Chapter 3
Teachers' Reflections on Their Changing Roles and Young Children's Learning in Developing Creative, Inquiry-Based Approaches in Science Education

Esmé Glauert and Fani Stylianidou

3.1 Introduction

This chapter is based on work conducted during the Erasmus+ KA2 project *Creativity in Early Years Science Education* (CEYS) (2014–2017), which built on the EU/FP7 research project *Creative Little Scientists* (CLS) (2011–2014). Funding for the CLS and CEYS projects reflected the high focus on science and creativity in European education policy (Council of the European Union, 2009). The Council of the European Union identified one of the Education and Training goals for *Europe 2020* as "Enhancing creativity and innovation, including entrepreneurship, at all levels of education and training" (Council of the European Union, 2009, p. 3). Strengthening science education had also been put forward as a key goal across Europe with both the Rocard Report (European Economic and Social Committee, 2007) and Osborne and Dillon (2008) advocating the importance of investigative approaches in engaging young students with science. In addition, there had been growing discussion of the need for greater attention in the curriculum to the nature of science (for example: High Level Group on Human Resources for Science and Technology, 2004). in particular the central roles of inquiry and invention, both triggered by curiosity, intuition, and imagination, all features closely related to creativity (as argued by Barrow, 2010). At the same time conceptions of children's creativity had begun to move away from traditional links with the arts to a focus on

E. Glauert (✉)
University College London Institute of Education, London, UK
e-mail: e.glauert@ucl.ac.uk

F. Stylianidou
IKY/Erasmus+ Hellenic National Agency, Athens, Greece
e-mail: fani@fani-stylianidou.org

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problem finding and problem solving (for example: Craft et al., 2012). Motivation has an important role to play in creativity too.

The work of the CLS and CEYS projects was also informed by growing recognition of the importance of science teaching in the early years, both for a child's development and for science learning. Young children's concern to explore the world around them from their earliest years can be nurtured and exploited through early science education. Moreover, quality science learning experiences provide important foundations for the development of key concepts, thinking, informed language and positive attitudes in science (see for example: Eshach & Fried, 2005). The projects built on new insights into learning and teaching, gained from close study of the learning of very young children and of classroom interactions made possible with new technologies. Over recent years there has been increasing recognition of young children's capabilities. A growing body of research in cognitive development and in early years science learning indicates that young children seek to explore and explain the world around them from their earliest years. They show awareness of patterns in observations and causal reasoning, albeit constrained by their conceptual knowledge, the nature of the task, and their awareness of their own thinking (Duschl et al., 2007; Goswami, 2015). This provides productive starting points for developing scientific reasoning. Work by Akerson and Donnolley (2010) indicates that young children can begin to recognise the empirical and creative nature of science.

Finally, the projects took place in a dynamic policy context. All nine partner countries (Belgium, Finland, France, Germany, Greece, Malta, Portugal, Romania, UK) across both projects were involved in processes of policy change. They were undertaken in a climate of debate about the importance and effectiveness of inquiry-based approaches (Minner et al., 2010; Welcome Trust, 2011), the role of the teacher in supporting young children's early explorations in science (Fleer, 2009) and the need to go beyond the rhetoric of creativity increasingly emphasised in international debate concerning the aims of education (Heilmann & Korte, 2010).

More specifically, the CLS research project sought to investigate the potential in policy and practice to promote creativity and inquiry in science education for children aged three to eight. The CEYS project, building on the framework and results of CLS, focused on developing materials for professional development to foster creativity and inquiry in science in partnership with early years teachers.

This chapter will first introduce key elements of the conceptual framework, developed by CLS and adopted by CEYS: the CLS definition of creativity in early years science; synergies between inquiry-based and creative approaches to learning and teaching; key features of inquiry-based approaches; and dispositions associated with creativity. It will then focus on one aspect of the work, the development of the *CEYS Curriculum Materials* by teachers through action research. The chapter will conclude by presenting and discussing findings from analysis of teachers' reflections on their learning journeys and those of their classes over time, focusing on children's learning progress and their own changing roles in relation to inquiry and creativity.

3.2 Conceptual Framework

The CEYS project drew on the *Conceptual Framework* developed for the CLS project (Creative Little Scientists, 2012). This was significant in offering a common framework and language to support planning, discussion and evaluation of learning and teaching processes, and provided a vital starting point for the development and design of the *Curriculum Materials*. Key components of the *Conceptual Framework* are outlined below.

3.2.1 Definition of Creativity in Early Years and Mathematics

The definition of creativity in early science in the *Conceptual Framework* was as follows: "Generating ideas and strategies as an individual or community, reasoning critically between these and producing plausible explanations and strategies consistent with the available evidence". This needs to be understood alongside the *Little c creativity* definition (Craft, 2001), as shown in Fig. 3.1 below. This signals both a focus on creativity as something of which we are all capable (Banaji & Burn, 2010), and a recognition of key roles of creativity in both generating and evaluating ideas and strategies in science and mathematics education. The importance of generation and evaluation of ideas *within a community* is also emphasised. This includes examination of ideas in the context of existing, widely accepted explanations and strategies.

