Creative Little Scientists: Exploring pedagogical synergies between inquiry-based and creative approaches in Early Years science

Teresa Cremin[1], The Open University, UK, Esme Glauert, Institute of Education, University of London, UK, Anna Craft[2], The Open University and University of Exeter, UK, Ashley Compton, Bishop Grosseteste, UK, and Fani Stylianidou, Ellinogermaniki Agogi, Greece.

(Received, 10th August, 2014; accepted 8 December, 2014)

In the light of the European Union's interest in creativity and innovation, this paper, drawing on data from the EU project Creative Little Scientists, (2011-2014) explores the teaching and learning of science and creativity in Early Years education. The project's conceptual framework, developed from detailed analysis of relevant literatures, highlighted the potential existence of a number of pedagogical synergies between inquiry-based science and creativity based approaches in Early Years education. The science and creativity literature reviews were thus re-examined to identify synergistic features of teaching and learning in the Early Years. These were seen to include: play and exploration, motivation and affect, dialogue and collaboration, problem solving and agency, questioning and curiosity, reflection and reasoning, and teacher scaffolding and involvement. Field work undertaken over a four month period in 48 sites across the nine partner countries provided the opportunity to examine the existence of these synergies in Early Years settings and primary classrooms with learners aged 3-8 years. Qualitative in nature, the fieldwork was framed by a case study strategy encompassing multiple methods of data collection: sequential digital images capturing interactions; observations supplemented by audio recording; timelines; and interviews with teachers and groups of children. The dataset comprised 71 cases in early science (and mathematics), with three episodes of activity per case encapsulating creativity in these domains, resulting in 218 episodes for analysis. A deductive–inductive analytical approach was undertaken in two phases with cross-case analysis both within and between countries. The paper exemplifies the pedagogical synergies innovatively identified in the conceptual framework and documented in the fieldwork, and highlights the potential for creativity in exploratory science contexts. Additionally, it highlights differences between practice observed in preschool and primary settings and advances a new conceptual definition of creativity within Early Years science education.

Keywords: creativity, science, inquiry, pedagogy, Early Years.

Introduction

The project Creative Little Scientists (CLS) (2011-2014) was undertaken in nine European countries (Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania, UK)

[1] Corresponding author:: Teresa.cremin@open.ac.uk

[2] Anna Craft was a member of the CLS project team until her untimely death in 2014.

representing a spectrum of educational, economic, social and cultural contexts. Across 30 months, the consortium explored the potential for creativity in the mathematics and science education of 3-8 year olds, combining comparative studies of policies and of teachers' views, with case studies of classroom practice. The current paper focuses solely on the pedagogical synergies identified between inquiry-based science education and creative approaches to education. The comparative dimension is reported elsewhere (Creative Little Scientists, 2014).

The project was informed by five drivers. The first, the economic imperative, highlights the need for scientists in Europe's knowledge economy (European Commission, 2011). Framed within 21st century neo-liberal narratives, it demands flexible innovative thinkers who are knowledgeable and enthusiastic about science. The second highlights the development of responsible, scientifically literate citizens (Harlen, 2010). The third relates to the development of the child and citizen through creativity (Chappell and Craft, 2011) and the fourth to the technological imperative; since digital technologies support inquiry (Wang et al., 2010) enabling and demanding creativity (Craft, 2011). The final driver relates to changing perspectives on children and the importance of Early Years education**.** Children are now commonly viewed as active participants who have capabilities and interest in science (Duschl et al., 2007), and, it is argued, gain long-term benefit from early science education (Eshach and Fried, 2005; Harlen, 2010).

The CLS consortium shared a common encompassing purpose to explore the approaches used in the teaching, learning and assessment of science (and mathematics) in Early Years in the partner countries and the role, if any, that creativity might play in these. Through this focus it sought to further understanding of relationships between inquiry-based science education

(IBSE) and creative approaches (CA) to teaching and learning. Although definitions of IBSE vary, internationally it is afforded value in both research and policy (Asay and Orgill, 2010). Its purpose is arguably to ‘introduce students to the content of science, including the process of investigation, in the context of the reasoning that gives science its dynamic character and provides the logical framework that enables one to understand scientific innovation and evaluate scientific claims’ (Drayton and Falk, 2001:25). Thus content knowledge and process skills are combined. Unlike IBSE, Creative Approaches to education are not as easily delineated. They tend to refer to repertoires of teaching strategies that allow practitioners to teach creatively and teach for creativity (Jeffrey and Craft, 2004), enabling learners to ‘believe in their creative potential, to engage their sense of possibility and to give them the confidence to try’ (NACCCE, 1999:90). As Dezuanni and Jetnikoff (2011: 264) note, creative pedagogies encompass ‘the imaginative and innovative arrangement of curricula and teaching strategies in school classrooms and the development of students’ creative capacities’. Whilst IBSE and CA differ in their purpose, origins and developmental histories, both are associated with child-centred philosophies from European and North American thinkers which foreground the child as an active curious thinker and meaning maker, and highlight the role of experiential learning.

