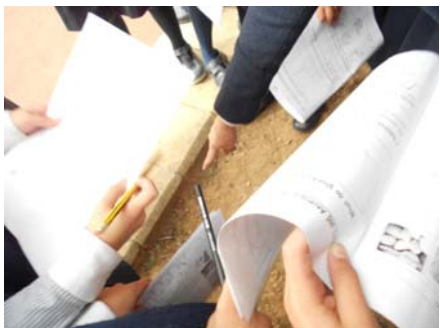
Child 2: *That is a pupa...it was a caterpillar once.*

Child 1: *Yes we had one in our garden...it turns into a butterfly.*

Child 2: *Look how it is stuck to the tree. Will it fall?*

Child 1: *How long do they take to become a butterfly?*

Children observing their environment, communicating about previous experiences and questioning their observations



Child 1: *Look, we have lots of those ants at home too.*

Child 2: *How many are there? (Children count the ants)*

Child 1: *We also have them in the garden the ants.*

Child 2: *We also have them inside. My mum does not like them in the kitchen.*

Child 1: *Look how they run about, they go fast...do they have food?*

Children are eager to explore the outdoors



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

Episode: PT Sun Distance	Setting: PreSch
Subject: Integrated Science/Maths	Age Group 5 years old Teacher Carol
Key factors:	
Learning activities: Gathering evidence (using observation) / Questioning	
Pedagogy: Diverse forms of expression valued	
Contextual factors: Sufficient space / Variety of materials	

Aims

To understand the relative sizes of the Sun and the Earth and the distances between them, using proportions; to know basic facts about the solar system.

Analysis of key features

First, in their classroom, they had a conversation with questions and hypotheses about the Sun's size, the Earth's size and the distance between them. Through dialogue between the teacher and the children, they gathered many facts about the Sun and its importance for life.

Then using a ball and a little piece of plasticine they compared the relative sizes of the Sun and the Earth. The teacher set the problem: *"If the Sun is represented by a ball what would the Earth's size be and what would be the distance between them?"*

The children were then challenged to think about what size people would be to be in proportion. One child's response was 'microbes', making connections to prior knowledge.

The children became interested in the notion of proportion and relative sizes and wanted to compare sizes further. They came up with **their own questions**, for example, *"If the ball was the Earth, what would be the Sun's size? And what would be the size of people?"* "What if the Earth was this room size?" and "If both were of the same size?" The teacher **encouraged children's questioning** and **allowed them time** to answer their peers' questions.

The focus of the lesson then shifted to the distance between the Sun and the Earth. The children were asked to use their hands to show the diameter of the ball (i.e. the Sun) and were asked how many diameters would represent the distance between the Sun and the Earth. When the children learned that it would take around a hundred of them, they were **fascinated** by it. The teacher then gave children one hundred pieces of paper, each was roughly the length of the diameter, to model the distance between the Sun and the Earth **out in the corridor**.

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

The activity provided opportunities for children to develop and **apply their knowledge** about the Sun and the Earth, showing creativity in coming up with their own ideas and new understandings.

The teacher talked about the **notions of distance and proportion** between the objects. She used **several ways to represent** the ball diameter. She gave opportunity to the children to **raise questions** and **explore hypotheses**. The children were very much involved in the activity and interested about the theme. They compared the size of the Sun and the Earth using proportions and also compared the distance between them using the size of the Sun.

Opportunities for inquiry and creativity

The activity created by the teacher was creative. She made use of **a variety of materials to represent** the size of the Sun, the Earth and people (ball, plasticine, grain) and to represent the distance between the Sun and the Earth (using hands and pieces of coloured paper).

The initial use of the ball and a little piece of plasticine to compare the Sun and Earth **sparked the group's curiosity**. Children had the opportunity and time to **raise questions, make many hypotheses and interpret evidence**. The teacher **gave them enough time to explore this**. The children represented their ideas in various ways: through dialogue in a group or drawing pictures where they may use their imagination. They showed creativity in suggesting **new ideas and explanations**.

After some days, when talking with the group about the activity, they explained very well what they had learned and made in that activity. Their curiosity was stimulated, they brought books about the theme, they talked with their parents and **raised more questions**. For example they showed drawings where they answered the question: *"How did Copernicus find out that the Earth moves around the Sun?"* They suggested many interesting hypotheses: *"He went on a rocket and he saw the Earth moving"; "He searched in the web"; "He searched in his books in his big library"*.

ILLUSTRATIVE EXTRACTS FROM DATA

Children's questions and hypotheses

(The teacher shows the ball and says it represents the Sun and the little piece of plasticine represents Earth.)

Teacher: *If the Earth was this size, what would be the people's size?*

Child A: *I think people were the size of microbes.*

(...)

Child C: *If the ball was the Earth, what would be the Sun's size? And what would be the size of people?*

Child B: *The people would be the size of microbes.*

(Children ask questions about the sizes of the Sun, the Earth and people)

Children: *What if the Earth was this size (ball size)? / And if the Earth was this room size?*

Teacher's scaffolding questions / representation using varied materials

Teacher: *If the Sun was this size (the ball) and the Earth this size (the grain), what would be the distance between them?* (Teacher put both objects on the table).

Teacher: *This would be a good distance?*

(A child separates the two objects.)

Child D: *Maybe the Sun would be here and the Earth would be in the next room.*

(The teacher uses the hands of each child to measure the diameter of the ball)



Teacher: *Do you see this length? What is the name of it?*

Children: *Diameter of the ball.*

Teacher: *Do you know how many of this we have to use to make the distance between both?*

Teacher: *One hundred.*

Children: *Ah!*

(...)

Teacher: *How far is the Sun from Earth?*

Children: *150 millions of km*

Teacher: *What is 1km?*

Children: *Is the distance from that wall (the opposite) to the window / The size of this school / From Braga to Lisbon.*

Use of corridor space /varied materials to represent the distance between the Sun and the Earth / Children gathering evidence through observation

(The teacher gives to each child a set of colored papers of the size of the ball diameter.)

Teacher: *Let's go to the corridor and see the distance between the ball and the grain.*

(They go to the corridor. They put the ball on the floor and start to put the papers through a line.)

Teacher: *What are we doing?*

Children: *We are going to see where we put the Earth.*

Teacher: *How many papers do we have to put between them?*

Children: *One hundred.*

(They put the papers – in pattern - between the two objects and they notice they can't see the plasticine from the ball)

Children: *We can't see the piece of plasticine from the ball!*



Episode: PT Swing Game	Setting: PreSch
Subject: Science	Age Group 5 years old
Key factors:	Teacher Olivia
Learning activities: Planning investigations / Gathering evidence (through observation) / Explaining evidence / Making connections	
Pedagogy: Role of problem solving and agency/ Fostering reflection and reasoning	
Contextual factors: Sufficient space / Rich physical environment for exploration	

Aims

For children to discover some principles of swings by executing experiments with the swing game, as well as for them to practise and develop the skills of systematic observation, questioning, planning and recording to obtain evidence.

Analysis of key features

The lesson began with children sitting in a circle on the carpet. They were presented with **a variety of materials**, such as ropes, adhesive tape, different weights to attach onto the rope, among others. They were then asked to design their own swinging game: *"If you want to make a swing (game), then you need a good swing. What is a good swing?"*

The teacher used questioning to foster discussion about the length of the rope and its effects on the motion of the pendulum, *"Which rope should we use? A long one or a short one?; "If you want to make a swing (game), then you need a good swing. What is a good swing?"*

The teacher started the activity with only one wire, all had the same size. Children began to predict that it was possible to have multiple movements. They concluded that the movement could be tilting to one side and the other, with a rhythm. The children also came to the conclusion that they could hang something at one end of the wire. Suggestions included putting oranges in a plastic bag and attaching the bag to the rope, or attaching a coffee bean to the wire. Some children also **made connections with their everyday experience**, by comparing the class pendulum with their grandmother's pendulum clock.

One child tried to attach the pendulum on the side of the door, but it kept banging the wall when the child was trying to swing it. Drawing from **their observation**, the children **explained** that *"We need to use a long rope, an open space (like the door opening) so the pendulum doesn't hit anything while moving"*, and suggested that the pendulum needed to be attached to an open space, specifically at the top of the doorway instead.

After this short exploration phase, children are confronted with specific **scientific problems** concerning the swing game:

For example: "If you want to make a swing game, then you need a good swing. What is a good swing? And what can be the rules for the game? How can you make such a game of your own?" This provided a valuable opportunity for **reflection and reasoning**.

Opportunities for inquiry and creativity

Creativity was present in the opportunities the teacher provided for **children's problem solving and agency**. The children were able to choose the context of their swing game. The **rich physical environment** and **the use of space** in the classroom enabled children to explore different ways of making a swing and what made a good swing game.

Children made their **own connections with experience** registered in expressions like: *"My grandmother pendulum clock as a swing like the one we are looking for,"* showing evidence of science process skills such as observing and describing the surrounding world. When the child was asked, *"How can we build a swing like your grandmother has?"* the child suggested ideas: *"Attach the swing to the wall, hanging something in the end of the rope,"* showing signs of **imagination and problem solving skills**.

Examples of creativity were also shown in children's suggestions of ways to extend activities or solve problems that emerged. For example when some children had made their swings they fixed them to the wall. When trying to make them go backwards and forwards they observed *"This isn't a swing! It hits the wall and doesn't swing."* Many children tried to make it swing, unsuccessfully so they reach a conclusion: *"The swing can't be fixed in the wall, because it's impossible to make it swing, hanged in there."* This part of the activity shows that students were able to use questioning, gathering evidence, interpreting evidence and communicating findings. And we see the process of scientific creativity at work as the children **reason critically between their strategies**.

ILLUSTRATIVE EXTRACTS FROM DATA

An open-ended problem

Teacher: *If you want to make a swing (game), then you need a good swing. What is a good swing?*

(...)

Child M: *With the plastic bag we hold the oranges fasten to the rope, and there is the pendulum!*

(...)

Child R: *Attach the swing to the wall, hanging something in the end of the rope.*

A variety of materials



Opportunity for children's reflection and reasoning

Teacher: *What do we know at this moment about pendulums?*

Child S: *We need to use a long rope, an open space (like the door opening), so the pendulum doesn't hit anything while moving.*

Children's own investigations / Children gathering evidence through observation
Rich physical environment for exploration



The teacher helped a child to attach a capsule of coffee to the end of the rope and fix it to the wall. Children tested their hypotheses, trying to swing it.

Child R: *This isn't a swing! It hits the wall and doesn't swing.*

Child S: *Pull away from the side.*

Child J: *Take it more out.*

Children: *Let me try, I think I can make it swing and don't hit the wall.*

Many children tried to make it swing, unsuccessfully. Finally, they reached a conclusion:

Children: *The swing can't be fixed in the wall, because it's impossible to make it swing, hanged in there.*

Child R: *Maybe we can fix it to the top of the door opening.*

Episode: PT Wolf, Sheep and Cabbage **Setting:** Sch
Subject: Integrated Science/Maths **Age Group** 8 years old **Teacher** Florence
Key factors:
Learning activities: Planning investigations / Communicating explanations
Pedagogy: Reasoning and reflection encouraged / Diverse forms of expression valued
Contextual factors: Small grouping

Aims

The aim of the problem is to move the wolf, sheep and cabbage to the opposite shore of the river. It gets more difficult though because when the man is not around, the wolf will eat the sheep, the sheep will also do the same when alone with the cabbage. This involves the use of knowledge of food chains to solve the problem – analysing possibilities and predicting if there is more than one solution.