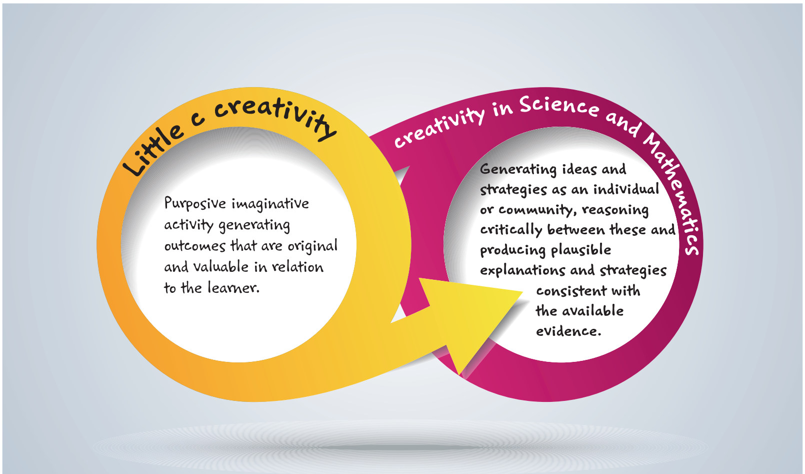

Fig. 3.1 Definitions of creativity (Creative Little Scientists, 2014, p. 5)

3.2.2 Key Features of Inquiry-Based Approaches to Learning and Dispositions Associated with Creativity

A central challenge was to determine how opportunities for inquiry and creativity would be identified. Based on a literature review encompassing science and mathematics in the early years, creativity in early years education, teacher education and comparative education, the *Conceptual Framework* set out key characteristics of the inquiry-based approaches and creative dispositions as shown in Table 3.1 below.

This was informed by an examination of features of Inquiry-Based Science Education (IBSE) and Creative Approaches (CA) discussed in the literature, both the subject of considerable debate (see for example: Minner et al., 2010; Chappell et al., 2008). In terms of features of IBSE, while a review of research revealed varied definitions (Minner et al., 2010; Asay & Orgil, 2010), a number of common processes could be identified. They reflect aims for science education that emphasise scientific literacy. In relation to CA similar processes were identified, linked with exploration, problem finding and solving, alongside dispositions associated with creativity, such as motivation, curiosity and imagination, which are also key in inquiry. Examining connections between these and the wider literature informed the definitions of creativity used across the project (shown in Fig. 3.1 above), and in addition provided the basis for examining synergies between *Inquiry-Based Science Education and Creative Approaches* to learning.

3.2.3 Synergies Between Inquiry-Based and Creative Approaches to Learning and Teaching

The *Conceptual Framework* also identified a number of synergies between *Inquiry Based Science Education and Creative Approaches* to learning and teaching as outlined below (Cremin et al., 2015). These provided a framework for examination of opportunities for creativity and inquiry in both policy and practice.

Table 3.1 Features of inquiry and creative dispositions

Learning activities (linked to key features of inquiry)	Creative dispositions
Questioning	Sense of initiative
Designing and planning investigations	Motivation
Gathering evidence	Ability to come up with something new
Making connections	Making connections
Explaining evidence	Imagination
Communicating explanations	Curiosity
	Ability to work together
	Thinking skills

- *Play and exploration*, recognising that playful experimentation and exploration is inherent in all young children's activity.
- *Motivation and affect*, highlighting the role of aesthetic engagement in promoting children's affective and emotional responses to science and mathematics activities.
- *Dialogue and collaboration*, accepting that dialogic engagement is inherent in everyday creativity in the classroom, enabling children to externalise, share and develop thinking.
- *Problem solving and agency*, recognising that through scaffolding the learning environment children can be provided with shared, meaningful, physical experiences and opportunities to develop their own questions as well as ideas about scientifically relevant concepts.
- *Questioning and curiosity,* recognising that creative teachers often employ open ended questions, and promote speculation by modelling their own curiosity.
- *Reflection and reasoning*, emphasising the importance of metacognitive processes, reflective awareness and deliberate control of cognitive activities, still developing in young children but incorporated into early years science and mathematics practice.
- *Teacher scaffolding and involvement*, teachers mediating the learning to meet children's needs, rather than feeling pressurised to meet a given curriculum.
- *Assessment for learning,* identifying and building on the skills, attitudes, knowledge and understandings children bring to school, supporting and encouraging children's active engagement in learning and fostering their awareness of their own thinking and progress.

3.2.4 Curriculum Dimensions – 'The Vulnerable Spider Web'

Finally, the *Conceptual Framework* not only identified characteristics of learning and teaching processes that have the potential to foster opportunities for creativity in science classrooms, but it also drew attention to the influence of wider factors, in particular, perspectives on the aims for science education, wider national and school contexts, and teacher characteristics. Here the *Conceptual Framework* adopted the curriculum dimensions associated with the *vulnerable spider web* from Van den Akker (2007, p. 39) as shown below.

- *Rationale or Vision*: Why are they learning?)
- *Aims & Objectives*: Toward which goals are they learning?
- *Content*: What are they learning?
- *Learning activities*: How are they learning?
- *Teacher role*: How is the teacher facilitating learning?
- *Materials & Resources*: With what are they learning?
- *Grouping*: With whom are they learning?
- *Location*: Where are they learning?

- *Time*: When are they learning?
- *Assessment*: How to measure how far learning has progressed?

