CREAT-IT: a new pedagogical framework for partnering the arts and science in science education

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Abstract

This paper focuses on the EU-funded CREAT-IT Research Project's approach to integrated arts/science teaching within science education. In particular it details the development of a new creativity-based pedagogical framework and principles intended in the future to inform the development of arts-science partnership to foster creativity in science education. Spanning 6 countries, CREAT-IT builds on creativity in science education research and good practice to develop a new pedagogical framework and accompanying practice. This paper reports on the former i.e. the pedagogical framework, and the literature reviews, survey and theoretical integration carried out in order to develop it. The literature review involved a broad systematic mainly pan-European primary and secondary education-focused review of integrated creativity, science and arts education. This supported a core review of creativity in education theories developed by the University of Exeter (UoE) team. The paper articulates how these UoE ideas shape the newly synthesised CREAT-IT pedagogical framework and principles: professional wisdom; individual, collaborative and communal activities for change; risk, immersion and play; dialogue; interrelationship of different ways of thinking and knowing; discipline knowledge; possibilities; ethics and trusteeship; empowerment and agency. It also offers examples of the framework's application across case studies of existing good practice: Caffè Scienza Junior' (CSJ), Science and Theatre (S & T) and Write a Science Opera (WASO). The paper concludes by offering insight into the framework's potential use as a catalyst for existing creative science teaching, and, as a secure mechanism to nurture less confident professionals creatively in diverse European contexts.

Keywords: creative science education; science/arts integration; creative science teaching; pan-European; creative pedagogies

Introduction

This paper reports on the CREAT-IT project's creation of a new methodology for designing, communicating and representing creative science education approaches for late primary and early secondary schools in Europe. Spanning 6 countries, CREAT-IT is building on creativity in science and arts education research (e.g. Glauert, Trakulphadetkrai, and Maloney, 2013; Chappell, Rolfe, Craft and Jobbins, 2011; Craft, 2013; Ayverdi, Asker, Oz Aydin, Saritas, 2012) and on good practice (e.g. CREST Star Awards: primary pupil science award scheme run by the British Science Association[i]) to investigate: How can a new creativity-based pedagogical framework inform the development of arts-science partnership to foster creativity in science education? This paper focuses on one aspect of the larger project to offer detail of the development of the pedagogical framework and principles. It offers insight into the theoretical positioning of the framework and principles through reviews of existing literature supported by the results of the European-wide survey.

The project was instigated in the context of research and policy literatures, which bear witness to the economic and societal factors driving the focus on developing creativity in science education. A number of reports (in Europe: Harlen, 2010, Gago, 2004, Millar, 2011, Roberts, 2002, Lord Sainsbury of Turville, 2007; in America: Donovan, Moreno Mateos, Osborne and Bisaccio, 2014, Barrow, 2010; in Australia: Tytler, 2007, Schmidt, 2011, 2010) stress the importance of maintaining and developing the scientific infrastructure, as this will 'ensure national security and economic prosperity in the future' (Millar, 2011: 174). The early 21st century has seen a twin pillared European Commission policy approach toward fostering creativity in science education. One pillar emphasises the need for all countries to develop innovative scientists in a global knowledge economy (European Commission, 2006) and therefore the need to teach for creativity in science. The other pillar proposes the need for greater understanding of science in the population as a whole, towards a more scientifically literate population who can use their skills productively in everyday life. This view proposes scientific literacy as an aspect of democratic citizenship, alongside the need for creative and innovative scientists (European Commission, 2004).