Analysis of key features

The teacher introduced the well-known **problem** ‘Wolf, Sheep and Cabbage’ on the blackboard, and explained the rules of the game to the children. The children had to carry the wolf, sheep and cabbage on a boat from one side of the river to the other, one by one. The conditions were that 1) if the wolf is left alone with the sheep, it will eat the sheep; 2) if the sheep is left alone with the cabbage, it will eat the cabbage; and 3) the wolf will not eat the sheep and the sheep will not eat the cabbage if the farmer, who is sitting in the boat, is right nearby to side of the river that they are on.

Using the paper cut-out models of the wolf, sheep and cabbage that the children had made and painted previously, and an *origami* boat that they created at the start of the game, they were encouraged to **work in groups** to solve the problem.

Throughout the activity, the children **collaborated** with their peers to think of different possibilities; to try out the different potential solutions; and to **give reasons** why certain ideas would not work.

The whole class reached conclusions and solved the problem presented in the beginning, and had the opportunity to verify their solutions against the on-line version of the game, which is available freely on several websites. The **use of ICT** allowed the children to experience and **represent the same problem in different ways**.

Opportunities for inquiry and creativity

The context of the game provoked children’s **imagination**, and the informal and fun nature of the task **motivated** the children to become engaged in the problem. Working in groups encouraged children to articulate their ideas and

reasoning. Children **collaborated** in sharing and discussing different ways to solve the problem.

Children’s **problem solving skills** were fostered as they suggested and modelled different potential solutions and gave **reasons** why certain ideas work or would not work. Children used and developed science skills such as predicting, observing, analysing and describing, demonstrating scientific or mathematical creativity in generating alternative ideas and strategies and **reasoning critically between them**. They also had to **make connections** between the combinatorial / mathematical aspect of the task and their knowledge of food chains.

ILLUSTRATIVE EXTRACTS FROM DATA

An example of children collaborating and giving reasons

Child L: *The sheep eats the cabbage.*

Child R: *The sheep has to go first because the wolf doesn't eat the cabbage.*



Examples of children explaining why certain ideas would work and would not work

Child R: *If we took the sheep first, then the cabbage, then the sheep will eat the cabbage.*

Child R: *So we have to leave the sheep and bring the cabbage back.*

Child R: *If we took the cabbage in first place, the wolf will eat the sheep. (...)*

Child G: *First we take the sheep across, then we go back and get the cabbage, then we take the sheep back and take the wolf across, then we take the sheep across.*

The informal and fun nature of the task helped in engaging children



The integration of ICT for children to verify their solution



Reflecting on learning

Child LA: *With this activity we learned that to solve a problem we have to make relationship between what we are 'analysing'.*

Episode: RO Float or Sink	Setting: PreSch
Subject: Science	Age Group 5-6 years old
Key factors:	Teacher Maria
Learning activities: Planning investigations / Gathering evidence (through observing) / Communicating explanations / Explaining evidence	
Pedagogy: Role of problem solving and agency / Reflection and reasoning encouraged	
Contextual factors: Variety of materials / Small grouping	

Aims

For children to become familiar with the concepts and processes of floating and sinking, as well as for them to develop their knowledge about the forest and the objects and materials that can be found there, in addition to insects and birds that live in the forest. Additionally, the activity also aimed to foster the children's problem solving skills.

Analysis of key features

Maria, the class teacher, started the lesson by inviting her 12 children to come and pick a card from her. Each card had a picture, and there were three different pictures altogether. Children with the same picture formed a group, resulting in **three groups of four children of randomly mixed abilities**.

She asked children what a forest is, what kind of trees can be found in a forest. There was a permanent dialogue with children who responded to teacher's questions. The little ant is looking for food. What seasons are used by the ants to gather food? All the children were engaged in the dialogue were asked if they agreed with the answers. Then one day, the little ant fell into a river. A dove flying by saw what happened and wanted to help the ant. Whilst telling the story, Maria showed the children pictures of both animals and the children were asked to describe the two characters and to compare their anatomical differences, before asking the main question of how the ant could be helped by the dove.

Initially, children's proposed solutions included those that required the dove to help the ant directly, for example, the dove should use its beak to pick up the ant and the dove pick the ant up using one of its paws. Through **class dialogue** and drawing from the previous discussion on the two animals' anatomical differences, other children highlighted the weaknesses of the two aforementioned solutions, including the fact the dove's peak would be too hard for the ant and it might injured the ant, or that the dove's feet would be too large and too long to hold the ant up properly.

Maria then hinted at the fact that the dove then tried to look for something that it could help to get the ant out of the water. Additionally, she also highlighted at the location in which the story took place. Through Maria's careful **scaffolding**, the children's focus then shifted from how to get the dove to help the ant

directly to thinking about what natural materials in the forest the dove could use to help keep the ant afloat and out of the water. Maria wrote down the names of each of these natural materials on the whiteboard next to the name of the child who suggested it.

Later, Maria suggested that the children run an investigation to **identify the best idea to solve the problem**. The children were given small containers with water in order to verify what materials existing in the forest could be used as little 'boats' for the ant. **A variety of materials** were made available including nuts, feathers, wooden sticks, leaves, little stones, acorns, pieces of bark, fir cones, etc. Maria asked every group to come to the front table and to take the materials they thought were the most suitable for the task to save the ant, items they intended to test. Children had to predict which objects would float.

Opportunities for inquiry and creativity

By providing an inquiry-based problem that had more than one solution and by giving them autonomy to come up with their own ideas, the children were able to **plan their investigations**. For example, some children proposed that *"The dove can place [a small stick] below the ant and lift it up and place it on the stone"*, whilst another child suggested that *"The dove keeps the stick in its beak and gives it to the ant and draws the ant from the water"*.

Through teacher scaffolding, children were given opportunities to foster their creative thinking **drawing on evidence from their observations**, as was the case when one child was asked to describe what happened to an object (napkin) he was experimenting earlier, to which the child responded: *"It sank. (...) It went wet and went to the bottom of the container"*, and to subsequently draw a valid conclusion when asked whether this object would be appropriate to help save the ant.

Through peer-to-peer dialogue, children's creativity was also noted when they made sensible **explanations** to their peers whether a proposed solution would work. While one child, for instance, recommended the dove to help the ant using its beak, another child explained that *"It does not work; dove's beak is too strong."* Through **making connections** with their knowledge of forest, the children were able to offer solutions that were practical and useful, for example a leaf, a wooden stick, a feather, a blade of grass, and among others.

Children's creative thinking was also evident when they were given freedom to **communicate their findings** in a variety of forms, be it through writing or drawing on their worksheet, as well as a verbal presentation at the end of the lesson.

ILLUSTRATIVE EXTRACTS FROM DATA

Children working together to find the best materials to keep the ant afloat



Children communicating their findings in various ways

[Name/Date/By what means did the dove save the ant from sinking?]



Example of teacher scaffolding and children's creative solutions

Teacher: *Then the dove looked around to find something to help the ant out of the water. I wouldn't tell you what it found. I shall leave you to guess what it used. You have to discover what is the object dove used.*

(...)

Child 3: *A liana.*

Teacher: *That is a stick?*

Child 1: *It was a stick, a small stick. The dove can place it below the ant and lift it up and place it on the stone.*

(...)

Child 5: *The dove keeps the stick in its beak and gives it to the ant and draws the ant from the water.*

Child 1: *The dove takes a stick with a hole inside and places it in front of the ant, and the ant goes inside and comes out.*

Example of class dialogue

Teacher: *What do you think the dove had done to save the ant?*

Child 1: *It took her with its beak.*

Child 2: *It does not work; dove's beak is too strong.*

Children using evidence from observation

Teacher: *Besides this conclusion I notice Child D that you tested a material which was discharged away by the end of the investigation. We had an object, which, according to my opinion, can be use to rescue the ant. What was that object?*

Child D: *The red feather?*

Teacher: *No, besides the red feather. What it was? A piece of ...*

Children: *Napkin.*

Teacher: *What did you notice happened to this piece of napkin?*

Child D: *It sank. (...) It went wet and went to the bottom of the container.*

Teacher: *Do you think this object can be used to save the ant?*

Children: *No. No.*

Episode: RO Ice	Setting: Sch	
Subject: Science	Age Group 7-8 years old	Teacher Stela
Key factors:		
Learning activities: Planning investigations / Making connections / Communicating explanations		
Pedagogy: Collaboration / Role of problem solving and agency		
Contextual factors: Variety of materials / Rich physical environment for exploration / Small grouping		

Aims

For children to become familiar with the concepts of liquids and their properties, and the melting process, as well as for them to conduct experiments to test their hypotheses.

Analysis of key features

The lesson started with Stela, the class teacher, showing a short animation of Scrat, a squirrel, who had been stranded on an island. In order to survive, it had to find a way to get acorns, Scrat's only food supply, out of ice cubes. Stela paused the video there, and turned her attention to the children, inviting them to help Scrat **find a solution to the problem**.

Children were asked to **work in groups to propose the best solution to the problem**, using **a range of materials** that had already been prepared for by Stela to test their idea. These materials included hot water in a thermo, sugar, salt, and a small hammer, in addition to ice cubes with acorns frozen inside.

For Group 1, the children chose to use hot water to try to melt the ice cube to get the acorn out, by carefully pouring hot water out from a thermos to the ice cube. Following the group's experiment, a child also suggested using sugar to melt the ice.

The children in Group 2 chose to use salt to melt the sugar, as one of the children recalled how salt is normally used to melt ice on the streets during winter, **making a connection** between the learning activity and their everyday life experience.

For Group 3, the children discussed and agreed to use the wooden hammer to break the ice to retrieve the acorn. One child attempted to hit the ice cube with the hammer several times, before the ice cube got was broken into small pieces (*"I broke the ice very quickly, it was not difficult. Scrat can eat the acorn now"*).

The teacher just supervised the children and offered some consultancy when needed. In dealing with the problem they were facing, the children followed some of the steps of the **inquiry-based learning: problem identification, proposal for a solution, set-up of an experiment, selection of materials to be used, observing a phenomenon, and recording the results**.

The inquiry approach was evident in the lesson as the children were asked to **record their findings** on a worksheet with the following headings: 'Planning' (*"we have to free the acorn by the impact of the hammer"*, *"the ice has to be crashed"*), 'List of materials used' (*"hammer, ice"*), 'Action taken' (*"we struck the ice with the hammer"*), '**Observation**' (*"the ice is broken"*), 'Conclusions' (*"the ice is took off rapidly"*).

At the end of the lesson, each group was asked to nominate a child to **present the results and conclusions to the rest of the class**, as well as comparing if the test result matched their predictions. One of the conclusions: *"the method works"*.

During the activity, Stela assisted the children to keep them safe from working with hot water and a hammer. Additionally, she also observed children during their investigations, focusing on the manner in which children adopt and apply various strategies to obtain a sound result, as well as other broader aspects of scientific learning, such as their attitudes, collaborative skills, discipline, vocabulary, and the way children progress in their "research". Stela also evaluated their outcomes based on their completed worksheets.