These different dimensions that frame the curriculum are regarded as vulnerable because they are interconnected, in that what happens in one dimension can have an impact on another.

These key elements in the Conceptual Framework: the definition of creativity in science, features of inquiry and creative dispositions, synergies between inquiry-based and creative approaches to learning and teaching, and the dimensions of the vulnerable spider web provided an important common reference point and language across the CEYS project in the development of curriculum materials on inquiry and creativity for and by early years teachers.

3.3 Development of Curriculum Materials on Inquiry and Creativity *for* and *by* Early Years Teachers

The CEYS project, building on the framework and results of CLS, focused on developing materials for professional development to foster creativity and inquiry in science in partnership with early years teachers.

This chapter is focused on one aspect of the work of the CEYS project, the development of the *Curriculum Materials*, designed to exemplify and illustrate the development of creative inquiry-based approaches in early years science, in varied national and ***local*** contexts across Europe. Participating teachers in Belgium, Greece, Romania and the UK were involved in action research in their classrooms aimed at developing creative, inquiry-based approaches to learning and teaching. They were supported by a series of *Curriculum Development Workshops* run in each country. The teachers produced *Curriculum Materials* to record and illustrate their learning journeys alongside those of the children in their classes. These *Curriculum Materials* provide evidence and analysis of learning and teaching sequences *over time*, and offer insights into teachers' decision-making and children's learning, linked explicitly to key elements in the *Conceptual Framework.*

3.3.1 Curriculum Development Through Action Research

Curriculum development using action research was at the heart of the CEYS project. Action research is one way of implementing change and supporting staff and curriculum development. It involves collecting a range of evidence on which to base rigorous reflection. Common assumptions underpinning action research include:

- Teachers and schools work best on issues they have identified for themselves.

- They need time and space to reflect on, evaluate and to experiment with practice in order to respond to the circumstances and needs of particular children, schools and communities.
- Teachers and schools can best help each other by working collaboratively.
- Action research involves collecting a range of evidence (qualitative and quantitative) on which to analyse strengths and weaknesses.
- Action research contributes to a culture of self-evaluation and school improvement.

(See for example: Hitchcock & Hughes, 1995; McAteer, 2013; Reason & Bradbury, 2012)

The adoption of this approach was influenced by a view that any materials to be used by teachers should be designed in collaboration with them and with the involvement of all relevant stakeholders, so they are relevant and have the maximum potential for impact. Collaboration between schools and higher education institutions has the potential not only to improve initial teacher education, but also to contribute to school development and teachers' professional development (Snoek et al., 2008). The choice of action research as an approach to curriculum development was underpinned by the perspective that making links between research and practice is complex. Bringing together knowledge from practice with knowledge from research to gain insights and improve practices is a dynamic, interactive and democratic process, involving interpretation in context (Brown, 2015).

The choice of action research, with its cycles of action and reflection over time was also influenced in particular by Guskey's model of teacher development (Guskey, 2002). He argues that traditional models of professional development are often ineffective. He suggests first that they fail to recognise that most teachers' interests are focused on enhancing students' learning and on gaining practical ideas for the classroom. Second, they are often designed to promote change in teachers' attitudes and beliefs, assuming this will then lead to changes in practice. Guskey's alternative model of teacher development turns this around. He emphasises the importance of trying out new ideas in practice *first* and then noting change and improvement in students' outcomes. This, he suggests, promotes changes in teachers' beliefs and attitudes. So that change is primarily an experientially based learning process.

Finally, the selection of an action research approach was informed by perspectives on teacher professional development in science found in the literature. These indicate *the need to pay attention to practitioners' beliefs,* conceptions and attitudes towards science, not merely changing, but building upon existing' beliefs (for example: Schepens et al., 2009). They underline the *value of learning by doing and of partnerships* between teacher educators and practitioners (for example: Cochran-Smith & Zeichner, 2005), and emphasise *the importance of multiple inquiry-based experiences* in developing practitioners' understanding of inquiry-based science instruction and the opportunities and issues involved (Varma et al., 2009). Finally, the selection of an action research approach drew on the work of Rizvi and Lingard

(2010) in highlighting the *need to interpret policy and practice in context* to problematise what works and to identify and build on potential in everyday practices.

3.3.2 Sample and Ethics

Each of the five CEYS partners from four countries selected a minimum of five schools each, following induction workshops to introduce the project, and subsequent meetings with headteachers and potential teacher participants to explain the commitment required. 34 schools and 61 teachers from classes across the age range three to eight were recruited. All participating schools were non-selective and worked with relevant *National Curriculum* requirements.

A common framework of ethical procedures was adopted across the project, including voluntary participation based on informed consent from the schools, teachers, parents and children, including explicit agreement for all forms of data collection, principles of confidentiality and anonymity, and procedures to ensure data security. All partners were required to identify and meet ethical requirements in their own national and institutional contexts.

3.3.3 The CEYS Curriculum Development Process

Participating teachers carried out two cycles of action research in their classrooms over the course of a year. The action research cycle followed is shown in Fig. 3.2 below. The questions in the inner boxes were designed to support teachers' ongoing reflections about their values, learning and interactions with the research process and ongoing review of evidence to inform that process. Five *Curriculum Development Workshops* were held in each of the four CEYS partner countries to support teachers' action research. These were spread over the year to ensure long-term impact, implementation and sustainability of the desired change. They also had an important role towards the end of the project in supporting the development of the *Curriculum Materials*. Additional support was also provided by project partners across the year through Skype conferences and classroom visits.