In IBSE there is more emphasis on the role of the teacher in supporting the development of scientific skills and understandings whereas in CA, the teacher’s role is less subject specific and oriented towards developing learner creativity. IBSE researchers tend to focus on questioning as context for inquiries (Drayton and Falk, 2001; Harlen and Qualter, 2004) and the generation, justification and evaluation of ideas within a community (Carlsen, 2008; Hmelo-Silver et al., 2007). Researchers of CA tend to focus on play and curiosity as drivers for problem finding-problem solving and highlight the role of innovation, originality, ownership and control (Chappell et al., 2008; Cremin et al., 2009; Jeffrey and Woods, 2003).

Notwithstanding their different emphases, both approaches are employed as tools for knowledge construction and ways of learning content, and offer motivational support for the development of positive attitudes with regard to science and creativity.

In examining relationships between IBSE and CA, this paper seeks to explore the following research questions:

- What are the pedagogical synergies evidenced in the research literature between inquiry-based science education and creative approaches in the Early Years?
- Are these manifest in practice and if so in what ways?

In order to address these questions, the conduct of the CLS literature reviews is discussed and the identified pedagogical synergies presented. The fieldwork methodology is then explained and illustrative episodes from the dataset offered. This is followed by a discussion, consideration of differences observed in preschool and primary settings, and explication of the project's new definition of creativity in science.

Pedagogical synergies: Reviewing the relevant literature

A set of five thematic literature reviews were undertaken, these encompassed material identified by the nine partners in the consortium, and fed into the project's conceptual framework. The reviews focused upon: Early Years science, mathematics, and creativity, teacher education across Europe, and comparative education. Detailed analysis of the first three of research literatures highlighted the potential existence of a number of pedagogical synergies between IBSE and CA in the Early Years. The science and creativity literature reviews were thus re-examined in order to identify more closely these synergistic features of teaching and learning and later empirical work was planned.

The pedagogical practices examined in this paper, related to theorised and examined practices, spanning pre-school and the first years of primary education. The work focused on peer-reviewed journal articles from 1990-2013, although exceptions were made for ’landmark’ studies and the work of significant theorists. Existing reviews within creativity (Davies et al., 2011) and science (Minner, Levy and Century, 2010; Duschl, Schweingruber and Shouse, 2007) were also consulted. To ensure consistency, members selected papers from the agreed period and produced rubrics encompassing attention to: research questions, methodological approaches, research design, sampling procedures and key findings. Advantageously, the consortium was able to draw on studies not published in English, ensuring more representative reviews. No particular theoretical perspectives were adopted; rather the authors sought to map the fields as comprehensively as possible, identifying broad themes. Methodologically, the studies, which numbered in excess of 400 papers ranged across interpretivist / positivist paradigms, both in terms of conceptual and empirical pieces.

It became clear that Early Years creativity and science education share in common recognition of children’s exploratory and investigative engagement, and their consideration of ideas and conceptions. More specifically, the research literatures pertinent to IBSE and CA reveal that to different degrees both approaches profile particular pedagogical practices that seek to foster children’s learning. The common pedagogical synergies identified across the two extensive reviews with regard to the Early Years include: play and exploration, motivation and affect, dialogue and collaboration, problem solving and agency, questioning and curiosity, reflection and reasoning, and teacher scaffolding and involvement. These are now examined. No hierarchy is intended.

Play and exploration. Widely recognised as inherent in all young children's activity, playful exploration represents the focus of considerable research within both approaches. It is argued playful hands-on experiences encourage children to make connections between science and their surroundings (Kramer and Rabe-Kleberg, 2011) and that sustained play increases children’s creativity (Garaigordobil and Buerrueco, 2011). Empirical studies suggest open-ended exploratory contexts are well suited to fostering both learning and creativity (Burnard et al., 2006; Poddiakov, 2011; Mitchell et al, 2002). Supported by the pedagogic space and scope offered for exploration, it appears children in these studies often extended boundaries and explored with interest, commitment and a marked degree of openness that their teachers sought to build upon. Such openness, alongside objectivity, is recognised as a critical feature of the development of a scientific stance or attitude (Feng, 1987).

Motivation and affect. Research in both science and creativity indicates that such play-based contexts afford opportunities to develop positive attitudes and affective engagement. In particular Larsson and Halldén (2010) argue that playful experiences nurture children’s motivation to understand their world and Milne (2010) contends that fascination, wonder and interest can prompt aesthetic engagement, spark curiosity and lead to the use of scientific inquiry to develop explanations of phenomena. Whilst the affective dimension of science learning has received less research attention than the cognitive dimension, Perrier and Nsengiyumva argue it is not merely a catalyst, but ‘a necessary condition for learning to occur’ (2003: 1124). Creativity focused research also highlights the importance of engaging children affectively (Craft et al., 2012; Millineaux and Dilalla, 2009) and the power of narrative has been shown to imaginatively involve children, fostering their creativity in different domains (Cremin et al., 2013).

Dialogue and collaboration. Research suggests dialogue is a critical feature of both IBSE and CA. In science learning it is claimed that it not only enables children to externalise, share and develop their thinking (Carlsen, 2008), but helps them consolidate their ideas (Chi et al., 1994) and develop verbal reasoning skills (Mercer et al., 1999). As Varela (2010) posits, the communication of scientific ideas and ways of thinking allows children to listen to others' strategies and ideas, developing increased awareness which may prompt a desire to restructure their own in the face of other more plausible or consensual ones.