Opportunities for inquiry and creativity

Children's problem solving skills were fostered as the children **conducted their investigation** and used their **observation** data to draw their conclusions. For example, when a child suggested that, in addition to hot water, sugar should also be used to melt the ice, and when he conducted the experiment with sugar, he observed that *"Nothing happens. The ice is already melting."*

An additional creative disposition was noted when a child made **a connection** between the provided resources and what was observed in their everyday life outside the classroom, more specifically when a child chose to use salt to melt the ice cube as a result of having the former being used to melt the latter on the streets during winter.

Children's creative thinking was also evident when they were given freedom to **communicate their findings** in a variety of forms, be it through writing or drawing on their worksheet, as well as a verbal presentation at the end of the lesson. An example of their communicated finding includes *"We expected ice to melt quickly, but it took some time, and still now the ice did not melt completely."*

ILLUSTRATIVE EXTRACTS FROM DATA

Children conducting their investigations



Examples of children communicating their findings both verbally and in writing

Teacher: One pupil of the group please present the results in front of the class.
Group 1: Conclusion: hot water was a good solution and ice melted rapidly. We added some sugar, but nothing happened.
Group 2: We expected ice to melt quickly, but it took some time, and still now the ice did not melt completely.
Group 3: Conclusion: I broke the ice very quickly, it was not difficult. Now Scrat can eat the acorn.



Name/Date/ Scrat is hungry.
 The Ice Age acorns are frozen. Let's help Scrat to release its favourite fruits from the ice trap. By which methods and by what means can you take out the acorns from the ice as fast as possible?
 Ideas/Hypotheses/ We use materials/ We experiment/ We observe/ Conclusions
 We liked this activity because.....

A child's curiosity was aroused, resulting in an additional investigation

Group 1 received a tray, one ice cube with an acorn inside and salt. Children poured hot water on the ice, the latter started to melt and finally the acorn was freed:

Child A: What if we shall add some sugar? Let's try!
 (...)
Teacher: What do you observe?
Child: Nothing happens. The ice is already melting...

Episode: RO Measuring Volume (Non-Standardised Units) **Setting:** PreSch
Subject: Integrated Science/Maths **Age Group** 5-6 years old **Teacher** Sanda
Key factors:
Learning activities: Gathering evidence (using equipment) / Gathering evidence (through observation) / Communicating explanation
Pedagogy: Reflection and reasoning encouraged
Contextual factors: Variety of materials / Rich physical environment for exploration

Aims

For children to understand the use of and become familiar with a range of non-standardised volume-measuring units. Additionally, the following were the concepts that the teacher wanted her children to grasp:

- measuring means comparing the quantity to be measured with a small quantity considered as “unit”;
- the number of units associated to a quantity to be measured depend on the ratio between the quantity to be measured and the unit value;
- in various measuring situations appropriate units have to be used.

Analysis of key features

The lesson started with Sanda, the class teacher, asking children which unit is used to measure liquids. Some children were able to identify the unit as the litre. They were told that they would not be measuring the volume using the litre, but “**various other units**”, for example, glasses, cups, tubes, bottles and cylinders. The teacher then asked what other liquids could be measured to which the children responded “oil, vinegar, milk, juice, beer, tea and wine”.

The children then worked **in groups** to compare the volumes of the different containers, as previously indicated. For example, some children were asked to pour water from a glass to a cylinder, others from a bottle to a cylinder, among others.

Conclusions about the volumes were then made by the children either independently or through **teacher’s scaffolding** (e.g. “*What can you say about the two vessels? Are they the same, in terms of volume?*”). As it can be seen in the ‘Illustrative extracts from data’ section, some children were able to give **reasons** for their conclusion based from their **observations**.

It might be worth noting that there was no worksheet in this activity as the teacher indicated that:

*“Sometimes worksheets are very useful during the work in class, but there are situations when children can get new knowledge much easily by **discussions**, both in each group and with the whole class, by repeating each new concept several times.”*

Opportunities for inquiry and creativity

Children’s creative thinking was fostered through their **observations** and in **communicating explanations** to others either independently or through teacher scaffolding. For example, when the children were asked to pour water from a bottle into a cylinder, they offered the following conclusion and explanation: “*The bottle is bigger than the cylinder because there still is some water in the bottle...*”. Similarly, when the children were asked to pour water from a cup into a cylinder, their conclusion and explanation were as follows: “*The cup is bigger because there still is some water in it that does not fit in the cylinder.*”

Arguably, the children’s **problem solving skills** were also fostered as they had to **conduct the investigation**, and used the data from their observations to draw a conclusion on whether the volume of a container was equal, greater or less than the volume of the other container in question. By the end of the exercise, the children concluded that not all units have the same volume.

ILLUSTRATIVE EXTRACTS FROM DATA

Children gathering evidence from observation and use of equipment



Children drawing conclusions and reasoning from their observations

Teacher: Now let's see the next experiment. You will pour water from the bottle in the cylinder till you will reach the last line on the scale.

Child 1: The bottle is bigger than the cylinder because there still is some water in the bottle...

(...)

Teacher: Now, you pour water from the cup into the cylinder.

Child 2: The cup is bigger because there still is some water in it that does not fit in the cylinder.

Teacher: Let's compare some other cups. You have water in the cylinder and now pour it in the cups. Does water fit in the cups?

Children: They are the same! The water from the cylinder fits in the cup!

(...)

Child 3: In my glass did not enter the whole quantity of water. There still is some water in the cylinder.

Teacher: And what can you say about the two vessels?

Child 3: The cylinder is bigger than the glass.

(...)

Teacher: How these two containers are, if the water from one of them can fill the other one?

Child 4: They are the same, they are equal.

Learning through working with others

Teacher: What can you say about the two vessels? Are they the same, in terms of volume?

Child 5: Yes.

Child 6: Nooo ... the glass is bigger than the cylinder!

Episode: UK(EN) Balancing Pens	Setting: Sch
Subject: Mathematics	Age Group 5-6 years old
Key factors:	Teacher Emily
Learning activities: Gathering evidence (using equipment) / Gathering evidence (through observation) / Questioning / Explaining evidence	
Pedagogy: Collaboration	
Contextual factors: Formative assessment / Variety of materials	

Aims

To estimate, weigh and compare objects using both standard and non-standard units or measuring instruments.

Analysis of key features

The episode was drawn from the Weighing activity that took place at the weighing table. The activity was a part of a carousel of measuring activities, including the 'Filling Boxes' activity, the 'Capacity of a Jug' activity, the 'Building Towers' activity, and the 'Measuring Length with a Metre Stick' activity. These activities were made available for children over two consecutive days and were carried out in mixed ability groups in a rotation. They illustrate the **play-based approaches** emphasised by the teacher, Emily, and her concern to foster **alternative ideas and reasoning**. In planning, the tasks were set up to also allow **problem solving** in mathematics. The episode was also drawn from Emily's plenary discussion at the end of the session.

The weighing table was set up with a range of **materials and equipment**, including small pens, Berol pens (larger), small animals, paintbrushes and a balance scale to be shared between two children. The children were asked to use the balance to find out how many of each object was needed to weigh 100gms. They had a worksheet to fill in as they went along. On the worksheet they had to record the object and how many of that object weighed the same as 100gms.

As it can be seen in the *Illustrative extracts from data* section, children were given opportunities to use their **observation** skills to solve the set problem. This was highlighted in one example when two children Neil and Henry were working **collaboratively**. They were having difficulties in getting the scales to balance using Berol pens. Based on their observations, they attempted to make predictions of whether to take one pen off or add another one to balance the scales. Furthermore, through such collaboration, evidence of **children's questioning and explaining** was also noted. This was illustrated below when Henry had suggested that mini pens, instead of bigger Berol pens, should be used to balance the scales, and Neil asked why. Henry attempted to explain that as 100gms is not heavy, the mini pens would be more suitable to balance the scales than the bigger Berol pens.

During the plenary, more evidence of children's creative thinking was elicited and **formative assessment opportunities** were made possible through Emily's

questioning. For example, when asked which tool, given the choice of unifix, a ruler and a metre stick, would be more appropriate to measure the width of their bedroom, a girl said unifix or cubes would be better. She explained that this is because there were lots of them and she could line them up along the entire width of the bedroom. As there was only one metre stick, it would not be enough to measure the bedroom's width.

In sharing her **evaluation** of the session, Emily indicated she was concerned that the children did not understand how to use a metre stick to measure longer lengths. The children seemed to think that it was impossible to measure without having many metre rulers. She decided therefore that in the next session she would provide activities going beyond a metre to give them the opportunity to think through the problem of measuring longer lengths.

Opportunities for inquiry and creativity

Creativity in teaching was shown through the rich opportunities Emily provided for **exploration**. Emily planned **meaningful contexts** and activities making links to **everyday events**. She modelled **enthusiasm** portraying the subject as being interesting. Emily **scaffolded** learning through small steps, slowly **building on children's ideas** in whole class discussion. She used **questioning** to motivate and to encourage children to express their ideas and to **foster reflection and reasoning** – making **connections** across experiences for example at the beginning of the plenary she talked about the appropriateness of the container for measuring the capacity and then moved onto the appropriate tool for measuring length.

The planned activities fostered children's **creative dispositions**. The children's attitudes to the mathematical activities were positive. They showed high levels of **engagement** and they were not daunted by challenges or by failing to get an answer. They showed a **sense of initiative** in coming up with ideas to **solve the problems** they faced and **reasoning skills** in justifying their suggestions.

ILLUSTRATIVE EXTRACTS FROM DATA

Variety of materials



Children working collaboratively



Two children, Neil and Henry, were using Berol pens to weigh how many pens would balance 100gms. They were working **collaboratively**. They were having difficulties in getting the scales to balance.

Neil: *It's not balancing.*

Henry: *Put on another one.*

Neil: *But now it's too heavy.*

Henry: *Take one off.*

Neil: *It's still not balancing. It doesn't make sense.*

Henry offered an **alternative idea** - that they use smaller pens to balance the 100g weight. Prompted by Neil, he **explained** his suggestion and his estimation of how many would be needed.

Henry: *Let's try the mini pens they will work better.*

Neil: *Why?*

Henry: *Because they are smaller.*

Neil: *It isn't 100.*

Henry: *Think we will need 30 to balance the 100g weight.*

Neil: *This is too little because they weigh nothing. 100gms is not heavy.*

Henry: *It's 39 that's right. 39 is 9 more than my guess.*

Opportunities for formative assessment and children's reasoning through teacher questioning

Teacher: *Which would you use – there is a choice of unifix, a ruler or a metre ruler?*

Child Grace: *Metre stick*

Child Sarah: (disagreeing) *The bedroom is bigger than a metre stick. Cubes would be better because there were lots and you could use lots of them. It would be better if you had 2 rulers. It won't stay like that if not enough sticks.*

Teacher: *What would choose if there were enough sticks?*

Child Audrey: *Using a metre stick isn't good because when you get to 10 then you have to go back to zero.*

Episode: UK(EN) Buttons	Setting: PreSch
Subject: Mathematics	Age Group 3-4 years old
Key factors:	Teacher Fleur
Learning activities: Gathering evidence (through observation) / Questioning / Explaining evidence	
Pedagogy: Role of motivation and affect	
Contextual factors: Formative assessment	

activity and their own explorations. Following this teacher led lesson the children were given opportunities to explore independently.