The teachers framed their own research questions in relation to the *Conceptual Framework*, and whilst these questions developed in response to needs in their classrooms and schools, they were expected to link directly to one or more aspects of the framework. Each teacher was invited to select a small focus group of three children, reflecting a range of experience and confidence in science, and the diversity of their school community. They were asked to record close observations of the children's creativity and science learning in response to actions taken across the action research cycles completed.

Teachers recorded and reflected on evidence of learning and teaching and own ongoing professional learning during the *Curriculum Development Workshops* (see

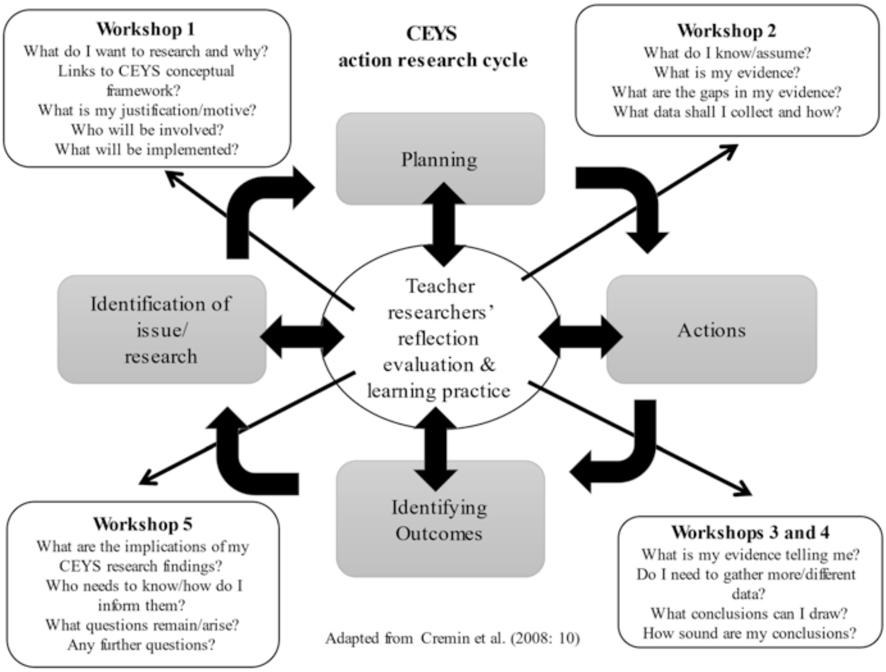

Fig. 3.2 The CEYS action research cycle (adapted from Cremin et al., 2008, p. 10)

Fig. 3.2) in their *Teachers' Portfolios*. The latter included reflective prompt sheets and supporting reference materials linked to the curriculum dimensions in Van den Akker's (2007) spider web and the factors associated with creative, inquiry-based approaches. All teachers were asked to fill in the prompt sheets to record their reflections at least once in the Autumn term and once in the Spring or Summer terms. The questions included in the prompt sheets are shown in Appendix 1.

These written reflections provided the foundation for the *Curriculum Materials* teachers produced to record and share their learning journeys and those of their focus children across the project. A common format was developed to inform the production of the *Curriculum Materials*, shown in Appendix 2.

3.4 Data Analysis: Impact of the CEYS Curriculum Development Process

In this chapter we will focus on results from analysis of the following data sources:

(a) From the *Curriculum Materials,* the teachers' reflections on:

- *their children's progress* – in relation to inquiry and creativity and linked to the initial aims of the project including any unanticipated outcomes and children's own reflections on their learning;
- *their own roles* – with links to the synergies between inquiry-based and creative approaches to learning and teaching;
- *the classroom environment* – in relation to other aspects of the design components associated with the *vulnerable spider web* that contributed to the development of children's inquiry skills and creative dispositions.

(b) From the *Teachers' Portfolios,* the teachers' ongoing professional reflections in relation to the following questions:

- In what ways is your thinking about science and creativity changing?
- What challenges have you and the children faced and in what ways have you overcome these?

Both sets of data were analysed in relation to key components of the *Conceptual Framework* as follows:

(a) Teachers' reflections included in their *Curriculum Materials*:

- *Children's progress in relation to inquiry and creativity*. Teachers' comments were coded in relation to characteristics of the inquiry-based approaches and creative dispositions (shown in Table 3.1 above):
  - Learning activities: questioning, designing and planning investigations, gathering evidence, making connections, explaining evidence, communicating explanations
  - Creative dispositions: sense of initiative, motivation, ability to come up with something new, making connections, imagination, curiosity, ability to work together, thinking skills.
- *Teachers' changing roles. Teachers' reflections on their changing roles were coded according to the synergies between creative and inquiry-based approaches (as outlined in The Conceptual Framework on p. 5 above): play and exploration; motivation and affect; dialogue and collaboration; problem solving and agency; questioning and curiosity; reflection and reasoning; teacher scaffolding; assessment for learning.*
- *Classroom environment*: Any additional comments on the classroom environment were coded in relation to the dimensions of the *vulnerable spider web*: aims and objectives; content; materials and resources; grouping; timing; location.