Similarly creativity research increasingly recognises the essentially social and collaborative nature of creative processes and that dialogic engagement is characteristic of classroom creativity (Vass, 2007; Wegerif, 2005). These studies suggest children benefit from support in developing their collaborative reasoning and when making use of puppets for example (Naylor et al., 2007), engage creatively. In contrast, Kramer and Rabe-Kleberg (2011) note that in problem-solving contexts without their teacher, pre-school children's collaborations often display creativity, enhancing their understanding of scientific processes. These researchers claim that open dialogue between children and teachers, and space/opportunities for children to experiment alone and in peer groups, are prerequisites for learner creativity in science.

Problem-solving and agency. Problem-solving is widely recognised as central to both IBSE and CA, however there are debates in the literature concerning the teacher's role in IBSE and whether scaffolding children's inquiries constrains or enables learner agency (Asay and Orgill 2010; Cindy et al., 2007). It is argued that an inverse relationship exists between the amount of direction from teacher materials and learner self-direction over the problem-finding/problem-solving process in science (Barrow 2010). It is also claimed that children are competent in using problem-solving strategies and that structuring the learning environment appropriately offers them the space and agency to develop these (Barrow, 2010; Torbeyns et al., 2002).

In creativity research, engagement with problems has been shown to foster child agency, ownership of learning and the development of self-determination and control (Craft et al., 2012; Cremin et al., 2006; Lan and Marvin, 2002). These studies suggest that young children's engagement in finding their own problems is central to creativity, and that teachers' interest and respect for children's questions facilitates their sense of autonomy and agency as learners. Rather than leading, teachers in these studies often set open-ended tasks which children undertook in self-organised groups following their own ideas and interests. The practitioners passed problems back to the learners to foster their decision making and agentic actions.

Questioning and curiosity. The role of questions, both children's and teachers', is another common research focus across these interrelated fields and recognised as central within IBSE and CA. Whilst it is widely accepted that children are innately curious and seek to explore the world around them, Nickerson (1999) suggests the educational process can inhibit their curiosity, their impulse to question and engage in mental play. Some studies indicate that teachers who use a lot of open questions achieve high-levels of pupil involvement and promote learning (Rojas-Drummond and Zapata, 2004). Others, focused on creative artists working in schools, note that they promote speculation by modelling their own curiosity (Thomson et al., 2012), potentially generating new questions on the part of the learners and 'developing intrigue' (Poddiakov, 2011), a core capacity of young scientists.

While Harlen and Qualter (2004) highlight diversity in the nature and purpose of scientific questions and Hmelo-Silver et al., (2007) stress their importance in driving inquiries, Harris and Williams (2007) show that if young children have little experience of open questions at home, they may find such questions in science difficult. Researchers also note children's curiosity and questions may be expressed through modes such as drawing, gestures, and actions with materials, illustrating the focus of their investigation and 'intellectual play' (Wood and Hall, 2011).

Reflection and reasoning. Although synergies exist here too, there is rather more research evidencing the importance of these skills in IBSE than in CA. Kuhn (1989) argues children are intuitive scientists and as (Duschl, et al., (2007) and Eshach and Fried (2005), also claim, have an early capacity to reason scientifically. However Aleven and Koedinger (2002) assert children need support to develop metacognitively and Metz (2004) suggests they are biased towards interpreting evidence in terms of their existing theories, and do not develop scientific reasoning automatically from experience. Such reasoning, which usually involves differentiating between theories and evidence, and evaluating hypotheses, arguably connects to creativity conceptualised as the generation and evaluation of ideas, yet there is limited discussion of reasoning in Early Years creativity research literature. Although Bancroft et al., (2008) document children evaluating and Reggio Emilia schools profile reflection, this is rarely seen through a creativity lens. Nonetheless research into IBSE and CA suggests children employ diverse modes to record their ideas, potentially encouraging reflection, discussion and evaluation (Stevenson and Dumcumb, 1998; Wollman-Bonilla 2000).

Teacher scaffolding and involvement. Notwithstanding the recognition that IBSE and CA both include attention to problem-solving in playful exploratory contexts, in which questions, dialogue, motivation and reflection play a significant part, the efficacy of these two approaches depends largely on the teacher's role in scaffolding children's learning. As Fleer (2009) notes, teachers mediate children's thinking between everyday concepts gained through playful interaction and more formal scientific concepts. Such scaffolding is claimed to foster children's independence as inquirers and problem-solvers (Metz, 2004), their conceptual knowledge (Coltman et al., 2002), meta-cognitive strategies (Aleven and Koedinger, 2002) and their creativity (Craft et al., 2012). The research literatures also imply a central role for assessment to inform responsive teaching, and modes of assessment sensitive to young children's varied capabilities.

As has been shown, the research literature indicates a dynamic relationship exists between IBSE and Creative Approaches to teaching and learning; inquiry-based science approaches link to the problem-finding/ problem solving approach developed by those who teach for creativity and teach creatively. It was this synergistic relationship that the CLS project sought to explore further through empirical investigation.