Aims

The aim of the lesson was to reinforce learning about changes to materials. The children had previous experience of melting chocolate and had also been exploring ice.

Analysis of key features

In this lesson Fleur, the class teacher, gave each child a chocolate button to hold while she read a poem called Chocolate by Michael Rosen. After listening to the poem the children were told to open their hands and observe what had happened. The teacher asked about the shape of the chocolate, which the children found difficult, whether it was soft or hard and whether it was still chocolate. The children were then allowed to lick the chocolate from their fingers to check.

This lesson with the afternoon group was based on **formative assessment** of these children's previous experiences of melting. Fleur had led a similar lesson with the morning children but had altered it based on her observations of that lesson. Questioning at the beginning and end of the short lesson allowed her to make further assessments. These then resulted in changes to future planning.

In her interview Fleur was pleased to note that the children had moved on from the previous activity; *"The first time most said it wasn't chocolate anymore but straight away this time they remembered it was still chocolate. They understood just because it looks different it's still the same and that's hard for them to understand."*

Opportunities for inquiry and creativity

Fleur had demonstrated a creative approach to **planning the activity**, recognising that the children would be **motivated** and **engaged** in an activity that involved chocolate. This was a material that they were familiar with and presented a good contrast to the previous activity on ice – which had the same learning objectives, and demonstrated that the effect of heat on different materials presented the same results.

Holding the chocolate while listening to the poem allowed them to **act out a small part of the story in the poem**. At the conclusion of the poem they had melted chocolate in their hands, just like the boy in the poem. Throughout the children were being encouraged to **make connections** between the previous

ILLUSTRATIVE EXTRACTS FROM DATA

Questioning based on previous lesson

Teacher: Who can remember what we did on Tuesday?

Child: Melted buttons.

Teacher: Yes, how did we do that?

Child: Squeezed.

Teacher: Yes, we squeezed in our hands. Why did we do that?

Child: Hot

Child: Warm

Child: Melted

Teacher: Did it still look like a chocolate button then?

Child: No.

Teacher: Was it still chocolate?

Child: Yes.

Teacher: How did we know?

Child: We licked our fingers.



The children then held chocolate buttons in their hands while the teacher read the poem *Chocolate* by Michael Rosen. This poem is about a child who is carrying chocolate home but it melts in the child's hand, who then licks it. When the poem was finished the children opened their hands and observed what had happened to the chocolate.



Explaining evidence

The teacher had held her own chocolate button, but interestingly this hadn't melted which led to more questioning. This demonstrated that the children understood the role of heat in the melting process.

Teacher: Why hasn't mine melted?

Child: Your hands are cold.

Child: Our hands are hot.

Girl: It's chocolate still but it isn't round anymore.

Motivation through chocolate



The children were allowed to lick their fingers to check that it was still chocolate despite having melted.

Episode: UK(EN) Café	Setting: PreSch	
Subject: Mathematics	Age Group 4-6 years old	Teacher Jenny
Key factors:		
Learning activities: n/a		
Pedagogy: Affect / Role of play and exploration		
Contextual factors: Sufficient time / Sufficient human resources / Variety of materials		

Aims

For children to apply mathematics in practical situations including counting, adding and subtracting, as well as for them to identify different coins and to understand that different coins are worth different amounts. The application of the children's mathematics was a key focus in the fruit café.

Analysis of key features

This episode is based around a single observation but the Fruit Café is an on-going, daily activity. Each day the children are provided with a snack of fruit or vegetables and a drink. Jenny the teacher has turned this into a mathematics activity by getting pairs of children to run the fruit café, supported by a teaching assistant. The children who are running the café take the coins and in some cases make change. They keep track of the children who have been to the café by ticking their names on a recording sheet and they serve the snack.

There is a menu with prices that are set each day for the various items. There are pots of real coins, which the children use to pay for their snack, determining the coins they need with the support of the teaching assistant. Because the children often purchase a drink and a piece of fruit there is addition of two numbers. By changing the prices on the menu Jenny is able to influence the numbers being added. In some cases the children running the café have to make change so are practising subtraction, either as counting on or as taking away or difference. There is also some data handling involved. The children have to find the prices for the relevant items on the menu, while the children running the café keep track of which children have taken part.

While the fruit café is a primary focus of this episode, this lesson contained several activities that developed counting and understanding what different coins are worth. The lesson started with the class singing *Hickory Dickory Dock, I am a digital clock*. In this activity, the children take turns clapping out the 'hour' and the rest of the class have to count the claps to identify the time. Jenny commented that counting sounds was more challenging than counting objects that could be seen and touched.

This was followed up with another sound counting activity. Jenny would take a number of coins and drop them one at a time into a metal tin, with the children counting the sounds in their heads, checking with their talking partner and showing the appropriate number of fingers. She was able to assess their

responses quickly and repeated the activity if there were many children with the wrong answer. When the children had successfully counted the number of 1p, 2p and 5p coins, she set these out on pieces of coloured paper. She set up a scenario where a kindly uncle was going to offer them some coins and they had to choose which ones they wanted by showing the appropriate coloured paper.

Opportunities for inquiry and creativity

An important aspect of teacher creativity in this episode is **recognising the opportunity** for developing mathematics in an everyday activity. It is common in England for children to have a morning snack but it is unusual to see this turned into a mathematical activity. By using **a variety of everyday resources** (fruit, vegetables, drinks and real coins) the teacher was able to **make the links between mathematics and real life activities** very explicit.

Time is also a positive factor in this episode. Although a single lesson was observed, this is an on-going activity that will be constantly developed throughout the year. **Sufficient space** allowed the fruit café to be in a separate area to the rest of the classroom so the different activities did not disrupt each other. **Sufficient human resources** allowed a classroom assistant to support the activity while the teacher worked with the rest of the class.

While the activity was teacher-initiated and structured in nature, the combination of **role play** and the use of everyday context promoted their imagination and kept children engaged as shown in one of the children's comments in the *Illustrative extracts from data* section below.

Jenny stated the importance of children learning to count and she had many different activities to practise this. **Using the song engaged** the children and made them count sounds. Dropping the coins in the tin gave them another chance to count sounds but this time they were able to check by counting visually. The children were encouraged to **make connections** between the different activities and the learning that was common to all.

ILLUSTRATIVE EXTRACTS FROM DATA

Two children are chosen to run the café each day



The teaching assistant helps with identifying and counting the coins



Fruit café menu



Child 2 and Child 3 are in charge of serving the fruit and drinks, taking the money and keeping track of the children

Child 1: *I would like an apple.*

Child 2: *An apple. And what to drink?*

Child 1: *May I have some water please?*

Child 2: *That's 2p and 1p. 3 pence*

Child 3: *What glass would you like? Green? There's your drink. I'll tick your name off.*

(...)

Child 2: *Do you want a drink with your banana?*

Child 4: *How much is a banana?*

Child 2: *5p.*

(Child 4 hands over 5p to Child 2)

Child 2: *That's fine.*

Children's enjoyment in running the café

Interviewer: *Is it good being in charge of the fruit café?*

Child 5: *Yeah, I get to put out the money and you get to tick the list off!*

Episode: UK(EN) Counting Minibeasts **Setting:** PreSch
Subject: Mathematics **Age Group** 4-5 years old **Teacher** Lisa
Key factors:
Learning activities: Planning investigations; Communicating explanations
Pedagogy: Diverse forms of expression valued; Role of problem solving and agency; Teacher scaffolding; Reflection and reasoning encouraged
Contextual factors: Sufficient space

Aims

The lesson provided opportunities for children to practise counting objects and to encourage them to communicate results in their own ways.

Analysis of key features

The lesson started with Lisa, the teacher, asking children to help count how many chocolates there were in a bowl. Children were asked to pass the bowl around and to make a guess. A number of children were invited to write their estimations on the board.

During the main part of the lesson, the children worked in **mixed ability groups** on a variety of activities. The selected episode is drawn from a group of three children, namely Aahil, Desiree and Eleesha, who were asked to sort, count and record how many plastic minibeasts there were in a bucket:

"I've got lots of bugs here. (...) I need to know how many spiders I've got. I need to know how many flies ... I need to know how many dragonflies. But I haven't got time to count, so I wondered if some of you could count them for me. And then you can use your paper to tell me how many there are."

Arguably, this provided an implicit link **between mathematics and science**, as they were also learning about minibeasts in science lessons in that week. The episode took place on the carpet area **inside the class** within **an informal setting**.

Throughout the lesson, Lisa occasionally came to observe how the children were getting on and used **her questioning to prompt** them to think about how they could record their results on a sheet of A4 paper.

During the plenary discussion, children were encouraged to **reflect** on their learning through **sharing** with the person next to them what they found difficult in their respective activity.

Opportunities for inquiry and creativity

By **standing back** and allowing children to **design their own method** for counting the minibeasts, children's creative thinking skills were fostered. For example, while Aahil started counting the spiders by placing them carefully in rows of five spiders, Desiree and Eleesha placed all the flies in a single half-circle row. Although once Desiree and Eleesha had seen Aahil's rows of spiders, they started adopting the same formation for their caterpillars and woodlice, the fact that there were initially **different forms of representation** highlights how children were encouraged to represent and **solve the problem** in their own ways.

It might also be worth noting that Aahil's array did appear to be more strategic than merely aesthetic or accidental. For example, when the girls were arranging their minibeasts into rows, their main concern appeared to be ensuring that all the rows were roughly of similar lengths, even when the number of minibeasts across the different rows might be unequal. The opposite was true for Aahil. More specifically, the spiders that Aahil was putting into rows, varied in size. Thus, even when an equal number of spiders were arranged in each row, the resulting row length would still unavoidably be different, and yet this did not appear to deter Aahil from working with rows of five minibeasts.

Through a combination of Lisa's scaffolding **questioning** and her encouragement for **diverse expression** of children's ideas, as evidenced in Eleesha's and Aahil's work shown in the extracts of data that follow, children's creative thinking skills were fostered. For example, while Aahil chose to write the names of the minibeasts, Desiree and Eleesha chose to draw the pictures of the minibeasts next to their respective total numbers.

By giving them **sufficient space** on the carpet, children were able to lay out different minibeasts in different areas of the carpet and were able to leave them as they were without having to clear their working space each time they finished counting each type of minibeasts. Consequently, this allowed children to learn from one another's work, and for Lisa to examine everyone's work at any point during the activity.

Through providing children opportunities for **reflection** at the end of the lesson, Lisa was able to draw out some aspects of the task that the children found difficult and their creative solutions to the problems. For example, Aahil was overheard saying to his talking partner that *"When you're lining them up ... 'cause you know when you're lining them up, and there's only one ... I don't know where to put it"*. Looking back at the photos of his work, it was found that he had four rows of five dragonflies with each of two remaining dragonflies being placed on the end of the fourth and fifth rows respectively.

ILLUSTRATIVE EXTRACTS FROM DATA

Children were given opportunities to design their own methods to count the minibeasts



The teacher fostering children's reflection and reasoning

Aahil was overheard saying to his talking partner that "When you're lining them up ... 'cause you know when you're lining them up, and there's only one ... I don't know where to put it". Looking back at the photos of his work, it was found that he had four rows of five dragonflies and two extra dragonflies, which were placed on both ends of the fifth row, highlighting Aahil's creative thinking in dealing with remainders.