In each case the presence or absence of each characteristic was noted.

(b) Teachers' responses in the *Teachers' Portfolios* were analysed according to changes in their practices and challenges experienced noted, in relation to *planning, teaching, learning, assessment* and *contextual factors.*

3.5 Results

3.5.1 Curriculum Materials

31 teachers produced Curriculum Materials.

Teachers' reflections on children's progress.

Table 3.2 indicates the number of teachers who commented on evidence of children's progress in relation to each of the *features of inquiry*.

Teachers' reflections overall included examples of commentary in relation to all the *features of inquiry*. Progress was most often noted in relation to children's *questioning* and *communication of explanations*. For example:

> Children's curiosity and their involvement in their observations was shown also by the many questions they asked: What are the little fibres in the soil? How high will the wheat grow? ….Many children were doing parallel observations at home too, where they... involved their parents in the investigative work. (Investigating materials)
>
> Discussing alternative views and explanations was of high importance. Children would ask questions including 'how do you know that?' (Crime Scene Investigation)

Table 3.3 indicates the number of teachers who noted evidence of development in children's *creative dispositions*.

Comments on children's progress in terms of their *motivation, curiosity and abilities to work together* were most prominent. For example:

> Once they had the opportunity to work with many ingredients they started to cooperate, they were interested in the solutions proposed by their peers and came up with new ideas. (Make Bread Right Now)
>
> The children were very motivated. They felt this was a team effort as a scientific community sharing their strengths and knowledge. They saw ways in which their ideas were incorporated across the sessions. (Skeletons)

Teachers made limited commentary on developments in children's imagination and thinking skills. This may reflect the broad nature of these terms, their interconnections with other elements in the framework and the focus in this project on creative dispositions in *science*. For example, thinking skills are associated in particular with the learning activities *making connections* and *explaining evidence*. Imagination often underpins the creative dispositions *sense of initiative* or *coming up with something new*.

Table 3.2 Children's progress: Features of inquiry N = 31

Learning activities	Questioning	Designing and planning investigations	Gathering evidence	Making connections	Explaining evidence	Communicating explanations
Number of teachers	21	10	11	12	13	16

Table 3.3 Children's progress: Creative dispositions N = 31

Creative dispositions	Motivation	Making connections	Curiosity	Ability to work together	Come up with something new	Sense of initiative	Imagination	Thinking skills
Number of teachers	22	12	20	16	8	7	2	4

3.5.1.1 Teachers' Roles

Table 3.4 records how many teachers referred to each synergy between inquiry-based and creative approaches in reflecting on their professional development across the project.

There were examples of teacher reflections in relation to all the synergies. *Fostering questioning and curiosity* and *teacher scaffolding* were mentioned by a majority of teachers. A number of teachers also noted the role of *assessment* in guiding their interventions. For example:

> I learnt how to use questioning to keep the learning going when the children became stuck, while guiding the learning sequence, while the children retained ownership over key aspects. (Life cycle of the frog)
>
> It was an open-ended project for me as I needed to tune into the children's conversations and scaffold their ways of thinking and create a dialogue to foster their creative dispositions. (An icy adventure)

3.5.1.2 Classroom Environment

Table 3.5 indicates the number of teachers who referred to contextual factors, related to the dimensions of the *vulnerable spider web*.

Teacher commentary on contextual factors focused mainly on *materials and resources, grouping* and *time.* There were also references to *location* in noting the benefits of linking learning in and outside the classroom. They referred to the key role of resources in stimulating and supporting learning. For example:

> I sought to develop children's creative thinking linked to science by providing sufficient time for them to wallow, think, ponder and wonder over what they experienced. (*Bath Bombs*)
>
> My role as a teacher to facilitate children's curiosity with an enabling environment with opportunities for children to pursue their own interests through open ended resources and making links to first hand experiences at home or at school. (*Properties of Materials*)

Teachers selected their aims and objectives at the start of their action research projects, related to the needs of their children and their own professional concerns, making explicit links to the *Conceptual Framework* and connections to school and national curriculum requirements. Teachers' reflections on their learning journeys tended to focus on the strategies they employed to achieve these aims and objectives building on ongoing assessment and evaluation, in line with the guidance provided to support the development of their *Curriculum Materials* shown in Appendix 2. The lack of explicit commentary on aims and objectives may reflect this, although the aims, objectives and rationale for each teaching and learning activity are made explicit in the body of the *Curriculum Materials*. Teachers' shifting emphases and reflections related to aims and objectives were more in evidence in their reflections in their portfolios, particularly in relation to planning, as indicated below.