Methods and data collected

Undertaken across four months, the project fieldwork focused on sites potentially offering 'exemplary practices' (defined in relation to insights derived from CLS literature reviews, policy surveys and conceptual framework) in fostering creativity and inquiry in early science (and mathematics), covering pre-primary and early primary education provision in each country. The sampling, which was purposive (Yin, 2009), was informed by information gathered from teacher surveys, school inspection reports, attainment records, local authorities and teacher education institutions. The project did not seek to undertake a systematic comparative study; rather it sought to examine and exemplify Early Years science (and mathematics) practices that foster inquiry and creativity in each national context.

The two main fieldwork foci were pedagogical, informed by Siraj-Blatchford et al., (2002:23):

- Pedagogical framing – including provision of resources, arrangements of space, daily routines to support cooperation, planning and assessment (documented through teachers' reflections on classroom practice and wider information)
- Pedagogical interventions – face to face interactions (documented through observing classroom practice and listening to children's reflections upon it) .

The fieldwork was qualitative in nature, and conducted in 48 different sites across partner countries resulting in 71 case studies of practices in early science (and mathematics). Each partner worked in at least four sites (i.e. preschools/schools), gathering data from at least six cases (i.e. one teacher/practitioner[3] and the children they work with). Partners identified three episodes of activity per case encapsulating creativity in these domains which resulted in 218 narrative episodes for analysis. In order to capture rich data, the fieldwork was framed by a case study strategy encompassing multiple methods of data collection demonstrating a combination of appropriate perspectives and methods suitable for taking into account different aspects of pedagogy (Flick, 2006). Data was collected from:

- Wider site contexts: information potentially framing pedagogy from school policies, websites, inspection reports, national/local curriculum documents;

[3] The term 'teacher' is used throughout, though it should be noted not all the adults in the case studies had qualified teacher status.

- Pedagogical contexts: information potentially framing pedagogy from teaching and learning policies, planning documents, assessment records, resources, a map of the space; teachers' reflections on practice in interview and during sessions;
- Observation: of face to face interaction and outcomes (episodes of learning involving children and teachers and children's reflections on this).

The core instruments included: sequential digital images capturing detailed interactions; field notes supplemented by transcribed audio recording; an overall timeline of the work observed; individual interviews (teachers); group interviews (children); child-led 'learning walks' and children's artefacts, for example their models, diagrams and drawings. Additional repertoire instruments, variously employed by partner countries, included supplements such as: video, conceptual drawings, teacher journals and Fibonacci (2012) style tools to support diagnostic observation. To ensure consistency a training workshop including a fieldwork visit was organised for all researchers to introduce and trial methods and approaches to analysis. A detailed fieldwork manual about each of the core and repertoire instruments was used in this context and sub groups of cross country researchers were established. These groups were sustained across the study's data collection and both phases of analysis to enhance dependability of the findings.

Ethical issues

All partners followed ethical approval policies for their institution, school system, region and country as appropriate. Nonetheless, sensitive ethical issues, including for example, the use of photographs and differential approval of video recording were encountered by some partners, prompting video to be positioned as an optional repertoire instrument, not a core tool for data collection. However, essential standards and protocols were agreed and applied across all settings in line with participation on an opt in and informed voluntary basis; explicit permission to take and use photographs/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 use of pseudonyms to protect all sites and participants.

Data analysis

Qualitative analysis was carried out in two phases. Initially data from fieldwork in each country was analysed by local research teams. Regular online sub group meetings were held for analytic triangulation with partners to ensure consistency of coding. In this strand of the work, a deductive–inductive analytical approach was adopted. The researchers worked deductively using the set of pedagogical synergies identified in the CLS Conceptual Framework, and inductively by examining the data to identify emergent categories and relationships. Thus the project benefited from the focusing function of a conceptual framework whilst still remaining open to new connections and aimed to 'ground' and 'support' theories (Glaser & Strauss, 1967; Strauss & Corbin, 1998). Country Reports[4] were created by each partner, consisting of a series of case studies. These each comprised background information (including notes about the wider context and pedagogical framing) and analysis of associated classroom episodes, (including attention to pedagogical interactions) and highlighted opportunities for creativity.

The second analytic phase involved cross-analysis of the Country Reports which synthesised the emerging deductively and inductively derived factors associated with inquiry and

[4] Available at http://www.creative-little-scientists.eu/content/deliverables

creativity identified in episodes. The cross country analysis highlighted the themes and issues discussed, as well as examples of opportunities for creativity in learning and teaching illustrated in episodes. In both analytic phases, as was the case during the data collection, time was set aside to develop common protocols and procedures for use by the consortium and to ensure these were employed rigorously by all partners. In this way the partners sought to ensure transparency and maintain quality and trustworthiness (Lincoln and Guba, 1985) in terms of credibility and dependability/confirmability.

As noted earlier, in foregrounding the science dimension of the study and drawing upon the literature reviews and fieldwork, this paper focuses upon a subset of the work exploring the pedagogical synergies between IBSE and CA in Early Years education, their manifestation in practice and additional inductively-derived themes in the nine partner countries.