Children were able to use the carpet space as a blank canvass to show their counting methods and to learn from others



Teacher scaffolding to encourage children to communicate their findings

The dialogue below demonstrated how through a series of guided questions by the teacher, Aahil was allowed to arrive at the conclusion himself of how to improve the quality of his data recording:

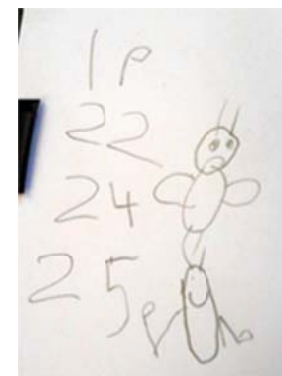
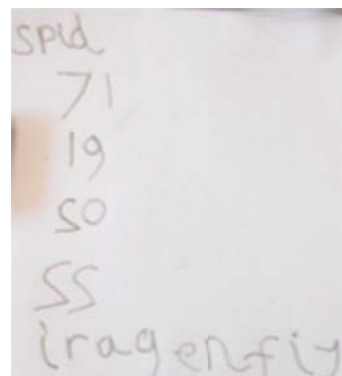
Teacher: Aahil, how do I know which of those numbers are spiders that you counted?

Aahil: 'Cause (sic) we write the numbers.

Teacher: You wrote those numbers? But how do I know those numbers mean spiders, and it doesn't mean the flies.

Aahil: Because if we write flies and spiders then we know it means they fliers and spiders. (see the left s right image)

Teacher: Fantastic! Fantastic! Thank you!



Another similar example was when the teacher came back to look at Desiree's and Eleesha's work a few minutes later:

Teacher: How many were there? (Pointing at the flies)

Eleesha: 21.

Desiree: I've got another one! 22!

Teacher: So what do you need to do now to remember it's 22?

Eleesha: Write it down. (Drawing a picture of a flies next number 22) (see the above right image).

Teacher: Well done. I think that's a brilliant idea. Desiree, how many of these are there? (Also, pointing at the flies)

Desiree: 22. (Drawing a picture of a flies)

Teacher: So what do we need to do?

Desiree: Write 22.

Teacher: Well done! I like the way you're doing.

Episode: UK(EN) Habitat	Setting: Sch
Subject: Science	Age Group: 6-7 years old
Key Factors:	Teacher: Ella
Learning activities: Making connections / Communicating explanations	
Pedagogy: Role of motivation and affect / Role of problem solving and agency	
Contextual factors: Peer assessment / Use of ICT	

Aims

This episode involved the children exploring how the colour of some animals enables them to be camouflaged in their habitat.

Analysis of key features

As a starter activity, Ella, the class teacher, used a programme on the interactive whiteboard (IWB) that showed five minibeasts and an environment with four habitats areas (e.g. a log pile, a flower bed). The children had to choose in which habitat each minibeast would live. Ella 'dragged and dropped' the minibeast to the area suggested by one of the children. Before she did so, the children had to **assess each other's answer** by indicating with a 'thumbs up sign' if they agreed with this suggested habitat. If it were an unsuitable habitat the minibeast would run to its most suitable habitat which the children found very engaging.

Using the IWB, Ella showed the children three paintings of the American artist Abbott Handerson Thayer (1849-1921), who painted animals almost completely disguised by their background. **Links were made with art and science** as the children had to identify how Thayer used colour in his painting of the background.

The main activity was for the children to select colours to draw the background of a camouflaged animal in its habitat. Working in ability groups, the children had to draw an animal themselves or they were given pre-prepared pictures of a variety of animals. They were able to **choose from 15 different coloured** pastel dye sticks.

Halfway through the lesson Ella selected two children's pictures to show to the rest of the class on the screen using the visualiser so they could begin **to assess each other's work**. She asked the children to identify the three colours used to colour in the background of the animal picture and asked *"Are these the colours of the animal? Do these colours help hide the animal?"* They could then go back **to their own work and assess their progress** so far as there was still time for children to improve their work if necessary.

The children were involved in further **peer assessment** at the end of the activity. They were asked to lay their pictures on their tables and go and look at each other's pictures as if they were at an art gallery. They had to find things

they liked about the pictures and one thing they would suggest to improve the picture.

For the plenary the children sat on the carpet again. Three children were chosen **to role play being scientists**. The children had to read out the information (prepared by the teacher) about an animal's camouflage and the rest of the class had to guess which animal it was from the description.

Opportunities for inquiry and creativity

The children's imagination was captured when the teacher **linked art with science** when they looked at the Thayer's paintings of the camouflaged animals. The peacock painting was particularly of interest to the children as it was difficult to see the peacock at first. The children's initiative was encouraged as they were able to **choose the colours for the background** of their own animal painting and, in some cases, choose the animal to be the subject of the painting as well.

The children were encouraged to reflect on an artist's work in a science lesson before using art work themselves to demonstrate their scientific understanding of animals' use of camouflage in their habitats.

Being asked to **look at each other's work developed a sense of curiosity** as they were given time to go round and look at all the pictures. This also **motivates children to improve** their work if necessary.

Displaying the children's work on the visualiser showed that the children's work was valued. Furthermore, as all the children display their work for all the class to view also indicates how each child's work is appreciated.

ILLUSTRATIVE EXTRACTS FROM DATA

Making connections between Art and Science



The teacher shows the children a painting by American artist Abbott Handerson Thayer (1849-1921).

This painting is called *Copperhead Snake on Dead Leaves*. The children look for ways to explain why they find it difficult to see the snake.

They are learning about camouflage in the science topic.

Formative assessment using the visualiser



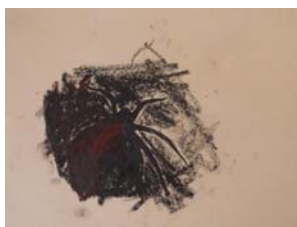
Half way through the lesson the teacher modelled a **peer assessment** strategy by selecting the lizard picture to show to the rest of the class on the screen using the visualiser.



She asked the children to identify the three colours used to colour in the background of the animal picture. She asks *“Were these the colours of the animal? Did these colours help hide the animal?”*

Self evaluation using ICT

In the lesson Sadik was upset as some children had criticised his picture of a black spider which he had scribbled over with a black pastel. The teacher stopped the lesson and put his picture on the visualiser. She asked the children if they could see the animal on the picture; they replied *“No”*.



She asked them why they could not see the animal and the children agreed it was because the background hid it so well.

She praised Sadik for choosing the right colour but asked him how he could have improved his work. He said that he would not scribble right over the spider next time but just shade in the background.

Peer Assessment

During the lesson the children stopped to view each other’s pictures and, using the same questions to evaluate the drawing, assess the quality of the work of their peers. In the discussion at the end of the lesson, the children gave their feedback to the rest of the class.



Role play in the plenary discussion



Children read out a description of an animal's colouring and its habitat.

The rest of the class had to suggest what the animal is and justify their answer using vocabulary used in the lesson such as:

Prey Predator Camouflage Survival Habitat

Episode: UK(EN) Shapes	Setting: Sch
Subject: Mathematics	Age Group 6-7 years old
Key factors:	Teacher Caroline
Learning activities: Planning investigations	
Pedagogy: Teacher scaffolding / Collaboration / Role of problem solving and agency / Role of motivation and affect	
Contextual factors: Rich physical environment for exploration / Summative assessment	

Aims

The teacher's (Caroline) goal was to have children work in groups with plastic interlocking polydrons to construct and explore properties of three-dimensional shapes.

Analysis of key features

This episode involved the children constructing 3-D shapes prompted by cue-cards which instructed them to make shapes under certain constraints (e.g. "make a shape with less than 8 corners", or "make a shape with more than six faces"). Initiated by the teacher as an activity in which the whole class works in groups of five at tables whilst the teacher moves between groups engaging with children as they work. The episode then focuses on the activity of two children, Tobias and Caitlin, who begin to work together to construct a shape with more than six faces. Once it has been constructed, the two children start to create a playful narrative around it. This draws in other children at the table who then participate in this narrative.

The task encouraged children to **recognise properties of three-dimensional shapes** (part of the 'Shapes and Space' section of the curriculum) by constructing a range of possible shapes using the interlocking shapes (Polydrons). The **problem-solving** nature of the task meant children were able to combine tiles to make regular or irregular shapes under the direction of different cue cards. There was minimal teacher input into the actual construction of the shapes, other than reminding the children about the cue cards, and asking further questions about the sides, vertices and/or faces.

Children could be heard counting edges of the two-dimensional Polydron tiles and counting corners, edges and faces of three-dimensional shapes, naming two-dimensional shapes (triangles, squares, rectangles, and hexagons) and using vocabulary such as 'regular' and 'irregular' shapes.

The children's behaviours reflected the Caroline's perspective that the children were confident in their knowledge, although some children, despite knowing vocabulary, such as 'irregular' and 'regular', were not able to determine which 3D shapes were 'regular'. Caroline emphasised having a strategy: *"some people on this table have picked up a sentence and thought about a shape that they already know might actually match ... Rory and Rick had a sentence which was*

"Make a shape that has less than six faces", ... And they knew straight away a shape on the board that would match that ... [but] Nick picked "Make a shape that has more than six faces", and had to do a bit of thinking ... you said, "Well, I know that a cube or a cuboid has six faces, but it needs to have more than six faces." So he .. stopped and had a think and we ... he's come up with quite a good plan of he can now make a shape that is not just going to have six faces, it's going to have more than six faces...." ... So think about what you already know."

Opportunities for inquiry and creativity

The children's mathematical exploration was framed by the teacher having posed the task for the whole class, providing resources and written provocations to action that would **stimulate mathematical thinking** and **generate original and valuable ideas**.

At the start of the lesson, Caroline devoted a short period to discussion of the task in hand. Then, working at tables in groups of five, the children worked with the cue cards and the plastic polydrons, whilst the teacher moved between the groups engaging with children as they worked and occasionally interrupting the class.

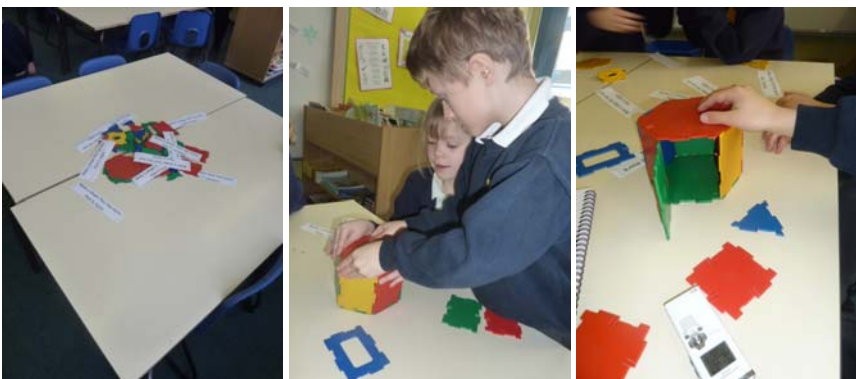
Caroline's focus was on **encouraging the children to have a strategy**. However, during this particular episode **the children prompted one another's learning**. Children were, then, **generating and reasoning between alternative strategies and ideas**, core elements of mathematical and scientific creativity.