Table 3.4 Teachers' roles: Synergies between inquiry-based and creative approaches N = 31

Synergies	Play and exploration	Motivation and affect	Dialogue and collaboration	Problem solving and agency	Questioning and curiosity	Reflection and reasoning	Teacher scaffolding	Assessment for learning
Number of teachers	11	9	10	11	18	9	16	14

Table 3.5 Classroom environment: contextual factors N = 31

Contextual factors	Aims and objectives	Content	Materials and resources	Grouping	Timing	Location
Number of teachers	0	0	14	12	11	7

3.5.1.3 Reflections and Interconnections

A number of common themes emerged from teachers' reflections, illustrating the dynamic interconnections among children's learning activities, creative dispositions, synergies between creative and inquiry-based approaches, and contextual factors. Teachers noted that the provision of rich resources with time and scope for decision making stimulated children's curiosity and motivation. They commented on ways in which this led to an increase in children's questions and agency, fostered cooperation in solving problems and encouraged children to share ideas and explanations within the classroom community. Teachers recorded examples of children extending investigations independently in the wider classroom environment, and at home with their parents. They highlighted the importance of teacher scaffolding to extend and sustain learning, building on observations of children's responses.

3.5.2 Teachers' Portfolios

42 teachers submitted their portfolios, providing a total of 101 reflections submitted and analysed overall. Their reflections offer additional insights into teachers' perspectives on their changing views and practices over the course of the project.

3.5.2.1 Planning

Teachers reflected on the need for careful planning of the activities, learning opportunities and science investigations with a view to engage children actively and allow them different ways to apply and extend their skills. They found this challenging, as it involved changing their linear view of planning to a more flexible and interconnected one. They also learned to focus their planning more on anticipating children's questions, actions and ideas, while nourishing their curiosity. They acknowledged the importance in planning to allow children more space and time to explore, while at the same time trying to capitalise on 'accidental' learning opportunities. For example:

> I am thinking more about what I want children to learn – such as skills, and trying to plan for different ways for them to apply and build on these.
>
> I am planning carefully the investigation in order to give children time for questioning and come with ideas from previous experience.

> I have had to change my rather linear view of how to 'deliver' the curriculum and adopt a more interconnected 'systems' view – learning is more like a web that [than] a straight path.
>
> Creativity has to do with the structuring of activities but can also appear spontaneously. You simply have to practice in spotting and exploiting it.

3.5.2.2 Teaching

As a result of their involvement in the project, teachers expanded their views about the teaching of science to early years children. They demystified the nature of the science experiences they needed to provide for children and learned to give more value to the roles of questioning, making cross-curricular links and encouraging collaboration. They showed greater appreciation for the importance of stepping back, while building on opportunities for extended play and exploration. Finding, however, the balance between standing back and guiding children forwards was a constant challenge. The quest for the appropriate way and time for scaffolding children's ideas, actions and questions was a regular concern. For example:

> Sometimes I make things too complicated: science can be experienced with a simple activity. I want to work more with questions from the children. I want to let them try out their own creative ideas. They should experience that they can fail, everyone does!
>
> I started thinking that in children's minds science and creativity are connected at different levels. I tried to secure this by guiding less, standing back more and giving more time and space to children-initiated ideas and actions.
>
> In my science teaching it was a challenge to manage properly the inquiry activities so that to allow children [to] find solutions to problems by themselves. I want to devote more time to children for they come up with questions or to lead them to ask questions. I want to work more on drawing conclusions so that I can motivate children to participate.

3.5.2.3 Learning

Teachers' thinking about learning also changed on the same lines. They reported they realised that children are much more capable of science learning and doing, than they had previously believed. They also learned to appreciate the importance of paying attention to children's actions and initiatives and not only to their words, as the former often betray a much deeper kind of understanding and learning. They reflected on the value of experiential learning and on children's ability to steer it in line with in their own interests. Teachers noted problems in fostering children's abilities to formulate 'researchable' and clear questions and to come up with explanations. Also, despite the obvious learning advantages of children working collaboratively, teachers found managing successful group work challenging. For example:

> The most important thing, I think, is that now I realise that science is accessible and understandable by pupils of Year 1.
>
> Children are noticeably more engaged in the activities, as they have more freedom in steering their direction of their own learning.
>
> Understanding that even though children are not verbalising questions they are still asking/trying to answer questions implicitly through their explorations.

> Children's difficulty with formulating questions…; they need to be more specific and not change topic so easily.

3.5.2.4 Assessment

Teachers reasoned that as a result of their action research project they now paid more attention to assessment, which they found challenging. They came to identify better opportunities for formative assessment and enhanced their use of different media (photos, drawings, picture books, etc.) for this purpose. As with children's learning, teachers also increased their trust in children's role in assessment, both of their peers' work and of their own.

> Formative assessment is a useful tool for me, because I can discuss with them in groups or individually and have "evidence" of their thoughts either through photos or through their drawings.
>
> Assessing children's understanding is complex; one mode of expression may not be enough. In some cases, despite the fact that the pupils had recorded their experience by simply drawing the experiment they had done, when I went to the group and asked some questions, I realized that their understanding was much greater...
>
> I use more frequently portfolios for children's formative assessment; I involve them in project work asking them to evaluate their colleagues' results.
>
> Collecting photos and evidence—need to think about what photos tell me in relation to learning. How are my lessons connecting? What's the link between them?—VIP (very important) to pin down for analysis and self-reflection.