The pedagogical synergies in practice

The 218 episodes of learning and teaching reported by CLS partners provide an overview of the range of pedagogical approaches observed during fieldwork. The episodes offer strong evidence of the existence of the literature-derived synergies between IBSE and CA in both preschool and primary settings (CLS, 2013a). The extent to which particular synergies were evidenced in these two settings varied, this is discussed following presentation of extracts from the episodes. Inductive analysis of the episodes identified additional themes in some countries regarding the pedagogical relationship between inquiry based and creative approaches in Early Years science; however these were not consistently identified across the consortium and are thus not considered here. Three extracts from episodes documented in different countries have been selected as illustrative examples of the pedagogical synergies identified in the research literature. The episodes selected draw upon observations and field notes. They attend both to the pedagogical interactions between children and children and children and teachers, and the young people's interactions with the available resources, recognised as an aspect of pedagogical framing.

Episode1: "Gloop" (4-5 year olds), Northern Ireland

"In this activity, children aged 4-5 years old were making and exploring 'gloop' – mixing water and cornflour in a large plastic tray on a table. Children were free to attend and leave the activity as they pleased. After a short time, the teaching assistant placed a number of different tools - for example spatulas of varying sizes, rubber paint brushes, a funnel – into the tray to further provoke interest and exploration.

One child, Ryan became immersed in this activity over a long period, observing the mixture, and trying out different ways to use the tools and their effects, for example scooping it with spatulas or drawing in it with the rubber-tipped paint-brushes.

Curiosity was evident in Ryan's sustained engagement and questioning "What can I do with this?' implicit in his actions. This was particularly apparent in his 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 gloop with the spatula and slowly dribbling it on to his forearm and hand. Creativity was indicated in his sense of initiative and generation of alternative strategies in using the tools in different ways, providing often novel and unexpected outcomes" (CLS, 2013b9: 280 - 285).

In this episode, adult provision of rich resources and sustained time for play and exploration fostered Ryan's motivation and interest. The material appeared to intrigue him as he was engaged for almost 45 minutes, observing the changes made by the use of tools and singing to himself. The task was very open ended providing opportunities for Ryan to use tools in his own ways as he generated implicit questions and experimented manually with the gloop. Adults largely stood back, occasionally intervening to provide additional materials or ask questions based on their observations of children's responses. Ryan did not collaborate with others, but was seen to observe others' exploratory actions and to imitate these as well as generate his own.

Episode 2: "The Wind" (5-6 year olds), Belgium

"During this activity children experimented with putting different materials in front of a fan, to see if they moved with the wind. The children had been given a collection of objects to sort according to how they moved in the wind. They were then given greater agency to experiment with materials of their choice found in the classroom. The teacher joined in at times to extend their explorations as illustrated in the extracts below, sharing her own excitement in the inquiry.

A child puts a toy canoe in front of the fan.

Mathis: "Mrs X, the canoe doesn't move!"

At that moment the canoe goes sideways.

Teacher: "Oh, Mathis, look what's happening."

Mathis: "It moves sideways."

Teacher: "And if we place it in the other direction, will it move too?"

Mathis places the canoe in a different direction and notices it doesn't move.

Teacher: "How is this possible?"

...

Later Mathis places a sheet of paper in front of the fan.

Teacher: “Oh, should the paper always fly away?”

Mathis places the paper folded in two on the table in front of the fan.

Teacher: “Look, does the paper fly away now?”

All the children look at the sheet of paper.

Teacher: “How come it flew away before?”

Elise opens the sheet of paper and sees it is flying away then.

Teacher: “What did you do with the paper?”

Elise: “I have opened it!”

Teacher: “You had opened it”.

Mathis picks up the paper and places it open in front of the fan, but pushes it flat against the table. The children and the teacher all look what will happen. The paper stays in place.

The children also discovered they could make the fan blow hard and soft, prompting experimentation with further materials” (CLS, 2013b1: 81 – 84).

During this episode children were given space and time to explore and experiment with the available materials. The teacher fostered their curiosity by asking them questions about what they had observed. They were able generate and test out their own ideas, building on evidence from their observations, promoting their agency. Throughout the episode, children were encouraged to collaborate, interact and discuss their ideas, to reflect critically and learn from their mistakes. Using this approach, the teacher gave children scope to solve problems and build up explanations for the phenomena.

Episode 3: "Building Blocks" (5 year olds), Germany

"The teacher had observed that the class of 5-year old children enjoyed playing with wooden building blocks. To extend their learning she gave the children a book with photographs of buildings. Inspired by these the children decided to build the 'Leaning Tower of Pisa' showing creativity in their sense of initiative and imagination in generating plans for a new building project. One child Luca started off with a plan but the tower tumbled down. The teacher encouraged him to reflect on the source of the problem and then stood back while he worked with Abel to find a solution.

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

Luca: 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.

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

Luca: We build a tower from below to fix it.

Abel starts to carefully slide bricks in the tower from the side.

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

Luca: Abel- Good idea!

Abel: And now it has to be unbuilt a little bit over here!

Teacher: What do you mean?

Abel: *(explains to Luca)* And here it has to support.

Luca: Yes, I know.

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

Luca: Luckily. At last.

The children demonstrated creative dispositions in making connections between observations and using reasoning skills in coming up with a solution” (CLS, 2013b4: 19 -21).