Whilst the task is set up to enable the generating of alternatives, as shown in the illustrated extracts of data the two children in this episode made a shape with six sides (therefore not a cylinder) and created a new name for it *"a cylinca"*. They became engaged in an imaginative narrative, making links between the 'new' shape they had made and the characteristics of a house, adding a roof and a door. The children had **space and time** to develop their own 3-D shapes and to consider their response to these, making first a pair-categorisation and then a group categorisation. The activity allowed **playful fluidity** in the children processing their shape construction and its mathematical meaning. Their **co-constructed spontaneous non-mathematical narrative** then led them back in to a mathematical place.

ILLUSTRATIVE EXTRACTS FROM DATA

Children construct shapes given teacher-defined parameters generating creative language use

In this guided task where some parameters are defined by the teacher, **scaffolding** is offered in whole-class discussion at the start, and through written activity prompts set up at each table (Image 1). Using this scaffolded framework, children's creative problem-solving is nurtured. Tobias and Caitlin consider how to describe the shape that they have made (Image 2). Caitlin points out, that the shape they have made is not a cylinder, having six sides, and so they name it a "cylinca" (Image 3). They inform the teacher, giving their justification for it, demonstrating by touching the sides. Here we can see **creative dispositions**, e.g. **sense of initiative**, **innovative thinking**, **imagination** and **reasoning skills**.



1 Start of lesson

2 'cylinca'

3 'house' of Polydrons

Within this episode, a further creative dimension was these two children's **development of a narrative** beyond the task. Their transformation of the activity towards developing an imaginative story around the transformation of the 'cylinca' into a 'house' took them into other forms of creativity beyond mathematics. So we see them becoming **immersed** in the space of their narrative (drawing in others including the researcher) and sustaining engagement with the materials and with their construction.

Across the episode the children mathematically explore together and manifest:

- Asking questions – 'What if...?' and 'what can I do with this'
- **Play** –operating in an exploratory, playful fashion

- **Problem-solving** – the problem is 'found' for them by the teacher's instructions however the children together chose one of these – make a shape with more than six sides - and then worked to solve it
- These children develop a **collaborative and communal outcome**.

In relation to synergies between mathematics and creativity, the children demonstrate:

- **Play and exploration** –using Polydron shapes and within the narrative
- **High value of motivation and affect** – particularly in the 'house'
- **Dialogue and collaboration** – Caitlin's explanation to Tobias of his cylinder misconception, and when discussing the 'house' narrative
- **Problem solving and agency** – how the task is constructed
- **Questioning and curiosity** – throughout the task
- (to an extent) **reflection** – in feedback to the teacher at end of lesson

And **teacher's scaffolding** is apparent in task structure, throughout the lesson.

Episode: UK(EN) Sound	Setting: Sch
Subject: Science	Age Group 7-9 years old
Key factors:	Teacher Louise
Learning activities: Communicating explanations; Gathering evidence (through observation)	
Pedagogy: Dialogue; Diverse forms of expression valued; Collaboration	
Contextual Factors: Formative Assessment; Self-assessment; Rich physical environment for exploration	

Aims

The aim of the activity was for children to understand how sound is made and to find ways of communicating this visually.

Analysis of key features

The tables were set up with a **variety of resources for exploration**: bass drum, snare drum or steel pan, each with a cup of rice; bottles and coloured water in a jug; trays, jugs, water and tuning forks; wind instruments; hollow tubes of different lengths; frog guiro; all tables have large paper and felt tip marker pens. The children had about 30 minutes to explore the resources on two tables and then had to **find a way to represent on paper** how sound is made. Louise, the teacher, said she was being experimental and did not know what would happen *"...but that's exciting, isn't it?"* Although she had set out the equipment with ideas about how it would be used, Louise was quite pleased when the children *"...took the resources in their own direction"* and noted how engaged the children were in the lesson.

The class was fortunate to have five adults to support the children but the teacher stressed **child agency**. "The adults are there to help but only if asked. You have to decide how the things on the table will show you how [sound is made]." She emphasised that the children had to take the lead even when seeking help. "No, not please can you help. You have to ask them direct questions. They can supply words, vocabulary."

The children worked in **small groups or pairs, which encouraged dialogue**. They discussed their **observations**, trying to find the vocabulary to **explain** what they had found. The children exploring the bottles of water focused on pitch and the fact that you could create different notes depending on how much water was used. Several children used the terms darker and lighter when referring to pitch, rather than lower and higher, but some did know the technical vocabulary and this was further modelled by the adults. In the plenary children demonstrated making higher and lower notes with bottles, with tubes of different lengths and with wind instruments. One child was able to offer an **explanation** of why this happened.

The children with the drums and the tuning forks focused more on the vibrations that occurred when the instrument was struck. They could see this through the

rice jumping on the drum and the waves created in the water by the tuning fork. The children were able to use the term vibrations. Some **represented** this just through drawings, while some children used a combination of drawings and words.

Part way through the lesson the teacher asked the children to **self-assess** whether they had learned about how sound works. The children were then given time to explore a different set of equipment before being asked to self-assess again. Then, those children who were confident about how sound was made explained to another group, demonstrating on the equipment and using their posters.

At the end of the lesson some children explained orally what they had found. Then the teacher used ICT to present the percussionist Evelyn Glennie in concert. They discuss why she might be bare foot and come to the conclusion that she feels the vibrations through her feet because she is deaf.

Opportunities for inquiry and creativity

The children had **freedom to explore** the equipment provided. Some did this in unexpected ways, such as making maracas out of the rice cups and clanging the bottles together. Because they used at least two sets of equipment themselves and then observe others, the children were encouraged to **make connections** between different ways of making sounds. Having to represent sound visually challenged the children to make connections between the senses. Some children **developed new understandings** of how sound is made and were able to explain this.

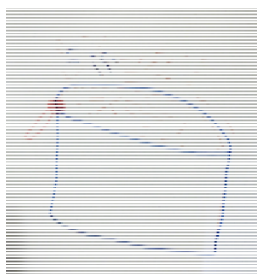
ILLUSTRATIVE EXTRACTS FROM DATA

Resources for exploring sound.



Some of the children used the resources as the teacher expected, such as putting rice on the drums, but others used them in unexpected ways, such as using the rice cups as maracas.

Small groups explore making sounds and then represent this visually.



Rice in steel pan drum
Child 1: *It's jumping!*
Child 2: *The noise is so loud it makes it jump.*
Child 3: *It's vibrations.*



Joseph and Maisie added different amounts of water to the bottles and discussed the impact when they clinked them together.

Maisie: *When the bottles have water and you bang them together they bounce off each other but when they don't, they just clang.*

Joseph: *It makes it darker. Thought it would be lighter.*

Maisie: *That one's gone really high pitched.*



Two children demonstrated blowing with bottles and different amounts of water. George explained the difference in the pitch.

George: *Because there was more air for the sound to go in and get back out and less for Marek because the water was taking up the space.*

He then related this to a flute.

George: *If you cover the holes the air has to travel farther to get out*

Child: *I just noticed when you whistle you make a column of air.*



Child 1: *I can make it jump really high.*
Child 2: *It's the vibrations.*

Self-assessment

Teacher: *Thumbs up if you found a way for showing sound. Wiggle if you're not quite sure. Have you learned something more about sound? How does sound work? What is making it travel? Yes, you can see sound or I'm not really sure. Show me.*



In addition to the self-assessment, the teacher formatively assessed the children by observing and questioning them during the explorations, listening to their explanations and analysing their visual representations.

Teacher: *Lovely explanation. You can really see it.*



Episode: UK(EN) Starting Point	Setting: Sch
Subject: Science	Age Group 5-6 years old
Key factors:	Teacher Wendy
Learning activities: Questioning	
Pedagogy: Fostering questioning and curiosity	
Contextual factors: Formative assessment	

Aims

The purpose of this session was to elicit the children's current conceptual knowledge of animals and their needs for formative assessment purposes. The intention was to raise questions and potential gaps in understanding, which would form the basis for planning future topic work sessions.

Analysis of key features

Wendy, the class teacher, had prepared for the 'Carnival of Animals' topic by setting up a role play area with a fish tank and other animal toys. On the carpet, she asked if the children knew what the new topic would be, hinting at the new items in the role play area. Children correctly indicated that the new topic would be about animals. The children were particularly excited by this topic as this is an area in which they had some prior knowledge.

Wendy then asked the children to tell her what they already knew about animals and **what they wanted to learn about them**, beginning by asking, "So what do we mean carnival of animals?" The children came up with terms such as 'carnivore' and 'herbivore', which Wendy praised them for remembering from a previous activity; in her interview Wendy identified that this built on knowledge from their topic on dinosaurs.

The children were eager to participate and Wendy used a good range of open questions to engage the children in discussion; alongside this she helped them with their vocabulary – introducing correct vocabulary alongside their own word choices. Examples of the questions included how heavy different animals are, where they live and what they eat.

On a flipchart, Wendy wrote the children's prior knowledge and questions. Wendy also used this opportunity to **formatively assess** her children, particularly by looking at what they already knew. This is an activity which was familiar to the children as each time they start a new topic they begin with a brainstorm of what they already know about a topic and what they would like to find out.

Wendy's questioning directed the children towards different categories / classification of animals, which were recorded on the flip chart and then she began to focus on how the children could research information on different animals; "I didn't know that, perhaps this is something we could find out children, remember I don't know everything, sometimes we have to write

questions to find out later – let's write the questions down". These questions were written down on post-it notes and added to the brainstorm. The children identified different ways to research from asking parents to the internet. Finally, Wendy reviewed what had been put on the flip chart and reminded the children of what questions they were going to find out as a result of this.

Opportunities for inquiry and creativity

This episode demonstrated the commitment Wendy showed to working from children's current knowledge and understanding, and there was evidence of rich **dialogue and communication**.

Questioning was used throughout as a means of generating discussion and gauging the children's current levels of knowledge and understanding, and the children were actively encouraged to formulate their own questions, which would be answered as part of planned activities later in the topic. This reflects Wendy's comments in her interview about motivating the children to learn.

Some child **agency** was evident in this approach to the start of topics. The brainstorming activity also illustrated the approach to **assessment**, eliciting conceptual knowledge at the start of the topic and "at the end of each term... well half term now it's changed... we look at what the children have done... we go back to the brainstorm and children tell us what they have learned ... and any answers to questions we have found out... I like the children to find things for themselves, not that I know everything sometimes I don't know so I set them a challenge".

ILLUSTRATIVE EXTRACTS FROM DATA

Examples of what children already knew and what they wanted to know about animals.

Teacher: Yes, what do we know about animals?

Child: Carnivore.

Child: Herbivore.

Teacher: Well done, you remembered that from last time, anything else?

Child: If they're big or small.