This is supported by the work of Archer, DeWitt, Osborne, Dillon, Willis, and Wong (2013a) who argue that education needs to broaden and diversify the perpetuating view that to study science means, necessarily, becoming a scientist. They want to promote the message that science 'keeps your options open and is useful for a wide range of careers, at both graduate and technical levels, both in and beyond science' (Archer et al, 2013a: 4), together with a strong argument across the literature, that science is for all (Gago, 2004; Murphy, Lunn, and Jones, 2006; Harlen, 2010; Hofkins & Northen, 2009; Orion, 2007; Kolstø, 2008; Jorde and Bungun, 2003). Harlen (2010) states that the main 'purpose of science education should be to enable every individual to take an informed part in decisions, and to take appropriate actions, that affect their own wellbeing and the wellbeing of society and the environment' (Harlen, 2010: 5).

Despite this, Osborne and Dillon (2008) and Rocard (2007) have identified that across Europe insufficient numbers of young people are entering science careers and fully engaging with their potential. Archer et al (2013a) suggest that one solution is to readdress science's image and perception. Their argument draws on evidence from a study of 9000 English primary children: 70% enjoyed science, but only 17% would consider a career in science because they considered scientists as "geeky" and "brainy"; science was therefore "hard" and not for them. Educational research also suggests that gender is a significant factor in how students engage in science (see, Archer et al, 2013a, 2013b; Graf, 2013; Watermeyer, 2012; Harlen, 2010; Reid and Skryabina, 2002; Murphy, 1991; Green 1997). Murphy (1991) suggests that this is because culturally 'girls are not encouraged or expected to achieve as well as boys in science' (Murphy, 1991: 206). This is reflected in the Trends in International Mathematics and Science Study (2011) that reports a strong gendered pattern across most countries.

Rocard (2007) also argues that lack of appropriate teacher skills are a key factor. He proposes a solution, which might address the perception, engagement, gender and teaching skills issues, is to harness the motivational potential in inquiry-based and interdisciplinary work, including that which involves the arts (also supported by Avissati et al, 2013). His argument is also underlined by the European Ambassadors' Manifesto of the European Year on Innovation and Creativity (during 2009), which stressed the need to integrate science education, creativity, culture and the arts.

The CREAT-IT research project therefore aims to move forward from this position in which, against policy makers' desired trajectories for the future of science and science education, engagement in science education is not satisfactory, and not addressing the need for the provision of future scientists or a science-literate general population. CREAT-IT is designed to address these issues employing a fresh perspective by investigating how a new creativity-based pedagogical framework can inform the development of arts-science partnership to foster creativity in science education. A Norwegian team from Stord Haugesund University College led on the conceptualisation of the CREAT-IT project bringing in colleagues from Serbia, Greece, Italy, Belgium and England. The project built on their previous work on Write a Science Opera (WASO) and the other case studies, and proposed that the creativity in education theory developed by the CREATE Research Group at University of Exeter could provide a strong theoretical core for this new perspective. The Norwegian team judged that this was because, over a 15 year period, the University of Exeter

(UoE) group's work had become well-respected in both the academic and practice communities, for considering creativity in arts, science and generic contexts and was judged to have breadth and depth. The project consortium therefore positioned the Exeter theory as the key source of creativity in education ideas to generate the new framework within the research project, supported by a broader understanding of European literature in the area. Their bid to the Lifelong Learning Programme Comenius Multilateral Projects programme was successful on these grounds (Grant number 539818-LLP-1-2013-1-NO-COMENIUS-CMP).

The project therefore had three starting points, i/ reviews of the literature, ii/ an on-line survey and iii/ defining 'creativity in science education'. The first starting point was the literature review, which comprised of two parts. Part one incorporated current European understanding of creativity in science, and combined science/art education and the second part encompassed the review of the body of creativity in education theorising developed by UoE academics. These latter UoE theories were intended, by the project Description of Work, to provide the underpinning ideas for the CREAT-IT framework and pedagogies. In order to understand whether the picture portrayed in the literature was reflected in the views of those involved in science education within Europe, the CREAT-IT team had a second starting point of a survey (Greenwood, Black, Hennessy, Slade, Craft & Chappell, 2014). This was carried out with consortium members and teachers from across the partnership and beyond. Thirdly, the CREAT-IT team considered a final important starting point was to define our term 'creativity in science education'.