This activity, designed by the teacher built on her observations of the children’s interests and her provision of bricks and photographs. Children were encouraged to make their own plans for their building projects and to collaborate in solving problems. She provided opportunities for children to take the lead and through her questioning, helped them to communicate and reflect on their observations and ideas, and to identify problems and offer alternative solutions and reasoned justifications for their actions. Her own interest and curiosity helped to create an environment in which children were confident to make mistakes and motivated to find alternative solutions.

Discussion

The fieldwork examined practice in nine European countries and the manifestation of the pedagogical synergies evidenced in the science and creativity research literatures between inquiry-based science education and creative approaches in the Early Years. It contributes new understandings about teaching and learning approaches in science and their relationship to teaching creatively and teaching for creativity. As the illustrative extracts evidence, teachers planned motivating contexts for learning often linked to children’s interests and everyday events, some capitalised upon familiar stories as framing contexts. Teachers provided rich physical environments for inquiry in their classrooms, making good use of everyday and household materials and natural resources. Episodes drawn from the outdoor environment, whilst relatively few overall, highlighted the potential of sustained engagement with the outdoors and with living things to generate children's interest and questions, expressed both verbally and behaviourally. Group work was commonly observed as a feature of teachers' practice and often prompted dialogue and collaboration. Very few of the teachers relied on published resources, they planned or adapted activities flexibly and in response to the children and wider curriculum framing. Core to this work was the opportunity for children to engage agentically in exploring diverse materials and resources. They frequently did so with curiosity and with what the project came to describe as 'hands-on, minds-on exploratory engagement' leading to problem solving, problem finding, dialogue and learner creativity (CLS, 2013a). Thus the fieldwork demonstrates that IBSE and CA to teaching and learning are closely connected in practice; they operate in a synergistic relationship.

Whilst these pedagogic practices were evidenced across the age span 3-8 years, several were documented more frequently in preschools than in primary settings. Synergies as well as differences were documented. Across all partner countries, opportunities to play were much less common as children got older. In pre-school settings, play and exploration, as well as motivation and affect, were considerably more prevalent than in primary schools and there was greater evidence of encouragement of questioning on the part of adults. Pre-school children's curiosity and questioning was often prompted by adult provision of rich resources, alongside space and time for play and exploration. Teachers in pre-school settings in particular appeared to show sensitivity to questions implicit in children's actions and these were often voiced by teachers, mirrored back to the young thinkers and used to encourage conversation and reflection. In preschool contexts however, the potential for extending child-initiated inquiry and children's agency was not always recognised by teachers, although far more science inquiries were driven by pre-schoolers questions than by older children's questions, and time for child-initiated inquiry was much more limited in the primary years.

Some teachers of older learners reported that time pressures and policy expectations acted as constraints on their professional practice, challenging their ability to balance the provision of both structure and freedom. Other research has also shown that teachers find this balance difficult, though for different reasons; Kramer and Rabe-Kleberg's (2011) research suggests that some teachers struggle to 'allow' open-scientific inquiry due to a lack of confidence or loss of control. As a consequence, they present well-defined problems and limit children's problem solving. In some of the CLS project case studies, particularly in the primary age phase, such firm pedagogical framing was evidenced with teachers setting explicit problems to be tackled and affording limited scope for learner- led inquiries. Restrictions to child-initiated and child-led inquiries were also noted by Asay and Orgill (2010) who found these depended on the teacher's views of children's capabilities and the nature of the inquiry. However in the CLS study even at the primary phase there were some, opportunities for children to make decisions about the materials or approaches to be adopted, with varied levels of guidance. Regardless of the age of the children, there were few examples of teachers employing highly structured approaches to inquiry or problem-solving.

The differential employment of particular teaching and learning approaches at pre-school and primary appeared to be influenced by contextual factors such as wider policies, planning and assessment. These pedagogical framing factors arguably served to enable or constrain opportunities for both child-initiated and child-led inquiry and for creativity in early science. The episodes illustrate both dynamic interaction between the synergies and the complementary roles of pedagogical framing and pedagogical interactions in fostering children's inquiry and creativity.

Significantly, the teachers involved in the fieldwork commonly expressed the view that they had not thought explicitly about opportunities for creativity in science; they planned science focused activities and creativity was either unrecognised or implicit in their planning and practice. Accordingly, the consortium developed a dual definition which combines little-c creativity: 'Purposive imaginative activity generating outcomes that are original and valuable in relation to the learner' with a definition specifically related to creativity in science (and mathematics):'Generating ideas and strategies as an individual or community, reasoning critically between these and producing plausible explanations and strategies consistent with the available evidence. (CLS, 2014: 8). These new definitions have potential in identifying opportunities for creativity in learning in early science.

Conclusion

This research significantly furthers understanding of the relationship between inquiry based science education and creative approaches in the Early Years. Initially, the identified synergies were innovatively derived from the research literatures on science and creativity. Conceptual connections revealed numerous pedagogical synergies including: play and exploration, motivation and affect, questioning and curiosity, problem solving and agency, dialogue and collaboration, reflection and reasoning and teacher scaffolding and involvement. Later their existence was examined empirically in 71 different classroom contexts across Europe; they were manifest across geographic and age contexts (3-8 years). Their existence affords a new contribution to the interrelated fields of inquiry and creativity-based approaches in the Early Years.