(Teacher writes different sizes on the flip chart)

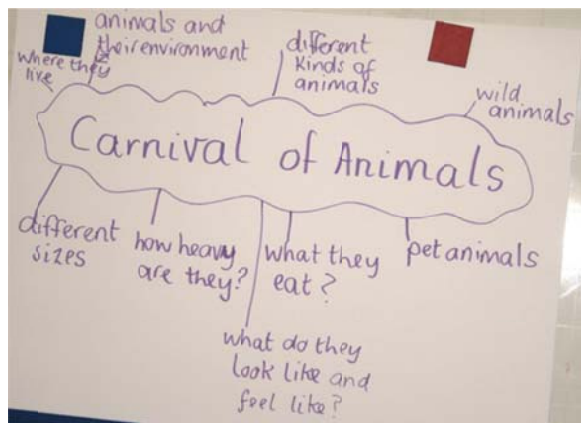
Child: How much they weigh.

Teacher: Yes, how heavy they are. (Teacher writes on flip chart)

Teacher: What could we find out about animals?

Children: Where they live / What they eat.

The teacher creates a topic web based on the children's questions



Fostering children's problem solving skills



Teacher: Where do we find this information?

Child: From home / Ask mum.

Teacher: Yes ... good idea, anywhere else children?

Children: Books / Internet.

Child K's drawing from her everyday experience

TA: Ooh fish now – Child K knows all about fish – she has a big tank at home.

Child K: Two tanks.

Researcher: Two tanks – goodness, who looks after them?

Child K: My daddy – he has to clean them out a lot.

Researcher: What else does he do?

Child K: He has to feed them – with flakes.

Researcher: Not bacon and eggs?

Child K: (laughs) No silly, they have to have special food – not people food or they would die.

Researcher: Well we wouldn't want that. Do they have special water?

Child K: I don't know... but we have a light in the tank, and they have to have plants because they like to hide, and lots of room so they can swim around.

Episode: UK(NI) Gloop	Setting: PreSch
Subject: Science	Age Group: age 4-5 years
Key factors:	Teacher: Siobhan
Learning activities: Questioning / Gathering evidence (using observation) / Gathering evidence (using equipment)	
Pedagogy: Role of play and exploration / Role of motivation and affect / Fostering questioning and curiosity / Role of problem solving and agency / Teacher scaffolding	
Contextual factors: Rich physical environment for exploration / Informal learning resources	

Aims

This activity presented a wide range of aims and objectives. The activity provides opportunities for children to develop “an awareness of texture, motor skills necessary for writing, pattern making... the ability to work with small tools... (and) to communication with one another in a group setting” as indicated in the school documentation.

Analysis of key features

This episode comes from the activity of making ‘gloop’ – mixing water and corn flour in a large plastic tray that had been placed on a desk. The activity was largely child-directed and ran for the whole morning session. Children were free to attend and leave the activity as they pleased. Over the course of the morning, nine different children had visited the activity, with a maximum of six at any one time. After approximately 15 minutes, the teaching assistant placed a number of different tools – spatulas of varying sizes, rubber paint brushes, a funnel – into the tray to further provoke interest and exploration. Aside from this, practitioner intervention was limited to brief, sometimes less than 15 second visits by the practitioners (teacher plus two nursery assistants) in the classroom. During these visits, the practitioners observed the children’s activity, engaged in short discussion with the children and asked open-ended questions. This meant that the children were **exploring largely by themselves** or with one another (pairs or threes).

A wide range of curricular objectives was addressed during this activity. Sensory development was identified by the practitioner as the most important specific feature of this activity and this could be seen. Indeed, activity such as this that was initiated by one child was quickly imitated by their partner and then by the whole group.

In addition to this sensory development, there appeared to be links to areas of the science and mathematics curriculum, such as the development of exploration skills and (science), observation skills (science and mathematics) and making patterns (mathematics). The child-led nature of the activity ensured that children were able to discuss with one another, share what they were doing and

indeed **observe** what other children were doing and imitate and develop on these ideas.

Opportunities for inquiry and creativity

An overarching framing of this activity appeared to be to provide an engaging and **stimulating** activity that would capture the **interest** of all the children involved. The emphasis on developing the sensory aspect was clearly enjoyable to the children as they laughed and excitedly provided answers to the teaching assistant’s initial questions about what the powder felt like in the bag, what it felt like when poured out onto the tray and finally when adding the water.

The task was very open-ended, with few restrictive parameters, allowing Ryan in particular the **freedom to explore** it as he wished. The practitioners all stood back and provided only occasional, judicious intervention from the practitioners, often prompting more open-ended questioning from the children, scaffolding their learning.

Immersion in the task was particularly important. Ryan was clearly **immersed** in the **playful** task. He can be seen focused on his activity, closely observing cornflour and water mix, stirring it, straining it through his fingers, pushing it and scooping it up with the spatulas, or drawing in it with the rubber-tipped paintbrushes. He could be seen to be asking creative questions – “*What can I do with this?*” This was particularly apparent when analysing Ryan’s observable contemplation and subsequent use of tools in the tray. At one point, he was moving gloop across the tray with a wide spatula in his right hand, then trying to stop its return flow using a rubber paintbrush in his left hand. At another point he was scooping up the cornflour mix with the spatula and slowly dribbling it on to his forearm and hand. This generation of **alternative strategies** and ways to use the tools provided often novel and unexpected outcomes that relate closely to the aims of the task outlined on the poster (“Developing the motor skills necessary for writing” and “The ability to work with small tools – rubber pens, combs etc”). This would suggest then that the outcomes of the activity were of **value**. This immersion, development of motor skills through tool use and of exploration would all suggest that this was an extremely valuable and worthwhile activity for Ryan.

ILLUSTRATIVE EXTRACTS FROM DATA

Using everyday objects in the gloop tray



Here, Ryan was working with the spatula, 'picking up' and 'dropping' the gloop. This allowed Ryan to experiment with equipment and observe the effect that the equipment had on the cornflour mix.

Three children playing with the gloop



Ryan, Erin and Zoe all playing with the gloop – the mixture formed long strings as it dripped off the children's hands. This provided an added sensory element to the activity, where children could both observe and touch the changes to the cornflour as the water was added.

Children making patterns in the gloop with their hands/fingers



The cornflour and water mix was thick enough such that it held its shape long enough for patterns to be made in it, either using the tools provided or using their fingers. There was no requirement for children to work in a prescribed method with the tools, allowing the children to develop their motor skills, with a view to developing mark making and writing.

Episode: UK(NI) Gingerbread Man Raft	Setting: PreSch
Subject: Science	Age Group: 4-5 year olds
Key factors:	Teacher: Siobhan
Learning activities: Questioning / Gathering evidence (through observing) / Gathering evidence (using equipment)	
Pedagogy: Role of play and exploration, Role of motivation and affect, Role of problem solving and agency, Reasoning and reflection encouraged	
Contextual factors: Variety of materials	

Aims

This activity formed one of five structured activities in the classroom. The teacher selected which activity particular groups of children would do that particular day, and each child would do each activity over the course of the week.

The aim of this activity was for children to explore the properties of various objects and sorting them into those that either sank or floated using the large water tray and a variety of everyday objects - numerous food trays, such as those that hold fruit/meat from the supermarket, lollipop sticks, along with rolls of masking tape, items from the home role play corner (including rolling pin, sieve, plastic foods, tin foil) plastic piping and foam dominoes. Children were also free to go around the room and find other items that they might like to try.

Analysis of key features

The premise for testing items was based around the theme for the class learning – the story of the gingerbread man, who hitched a ride on a fox to cross a river. The children therefore need to find appropriate materials or objects that might act as a raft for the small plastic Gingerbread Man to cross the ‘river’.

The activity, involving six children, took place in a shared space between the two early years classrooms, thus it was not possible for the practitioners to be present for the duration of the activity. During the course of the activity, Siobhan (teacher) and Sinead (teaching assistant) each occasionally visited the group to discuss with the children their findings and to prompt further exploration and investigation. This allowed the children the freedom to explore the various concepts of floating and sinking, through an **inquiry-based** approach, gathering evidence through observation through independent problem solving and exploration and investigative activity. The practitioners identified this activity as an opportunity to build on the key explorative areas of the Northern Ireland curriculum. The children were therefore free to approach the task in whatever way they felt was most appropriate and plan their investigations accordingly.

Opportunities for inquiry and creativity

The way in which the practitioners stood back, **provided the time and space** for children to follow their **own avenues of exploration**. This could be seen in

children applying their everyday knowledge to the situation, such as Peter attaching lollipop sticks to a sieve in order to make a raft, connecting his knowledge of floating materials in the problem solving approach.

Leila, aged 5, could be observed extending the task, applying the gingerbread man story context to the activity in a way over and above what might have initially been expected or planned for. Following her experiments with a number of different objects, she focused on the clear plastic tray. Leila then returned to the table that had the items and began to look over what remained. Here she found green paper towels – none of which had been used by any of the other children. Leila then used the paper to cover the ‘Gingerbread Man’ on his raft

The creative activity in this episode can be seen in Leila’s extension of the task and application of ‘real life’ concepts to the abstract task. Leila then appears to be working in both the ‘real’, science based world, identifying materials that will float, but also within the make-believe world, where other, additional objectives are also of concern.

Finally, the activity provided by the practitioner was situated within a **motivating and engaging context** – the fairytale story – that captured and sustained the children’s imagination.

ILLUSTRATIVE EXTRACTS FROM DATA

Using materials to make a raft



Peter making a raft from sieve and lollipop sticks. The lack of teacher intervention enabled much interaction and discussion between the children, with individuals offering suggestions to one another (such as "Why don't you try this bit?") and a variety of expressions of interest and surprise (such as "Oh, that didn't work!" and "Look at this, it's floating!"). Children therefore were able to exert a strong sense of **agency** in this activity which offered them space to extend the task, and to develop their own investigations and inquiries, as well as developing their **communicative** skills between one another.

Leila looking through the different materials available to her



Leila (far right) was observed holding the paper for several moments, before laying it over the tray containing the gingerbread man and returning to the water tray. She could then be heard telling the other children "Look, I've got a protector blanket!". When queried by the teacher as to what the protector blanket was for, she replied "To stop the gingerbread man getting wet." Following this, a number of the other children copied her activity, some using paper, and another using tin foil. It is notable that the narrative creativity prompted by Leila moved off at a tangent from the scientific enquiry which had been their focus.

Episode: UK(Sco) Day and Night	Setting: Sch
Subject: Science	Age Group 5-6 years old
Key factors:	Teacher Petra
Learning activities: Questioning	
Pedagogy: Role of motivation and affect / Diverse forms of expression valued	
Contextual factors: Variety of resources / Use of ICT	

Aims

This episode took place as part of a planned topic on Day and Night, with the following overarching learning intention: “children will learn about the earth, moon, sun and stars. They will observe the sun and moon at different times and relate their findings to the concept of time” as shown in the school planning document.

Analysis of key features

This session was taught by Petra, who teaches all the science sessions in this class in consultation with Mary, the class teacher. In a previous lesson, Petra, the class teacher, had already asked children **what they would like to learn** about light and dark. Children’s responses, such as “About the stars”, “Some planets”, “Learn about space” and “To draw the moon and sun” were recorded on a mind map.

Petra started the lesson by reading children **a story**, called ‘The Park in the Dark’, which featured three different animals that got chased by ‘a THING’ and they ran into a dark park to hide. After reading the story, Petra posed questions including “*What is it like in the dark?*” and “*Why do you think it gets dark?*” to elicit discussion about children’s experiences and feelings about the dark. Petra used a container of lollipop sticks each marked with a name of the child in the class to encourage responses to her **questioning** and **dialogue**.