This paper was generated from a presentation of the CREAT-IT research at the British Educational Research Association 2014, Creativity Special Interest Group. It concisely draws together the integration of the definition, survey and literature reviews. It then articulates the new pedagogical framework and principles mainly derived from the University of Exeter theorizing but contextually supported by the broader literature review and the survey. It then offers an example of how the three CREAT-IT case studies of existing good practice (Write a Science Opera, Science & Theatre, Caffe Scienza Junior) were framed and understood in terms of the principles. The paper does not go so far as to offer evidence of the next stage research into the application of the principles to practice, as this was beyond its scope. However, we conclude the paper by considering early indications of the application of the framework and principles into European professional development and practice, and close with a discussion of the implications for theory and practice.

Literature review and survey methodology

The broader literature review involved a primary and secondary education-focused review of integrated creativity, science and arts education writing and research. A detailed search was made of the following databases using key search terms including 'creativity', 'science', 'arts' and 'education': British Education Index (BEI), Education Research Complete and Education Resource Information Centre (ERIC). The search parameters were European, peer reviewed literature from the previous 10 years with a core focus on consortium member's countries (United Kingdom, Belgium, Norway, Greece, Serbia and Italy), whilst consciously acknowledging seminal literature outside Europe or the date parameters. The partners involved in the project were also asked to provide literature regarding their national curricular and education policy documents, the key elements of which were translated as appropriate. The literature review ultimately included over 180 publications encompassing peer reviewed articles, handbook chapters, European level and national policy statements, key books and book chapters, online information detailing Continuing Professional Development in different European countries, EU project deliverables and science and arts agency reports. The literature review of UoE work involved reading and synthesising all the Exeter team's creativity theorising since 2000. This date was chosen as the turning point at which the team's main theories began to be conceptualised. This part of the review was ultimately theoretically clustered as shown in this paper around these key UoE theories: living dialogic space, wise humanising creativity, quiet revolutions, possibility thinking, and the 4Ps.

The survey was a semi-structured self-administered electronic LimeSurvey™ questionnaire, selected as the most appropriate tool as it could be distributed to, and self-administered by a wide range of international participants in a short time frame. The LimeSurvey™ tool was used for questionnaire design and the online hosting of the questionnaire, as well as data capture. Questions were derived from the literature detailed below, evidence of current good practice and the CREAT-IT definition for creativity in science education. For triangulation, thematic illumination and analysis, the survey included a variety of question types including: Likert-type rating scales; selection from pre-determined lists; open questions. To develop descriptions of frequency of mentions and obtain accurate comparisons between stakeholder groups quantitative questions were also asked. The open-endedness of qualitative approaches allowed for the inductive emergence of themes.

The questionnaire was in 6 sections. The first two sections asked the same questions of all respondents, the remaining sections used a branching structure to enable general teachers, consortium members, curriculum developers, scientists and science teachers to respond to tailored questions. We sought to survey a number of people with varying levels of experience of creative science teaching. Opportunistic/snowball sampling was used, the LimeSurvey™ questionnaire link was passed via email to each consortium member, who forwarded it electronically to:

- Primary and secondary teachers
- Curriculum developers
- Scientists
- Teachers with experience of a specific creative approach
- It was also completed by the consortium members themselves..

The survey was available in six languages.

It had 130 respondents from across the UK, Italy, Serbia, Greece, Norway and Belgium. Quantitative data underwent descriptive and inferential numeric analysis and comparisons; and a range of analyses on SPSS. Qualitative analysis involved thematic grouping.