The research reveals that in playful motivating and exploratory contexts, young children, often supported by their teacher, engage with resources, ask questions, collaborate and find and solve scientific problems. In this way they are afforded opportunities to generate ideas and strategies, individually or communally, to reason between these and produce explanations consistent with the available evidence. They are afforded opportunities to be creative young scientists. The new definition of creativity in science developed through the work extends the project's contribution and may, alongside the episodes, enable the profession to recognise and capitalise upon opportunities for creativity in Early Years science.

In terms of future work, alongside further developments enabled through Erasmus Plus[5], more nuanced understandings of the distinctive contributions of particular synergistic practices need to be developed to ascertain relationships within and across them. This is likely to afford additional professional support to those planning to foster creativity in Early Years science.

Acknowledgments

The *Creative Little Scientists* project (2011-2014) received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 289081.The authors would like to acknowledge the work of all partners in the consortium.

[5] 'Creative Early Years Scientists' (2014-2017)

References

Aleven, V. A. W. M. M. and Koedinger, K. R. (2002). An effective metacognitive strategy: *Cognitive Science* 26(2), 147-179.

Asay, L. D. and Orgill, M. K. (2010). Analysis of essential features of inquiry found in articles published in The Science Teacher, (1998-2007). *Journal of Science Teacher Education,* 21(1): 57-79.

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

Barrow, L. H. (2010). Encouraging creativity with scientific inquiry. *Creative Education*, 1 1-6.

Burnard, P., Craft, A., Grainger, T. et al. (2006). Possibility thinking. *International Journal of Early Years Education*, 14(3), 243–262

Carlsen, W. (2008). Language and science learning. In S. K. Abell and N. G. Lederman (eds.), *Handbook of research on science education* 55-74. New York: Routledge.

Chappell, K. and Craft, A. (2011). Creative Learning Conversations *Educational Research* 53(3), 363-385.

Chappell, K., Craft, A., Burnard, P., Cremin, T. (2008). Question-posing and Question-responding: *Early Years*, 28(3), 267-286.

Chi, M. T. H., De Leeuw, N., Chiu, M.-H. and Lavancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, 18(3), 439-477.

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

Coltman, P., Petyaeva, D. and Anghileri, J. (2002). Scaffolding learning through meaningful tasks and adult interaction. *Early Years*, 22(1), 39-49.

Craft, A. (2002). *Creativity and Early Years education*. London: Continuum

Craft, A. (2011). *Creativity and Education Futures*. Stoke on Trent: Trentham Books.

Craft, A., McConnon, L., & Matthews, A. (2012). Creativity and child-initiated play. *Thinking Skills and Creativity*, 71, 48–61

Creative Little Scientists (2014) *Comparative Report*. Deliverable D3.4. EU Project (FP7) (Coordinator: Ellinogermaniki Agogi, Greece). Leading Authors: S. Havu-Nuutinen, D. Rossis and F.Stylianidou.

Creative Little Scientists (2013a) *Report on Practices and their Implications*. Deliverable D4.4. EU Project (FP7) (Coordinator: Ellinogermaniki Agogi, Greece). Leading Authors: E. Glauert, N. Trakulphadetkrai and J. Maloney.

Creative Little Scientists (2013b) *Country Reports on in-depth field work* . Deliverable 4.3 Addenda. EU Project (FP7) (Coordinator: Ellinogermaniki Agogi, Greece).

Report 1 of 9: Belgium Lead Authors: H. Van Houte and K. Devlieger.

Report 4 of 9: Germany Lead Authors: A. Scheersoi and L. Pohl.

Report 9 of 9: UK Lead Authors: J. Johnston, A. Riley, A. Compton, E. Glauert, N. Trakulphadetkrai, J. Maloney, P. Barber, A. Manches, J. Clack, T. Cremin and A. Craft.

Creative Little Scientists (2014) *Set of Recommendations to Policy Makers and Stakeholders*. Deliverable 6.6. EU Project (FP7) Coordinator: Ellinogermaniki Agogi, Greece. Lead Authors: D. Rossis and F. Stylianidou.

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

Cremin, T., Barnes, J. and Scoffham, S. (2009). *Creative Teaching for Tomorrow*, Deal: Future Creative.

Cremin, T., Chappell, K., and Craft , A. (2013). Reciprocity between narrative, questioning and imagination in the early and primary years, *Thinking Skills and Creativity* 9:136-151.

Dezuanni, M and JetnikofF, A. 2011 Creative pedagogies and the contemporary school classroom. In J. Sefton-green, P, Thomson, K. Jones and L. Bresler (eds.) 2011 *The Routledge international handbook of creative learning*, London: Routledge

Drayton, B. and Falk, J. (2001). Tell-tale signs of the inquiry-oriented classroom. *NASSP Bulletin*, 856(23), 24-34.

Duschl, R. A., Schweingruber, H. A. and Shouse, A. W. (2007). *Taking science to school*, Washington: National Academy Press.

Eshach, H. and Fried, M. N. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology*, 14(3), 315-336.

European Commission. (2011). *Science education in Europe: National policies practices and research* Eaceae9 Eurydice, Brussels: EACEA

Feng, J. (1987). *Science, sciencing and science education* (ED319525). Retrieved from http://eric.ed.gov/PDFS/ED319525.pdf.