Petra then explained that they would be learning about what is happening to make day and night time. To help demonstrate the concept, she showed a globe to the children and a little picture of a person on where the school is located. Petra also incorporated **role playing** into her teaching by inviting Gideon to be the sun, and he was given a sun hat and a torch to hold and shine at the globe. Children were also given **opportunities to give reasons** as to why Gideon was given the torch. Some of the responses included “*because the Sun is bright*”.

Children were then asked to indicate whether the little person was experiencing daytime or night time as the globe was turned, and “*how much time do you think has passed between daytime once and getting dark and daytime?*”. This latter question attracted responses, ranging from “*quite short*”, “*about two weeks*” to “*I think it’s a day*”. To address these ideas, Petra **linked the turning of the globe to the children’s daily experiences**: “*So it is daytime just now and when you go home to have your dinner it’s going to be night-time. Then, you’re going to sleep all night and get up in the morning and it’s going to be ...?*”

In the next phase of the lesson, Petra integrated **ICT** in her teaching by initially introducing her new Space app on her iPad. First, she shared some high quality pictures of the Sun. These prompted much excitement, comment and sharing of new ideas and enthusiasm between the teacher and the children as they read the captions from the different images together. Petra then showed an animation of the solar system. This also provoked interest and enabled the class to revisit ideas about the Earth turning on its axis.

Children were subsequently asked to work in mixed-ability groups in one of the following four activities: 1) drawing pictures of how we get day and night using colouring pencils; 2) sorting photographs of animals into those that come out in the day and those that come out in the night; 3) sorting activities according to whether they take place at daytime or night time; and 4) making models of the Moon and Sun using plasticine. Not only did these activities demonstrate **a wide variety of materials** that Petra adopted, it also highlighted how she valued **diverse forms of expression** to help support children’s learning.

The illustrative extracts from this episode include examples from the the drawing and modelling activities both of which offered opportunities for children to **express** and **reflect on** their ideas in different ways. Petra showed interest in children’s progress and encouraged them to talk about what they were doing, but did not direct children’s responses. Children’s representations reflected the inspiration from their experiences in the earlier part of the lesson.

Opportunities for inquiry and creativity

Creative teaching was shown in particular in the **rich resources** and experiences organised for the session. Ideas about day and night were presented in a **variety of ways**. Petra encouraged engagement through sharing her own enthusiasm for sharing the wonders of the solar system. The opportunities for children to **represent their ideas in their own ways** promoted **reflection** on experiences.

The range of learning and teaching approaches adopted fostered children’s **interest** and **curiosity** in the solar system. They showed imagination in the development of their models and drawings. In dialogue with peers and with adults they **raised questions** and began to **make connections** between the pattern of their experiences of day and night and the rotation of the Earth on its axis.

ILLUSTRATIVE EXTRACTS FROM DATA

The use of role play to engage children



Children's reasoning skills fostered, making connections between features of the model and everyday observations

Teacher: *Gideon, you are going to be the sun so I want you to wear the sun hat – do you think you could wear that on your head? You are going to be the sun. (...) I'm going to give Gideon the torch. Why do you think we would give Gideon the torch if he is the sun?*

Lewis: *Because the Moon – because the Sun is bright.*

Teacher's scaffolding, making connections with children's daily experience

Teacher: *How often do you think the world turns all the way around? (...)*

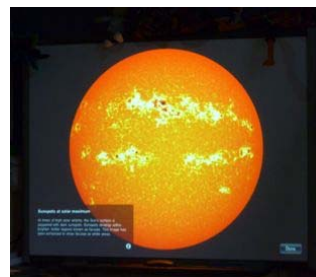
Children: *Quite short / About two weeks? / I think it's a day*

Teacher: *So it is daytime just now and when you go home have your dinner it is going to be night-time. Then, you are going to sleep all night and get up in the morning again it's going to be ...?*

Children: *Daytime!*

Teacher: *So the world or the Earth rotates once a day can you see that?*

The integration of ICT through the use of high quality images and animation of the solar system



Teacher: *I have brought in my iPad again today and (...) I've got a really interesting app on the iPad that shows the Earth turning. (...) There are also some really nice pictures of the sun taken with really powerful telescopes and it shows you that it does not really look like that – round and yellow. (...)*

Lewis: *You can see the fire and it's burning. (Children all very captivated)*

Examples of children's work – Ronald's drawing of the Sun (left) and Donald's model of the Sun (right)



Ronald: *There's lots of solar flares Earth is so far away you can never reach that... got explosions – that's the light shining at the Earth. This shows all the planets are – going round and round. That was Jupiter and one next to Jupiter – and Saturn – closest to the sun. The blue bits are the sea and the green bits are the land.*

Donald: *That's fire coming and they're the holes and that's all the lava ... the sun is boiling hot fire.*

Episode: UK(Sco) Forest School	Setting: PreSch
Subject: Science	Age group 3 -5 years old
Key factors:	Teacher: Sarah
Learning activities: Gathering evidence (through observation) / Making connections	
Pedagogy: Role of exploration /Fostering questioning and curiosity	
Contextual factors: Recognition of outdoor learning / variety of resources	

Aims

Visits to Forest School were planned to provide children with opportunities to explore the natural environment and observe change over time for example in the weather and in the life cycles of living things as highlighted in the interview with the teacher Sarah: *"seeing that place and being there in all weathers that's very important in schools – going to the same place and up the same road to get there – of course every time is different – they are affected by the weather, by the temperature, they notice that things that were here last week have been eaten or whatever that is."* Visits were also designed to encourage a range of inquiry skills in particular **observing** and **exploring, asking questions**, developing skills associated with reasoning and **making connections**.

Analysis of key features

The setting for the episode was a protected wildlife area in the city walking distance away from the preschool centre. It has open areas of vegetation, woodland and a pond. Children visit the site weekly, on an eight-week cycle. Activities and routines at the site have been developed over time, influenced by children's responses as well as incorporating common Forest School activities. These include making a shelter, litter picking, making a fire for cooking, climbing and balancing using ropes, as well as **observing changes** in the natural environment. Sarah indicated that the children often bring ideas and materials back to the centre, for example ideas for moving water or a hammock in the outdoor area and physical materials such as water samples from the pond or plant material, fostering on-going links between contexts.

On the day of the visit it was snowing. Centre staff, in partnership with parents, organise clothing and resources carefully to enable visits in all weathers. Mats, blankets, thermal clothing, warm drinks and snacks were taken to help children keep warm and comfortable. The outdoor trip, in harsh weather, offered the chance to encourage reflection on needs for survival, including warmth and shelter. A **variety of equipment** was packed to support activities at the site, including tarpaulin and ropes for making a shelter, magnifiers, binoculars and a camera to support observations, litter pickers and spades. Sarah was joined by two other adults on the visit, Marta and Gareth.

Conversations between adults and children on the way to the site focused on **observations** of the feeling of the wind and ice particles on their faces. Adults **asked questions** to encourage children to articulate their **observations** and to

speculate on possible **explanations** for grit and salt on the paths. When they arrived at the site Sarah suggested various activities children might undertake including making a shelter, litter picking, climbing with ropes and observing ice on the pond. Children were encouraged to make their own decisions about what they would like to do.

This episode follows the **explorations** of Ian to illustrate the opportunities provided for children to **follow their own interests** and **make connections** to their previous experiences at the site. His immediate focus was the pond. He poked the ice with a spade. He **observed** holes in the ice and collected some water in his spade to look at it more closely. Sarah **built on his interest** drawing attention to the differences in the pond compared to the previous week and suggesting that he might look at the water more closely with a magnifier.

After some considerable time Ian was still at the pond. This time he was poking at the ice with a litter picker. Marta the Nursery Nurse asked him about what he was noticing, encouraging him to explain what he was doing. Ian explained that he had noticed bubbles. He thought that these might come from frogs and he was breaking up the ice *"so they (the frogs) can breathe"*.

Later Ian took the researcher round the site to photograph the different fungi he had noticed, another developing area of interest over time. In a conversation with the researcher about this visit to Forest School later in the afternoon, Ian highlighted these two activities (breaking ice and photographing fungi), **making connections** with previous experiences at Forest School. The photographs taken by Ian in collaboration with Sarah were included with Ian's reflections (**self assessment**) in his profile.

Opportunities for inquiry and creativity

The visit to Forest School offered rich opportunities for fostering creative dispositions including **motivation, curiosity and sense of initiative** reflected in Ian's active pursuit of his interests and observations. He showed **imagination and made connections** to his prior knowledge and experience in seeking to explain the bubbles he noticed in the pond and his actions in breaking the ice.

Features of creative teaching were reflected in the opportunities for learning in the **outdoor environment** made possible by careful organisation and preparation of **materials** to support **explorations** and ongoing assessment with children of the potential risks involved (for example in climbing or breaking the ice). Adult interactions fostered children's **own interests actively encouraging explorations, questioning** was used to encourage children to extend observations and **articulate explanations**.

ILLUSTRATIVE EXTRACTS FROM DATA

The Forest School Setting: Variety of resources to support activities



Noticing ice on the pond: Fostering questioning and curiosity

Teacher: *It wasn't frozen last week was it?*

Ian: *It's got a little hole there.*

Teacher: *I wonder why that is? Can we find a reason why?*

Ian poked the ice with a spade and picked up some water in the spade to look at closely:

Teacher: *Very muddy water isn't it? Full of all sorts of things. Possibly if we had a really good look with a microscope we might see something?*

Ian: *I know we can put some water in and put the top back on.*

Teacher: *You mean in one of these ones (a magnifier) – if you put something in you can look through the top – try that one.*

Ian put some water and ice in the magnifier – and held it up to show – “sample of water – it's a little piece of wood”. He took another scoop of ice and water with his spade to look at.

Encouraging communication of observations and explanations

Nursery Nurse: *What can you see?*

Ian: *Bubbles.*

Nursery Nurse: *Where do you think they are coming from?*

Ian: *Animals – may be frogs? Maybe air coming up?*

Nursery Nurse: *You're doing a good job – the animals will be really pleased. Can you see the bubbles moving around?*

Ian: *Putting more air for the animals. (...)*

Ian splashed round the edge of the pond, breaking up the ice.

Ian: *Can see big bubbles – when you hit the bubbles it makes much more.*

Nursery Nurse: *Why are you rescuing the animals?*

Ian: *So they can breathe – whole pond nearly dug up now – saw breathing.*



Self assessment: observing variety of life, noticing change over time, making connections with prior experience



Ian: *When I went to Forest School it was brilliant. I liked the most taking pictures (of fungi) and that was the best thing I did there.*

Researcher: *So the best thing was taking pictures?*

Ian: *And lots of smashing ice on the pond. (...)*

Researcher: *What were you doing in smashing the ice (...)?*

Ian: *So the animals could breathe under the ice?*

Researcher: *Have you been there another time? Have you seen any animals?*

Ian: *I think I been there a long time ago.*

Researcher: *What did you see?*

Ian: *I think I saw frogs in the summer – and before I saw frogspawn.*

Researcher: *That sounds exciting what was it like?*

Ian: *It was sort of jelly – and tadpoles inside the ball of jelly.*

Researcher: *Wow!*

Ian: *Not the kind of jelly from what you eat and got tadpoles inside it.*