3.5.2.5 Contextual Factors

Teachers said they appreciated more the value of appropriate and varied resources, though finding time to prepare them was a challenge. The importance of making time and space for children's play and exploration was reaffirmed, as well though as the difficulty of organising space for investigative work. Grouping was acknowledged as having impact on children's motivation, though its organisation and management was not straightforward. For example:

> It is more open that I imagined, it should not be limited by your resources/materials—it is about understanding and exploring an idea and how this can be filtered into the classroom and children's play—but should also be structured and organised with appropriate resources to help.
>
> Children need more time for play and exploration, but curriculum and timetables constrain us. Creativity is being lost and science requires it to progress.
>
> My main challenge is setting—as work is done as a whole class rather than small groups. Lack of adult support for proper supervision and ensuring that groups are on task at all times.

Finally, teachers also acknowledged challenges related to their own professional development: lack of science knowledge and experience, lack of confidence or insecurity. For example:

> I feel safer when using a step-by-step plan or another helping tool.
>
> Sometimes children ask difficult, very technical or scientific questions (and I don't always have the answers).
>
> It was a challenge to let go, to let the children experience things on their own without me interfering.

3.6 Discussion and Implications

Teachers' reflections in their *Curriculum Materials* and *Teachers' Portfolios* provided insights into ways in which they were opening up their practices to enhance opportunities for inquiry and creativity in children's learning, in particular through providing rich contexts and materials to foster children's motivation, curiosity and questioning; offering greater scope for children's decision making and scaffolding children's questioning, dialogue and collaboration. Teachers also showed greater appreciation for the central role of creativity *in* science and the potential for development of children's creativity *through* science.

As suggested by Guskey's (2002) model of teacher development, teachers' *Curriculum Materials* and *Teachers' Portfolios* provided evidence of the impact of the curriculum development process on their beliefs. As illustrated in the examples above, teachers included commentary on their growing recognition of young children's capabilities, highlighted by Duschl et al. (2007) and Goswami (2015). They noted shifts in their perspectives on learning and teaching from 'delivering' content to more interactive and responsive approaches as advocated by Siraj-Blatchford and Sylva (2004) and Fleer (2009). Teachers referred, for example, to giving time for questioning, picking up on spontaneous events and building on children's ideas and experiences. They highlighted their increased understanding of the importance of classroom assessment and growing adoption of varied approaches to assessment, including self and peer assessment. This resulted in teachers positioning the children at the centre of their planning and teaching. Being better able to anticipate, but also to provoke and trust children's ideas, questions and actions, increased teachers' confidence to step back and allow children to steer their own learning.

However, while teachers indicated developments in their views and practices, they also drew attention to challenges they experienced that have implications for programmes of continuing teacher development and school provision. For example, teachers referred to the need for greater subject knowledge and for skills in managing group work, questioning, assessment and feedback. They drew attention to limiting contextual factors such as time, space and resources that had an impact on opportunities for inquiry and creativity.

More generally, findings illustrate the significance of an explicit conceptual framework to guide professional development. The *Conceptual Framework* used was a product of extensive research and validation. Teachers' references to the concepts embedded in the *Conceptual Framework* in communicating and reflecting on children's learning and their own professional development suggest it provided a common language for identifying and then capitalising on opportunities for fostering inquiry and creativity within their everyday practices. It offered a reference point for recognising and building on what they were already doing, as a foundation for further development. In addition, the links to the *Conceptual Framework* in the guidance provided for the *Curriculum Materials* and *Teachers' Portfolios* encouraged teachers to make features of inquiry and creativity explicit, both in the teaching strategies they were adopting, and in examining evidence of progress in learning and teaching over time. Teachers' reflections suggested that the CEYS action research cycle and iterative processes of action research over a year also provided a support framework for teachers in initiating and sustaining developments in their practice. They included evidence of teachers' growing confidence and sense of self-efficacy across the course of the project, suggested by Kinskey (2018) as an outcome of engagement in action research.

Overall, findings offer indications of how the combination of an explicit conceptual framework with an action research approach to curriculum development may contribute to teachers' professional development. They illustrate the potential of learning both *from* and *through* research as advocated by Brown (2015), bringing together knowledge from research and knowledge from practice, to offer new insights into classroom practices and promote developments in learning and teaching.

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Appendicies

Appendix 1: Prompt Questions to Support Teachers' Reflections on their Changing Practice and Evidence of Children's Learning

- **Actions**: What changes have you made to your practice when developing creativity in science in relation to the spider web curriculum dimensions?
- **Impact**: What impact is evident in children's strategies, creative engagement and attitudes to science (linked to the *Conceptual Framework*)?

- **Evidence**: How do you know the work has impacted on the children? What is your evidence?
- **Professional reflection**: In what ways is your thinking about science and creativity changing?
- **Professional reflection**: What challenges have you and the children faced and in what ways have you overcome these?

Appendix 2: Format of the Curriculum Materials

The curriculum materials vary in presentation but they share a number of common elements for example:

Initial information (provided in the first page(s))

- Title of the Learning Journey
- Details of the ages of children in the class—note the examples cover a wide age range in both preschool and primary settings.
- A list of the particular *learning activities* (features of inquiry), *creative dispositions* and *synergies* (teaching approaches common to inquiry based and creative approaches) the teacher was seeking to promote (linked to the definitions of creativity outlined above).
- *Background*—key features of the background to the example, such as aspects of the school setting, age group, school policy for science, curriculum links (as appropriate).