The three starting points (literature reviews, survey and definition) which ultimately led to the new CREAT-IT framework and principles were not carried out in a linear or parallel fashion, but were responsive to each other in an integrated way. For this reason they are not presented sequentially here but the outcomes from them are woven together as thematically appropriate. Each was developed in conversation with the other two and also written up in this way for the European Union Comenius scheme project deliverable (Craft, Chappell and Slade, 2014). This is especially relevant as the background and structural template for this peer-reviewed paper. However it is over 40,000 words in length and this paper seeks to provide a concise insight into the analysis and ideas within it. Therefore, rather than offering a traditional Findings section, the next section of the paper reports on the integrated synthesis of the literature reviews and survey outcomes which needed to be woven together to create the framework and principles that follow after.

Definition and contextually relevant survey outcomes

Firstly, we provide the creativity in science education definition used in the survey and then offer insight into the survey and its findings relevant to the context and policy discussed in the introduction above.

Creativity in science education definition

A definition of creativity in science education was a necessity as there is currently no agreed definition which could be employed within the project. A recently completed European project, *Creative Little Scientists*[1], which focused on creativity in science and mathematics in early years education, offered a useful working definition for creativity in science education, based on its own literature review, and was adopted as the starting point for the CREAT-IT project: “Generating ideas and strategies as an individual or community, reasoning critically between these and producing plausible explanations and strategies consistent with the available evidence” (Craft, Chappell and Slade, 2014: 13). This definition of scientific creativity is seen as fuelled by ‘little c’ creativity, i.e. purposive and imaginative activity generating outcomes that are original and valuable in relation to the learner. These definitions are represented in Figure 1. Prior to its finalisation, the two definitions were put to the survey participants and over 85% agreed both with the proposed CREAT-IT definition of creativity in science education (86.2%) and the given definition of ‘little c’ creativity (86.9%). This gave the theoretical team confidence to move forward with this definition, supporting the literature review and feeding into development of the pedagogical framework.

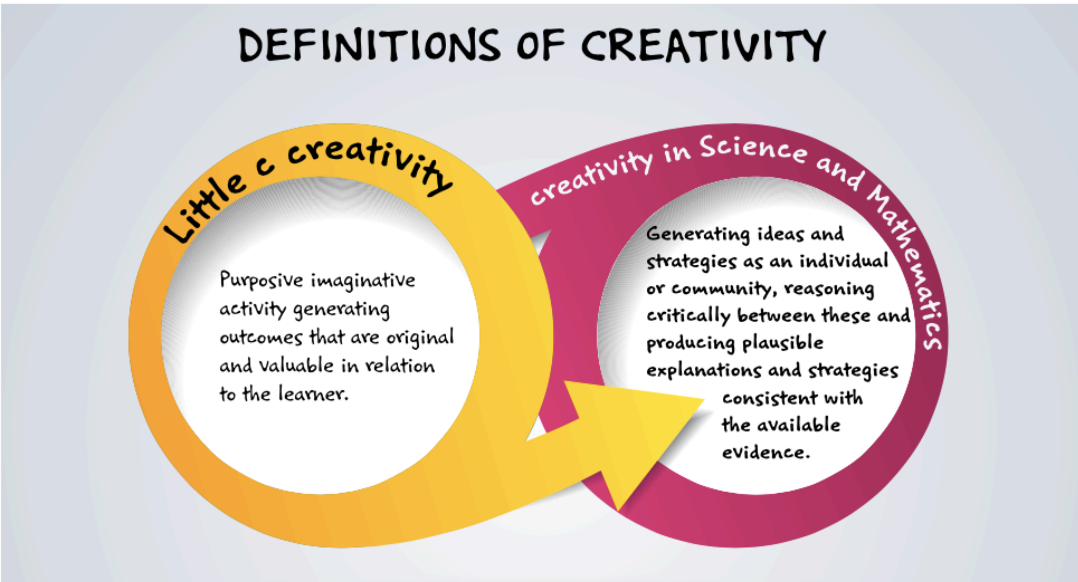

Figure 1: Definitions of creativity From http://www.creative-little-scientists.eu/node/57 (9th May 2014)