Fleer, M. (2009). Supporting scientific conceptual consciousness or learning in a roundabout way' in play-based contexts. *International Journal of Science Education*, 31(8), 1069-1089.

Flick, U. (2006). *An Introduction to qualitative research*. London: Sage.

Garaigordobil, M. and Berrueco, L. (2011). Effects of a play program on creative thinking of preschool children. *The Spanish Journal of Psycholo*gy, 14(2), 608-618.

Harlen, W. (2010). *Principles and big ideas of science education.* Available from http://cmaste.ualberta.ca/en/Outreach/~/media/cmaste/Documents/Outreach/IANASInterAmericasInquiry/PrinciplesBigIdeasInSciEd.pdf [Retrieved 18th January 2014]

Harlen, W. and Qualter, A. (2004). *The teaching of science in primary schools* London, David Fulton.

Harris, D. and Williams, J. (2007). Questioning 'open questioning' in Early Years science discourse from a social semiotic perspective. *International Journal of Educational Research*, 46(1-2), 68-82.

Hmelo-Silver, C., Duncan, R, Chinn, C. (2007). Scaffolding and Achievement in Problem-Based and Inquiry Learning: *Educational Psychologist*, 42(2): 99-107.

Jeffrey, B. and Craft, A. (2004). Teaching creatively and teaching for creativity, *Educational Studies* 30(1)77-87.

Jeffrey, B. and Woods, P. (2003). *The Creative School:* London, RoutledgeFalmer

Kramer, F. and Rabe-Kleberg, U. (2011). Wissenschaftliche Untersuchungen zur Arbeit der Stiftung „Haus der kleinen Forscher",. Available: http://www.haus-der-kleinen-forscher.de/fileadmin/Redaktion/4_Ueber_Uns/Evaluation/Wiss.Schriftenreihe_(2011)._Band_2.pdf [04 November 2011].

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

Lan, K. and Marvin, C., 2002. Multiple creativities? Investigating domain-specificity of creativity in young children. *Gifted Child Quarterly*, 46(2), 98-109

Larsson, Å and Halldén O. (2010). A structural view on the emergence of a conception *Science Education* 94, 640-664.

Lincoln, Y.S., and Guba, E.G. (1985). *Naturalistic inquiry.* Beverley Hills, CA: Sage.

Mercer, N., Wegerif, R. and Dawes, L. (1999). Children's talk and the development of reasoning in the classroom. *British Educational Research Journal*, 25(1), 95-111.

Metz, K. E. (2004). Children's understanding of scientific inquiry, *Cognition and Instruction*, 222, 219-290.

Millineaux, P. Y., and Dilalla, L. F. (2009). Preschool pretend play behaviors and early adolescent creativity. *Journal of Creative Behaviour*, 43(1), 41-57.

Mitchell, l., McCoy, J. and Evans, G. W.(2002). The potential role of the physical environment in fostering creativity. *Creativity Research Journal*, 14(3-4) 409-426

Milne, I. (2010). A sense of wonder arising from aesthetic experiences should be the starting point for inquiry in primary science. *Science Education International*, 212, 102-115.

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

.National Advisory Committee on Creative and Cultural Education (NACCCE) (1999) *All Our Futures: Creativity, Culture and Education*, London, DfEE.

Naylor, S., Keogh, B., Downing, B., Maloney, J. and Simon, S. (2007). The Puppets Project in: Pinto, R. and Couso, D. (eds.) pp. 289-296 *Contributions from science education research* London: Springer.

Nickerson R.S. (1999). Enhancing creativity in Sternberg, R. J *Handbook of Creativity*, 392-430. Cambridge: Cambridge.

Perrier, F. and Nsengiyumva, J. B. (2003). Active science as a contribution to the trauma recovery process, *International Journal of Science Education*, 25(9): 1111-1128.

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

Rojas-Drummond, S. and Zapata, M. P. (2004). Exploratory talk, argumentation and reasoning in Mexican primary school children. *Language and Education*, 18(6):539-557.

Siraj-Blatchford I., Sylva, K., Muttock, S., Gilden, R. and Bell, D. (2002). *Researching Effective Pedagogy in the Early Years*. DfES RR 356. Norwich: DfES.

Stevenson, J. N., and Duncum, P. (1998). Collage as a symbolic activity in early childhood. *Visual Arts Research*, *24*(1), 38-47.

Torbeyns, J., Verschaffel, L. and Ghesquiere, P. (2002). Strategic competence *European Journal of Psychology of Education*, 17(3): 275-291.

Varela, P. (2010). *Experimental science teaching in primary school*, University of Minho, Braga.

Vass, E. (2007). Exploring processes of collaborative creativity *Thinking Skills and Creativity* 2(2):107–117.

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

Wegerif, R. (2005). Reason and Creativity in Classroom Dialogues *Language and Education* 19(3): 223-237.

Wood, E. and Hall, E. (2011). Drawings as spaces for intellectual play. *International Journal of Early Years Education*, 193(4): 267-281.

Wollman-Bonilla, J. E. (2000). Teaching science writing to first graders, *Research in the Teaching of English*, 35(1): 35-65.

Yin, R. K. 2009. Case Study Research: Design and Methods. 4th ed. Thousand Oaks, CA: Sage.