Setting the Scene—brief outline of the focus and rationale for the project and implications for planning and teaching for example:

- *Focus*—The aspects of children's creativity and inquiry the teacher focused on—the differences the teacher was seeking to make and aspects of their own practice they aimed to develop (linked to the synergies).
- *Rationale*—The teacher's rationale for the focus—based on their assessments of children's inquiry skills and creative dispositions and/or evaluation of their own practice.
- *Implications for planning and teaching*—The implications for teaching approaches with links as appropriate to the curriculum design components associated with the 'vulnerable spider web'.

Overview of the learning journey—an outline of the sequence of activities involved in the project and the time frame. The time frames vary considerably—some projects took place over a few days, others over several weeks. This is indicated in the background details provided.

Developing the Learning Journey—explanation and reflections on the learning journey over time, illustrated by examples of learning and teaching including:

- *Starting points*—an indication of how the project began: this might include for example: a motivating stimulus, experience or event or observation or elicitation of children's questions/interests
- *Sequence of activities*—how the project developed over time.

For each stage in the learning journey teachers were encouraged to draw on records and discussion of their action research processes to:

- *Explain the decisions they made. How did each activity build on evidence of children's responses?*
- *Explain each activity*. Provide images to illustrate key features such as: nature of activity and resources, teacher interventions and questions, children's recording, comments, actions, inspiring moments.
- *Highlight examples of children's inquiry skills and creativity* and ways in which *they* fostered children's inquiry and creativity (linked to definition of creativity in science, the synergies and other creativity enabling factors linked to the spider web).
- *Indicate how this led to the next activity*—brief reflections to indicate connections

An example is shown in Fig. 3.3 below that illustrates some of the common elements included.

- The activity and rationale are indicated
- The photograph gives a flavour of the nature of the activity.
- The comment boxes provide examples of teacher/child commentary or questions.
- The thought bubbles include teacher reflections on learning/their own teaching.
- The arrow at the bottom suggests implications/next steps.

Reflections on the Project Including

- *Reflections on children's progress*—based on analysis of children's progress in relation to inquiry and creativity and linked to the initial aims of the project. In some instances, this includes any unanticipated outcomes and children's own reflections on their learning.
- *Teachers' reflections on their own roles*—analysis in relation to the aims of the project with links to the synergies between inquiry-based and creative approaches
- *Reflections on the classroom environment*—other aspects of the design components associated with the 'vulnerable spider web' that contributed to the development of children's inquiry skills and creative dispositions
- *Next steps for learning and teaching*—based on evidence of learning.
- *Reflection questions for the reader*—designed to encourage readers to consider applications to their own practice.

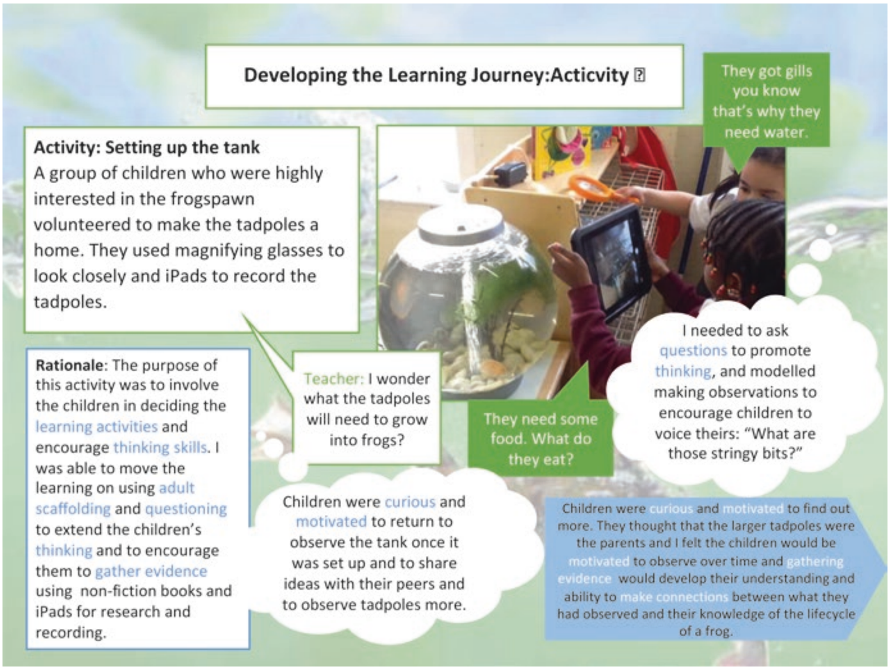

Fig. 3.3 Example of a page format from the 02_UCL_IoE Curriculum Materials: Life Cycle of a Frog (Creativity in Early Years Science, 2017, p, 87)

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Esmé Glauert is an Associate Professor in Primary Education at UCL Institute of Education. Her research interests include young children's reasoning in science, pedagogy in early years and primary science and the role of research in teacher professional development and curriculum design. She contributes to teacher education, Masters and Doctoral programmes at the Institute of Education.

Fani Stylianidou is a Senior Project Manager in the Hellenic Erasmus+ National Agency, Higher Education sector. She has a wide research experience in the field of science education, focusing on students' learning and teachers' professional development. In Ellinogermaniki Agogi, she coordinated the EU/FP7 project *Creative Little Scientists* and the Erasmus + project *Creativity in Early Years Science Education*.