Contextually relevant survey outcomes

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[1] CREATIVE LITTLE SCIENTISTS: funded by European Union Seventh Framework Programme (FP7/2007-2013) grant agreement no. 289081: http://www.creative-little-scientists.eu/

Part of the survey aimed to discover to what extent the participants considered their national governmental policies promoted creativity in science education, as defined above. Participants were asked: “To what extent do you think national level governmental policy promotes creativity in science education in your country?” in the policy areas of school ethos, initial teacher education, curriculum policy, assessment strategies and performance indicators. (Scale ranged from -5 [strongly prevents creativity in science], through 0 [no effect], to +5[strongly promotes creativity in science]). The means showed that school ethos and initial teacher education were seen to have a neutral effect on the promotion of creativity in science education (mean= 0.29 s.d 2.499 and 0.23 s.d. 2.563 respectively), whereas assessment practices and performance indicators were seen as having a negative effect (mean = -1.25 s.d 2.759 and -1.39 s.d. 2.700 respectively)– indeed respondents felt they actively prevent the development of creativity in science. When histograms are drawn they show skewed distributions. This, along with large standard deviations, demonstrates that the means should be treated with caution. Four of the six countries recorded a low mean for the impact of assessment practices on the promotion of creativity in science education, only Belgium and Serbia gave neutral responses. Half of the countries recorded performance indicators as a barrier, with Belgium and Serbia reporting this as a strategy that may actually promote creativity in science (albeit at a low level). All countries suggested that assessment practices had a negative impact on the promotion of creativity, and half of the countries suggested that performance indicators were also a barrier. However, Belgium and Serbia contradicted this result suggesting that performance indicators may actually be a strategy that promotes creativity in science.

The participants also responded to say that they felt that both government and non-government schemes promoting creativity in science education are having little effect (mean on a rating scale from -5 [strongly prevents creativity in science] to 5 through 0 [no effect], to +5[strongly promotes creativity in science] = 0.00, s.d. 2.352). So, despite the fact that policy makers are beginning to recognize the potential role creativity can have in engagement in science education, (EU Commission, 2006) the survey results demonstrate, alongside the policy and context literature above, that teachers and schools are struggling to either engage with the work or need support to access the good practice that is available to them. The CREAT-IT team took these findings as further support for their endeavour to investigate how a new creativity-based pedagogical framework can inform the development of arts-science partnership to foster creativity in science education.

Broader Literature Review and Related Survey Responses

The broader literature review involved a systematic mainly pan-European primary and secondary education-focused review of integrated creativity, science and arts education writing and research. This was intended to provide the contextual supporting background for the detailed review of UoE creativity in education theorising. This latter UoE review informed by relevant integrated survey responses then provided the main driver for shaping the principles.

To demonstrate the contextual supporting background, this section outlines a brief summary of the history of creativity in education, followed by a synopsis of research, practice and policy within Europe across the domains of creativity, education, science and the arts. Within this, we discuss creative pedagogies and explore current policy and curriculum constraints in science education in Europe, and offer examples of good practice and emerging tensions and dilemmas.

The Nature of Creativity.

The literature regarding creativity spans centuries and multiple disciplinary perspectives (Craft, 2001). This review is informed by research in the social sciences, arts, and science and can only present a brief summary. Whilst there are many approaches to the nature of creativity there is also broad agreement across disciplines that at its most fundamental, inherent to creativity is a generation of new approaches or questions that facilitate transition from what is to what is might be (Craft, 2002, 2005, 2013; Caselli, 2009; Banaji et al, 2010; Walsh et al, 2013). Manifestations of creativity are outcomes that are considered both original and novel and also valuable or useful (Boden, 2004; Craft, 2005; Csikszentmihalyi, 1996; Mumford, 2003; and Sternberg & Lubart, 1999). This forms the foundation of the CREAT-IT definition above.

At one end of the creativity continuum, there is everyday, or ‘little c’ creativity, which involves a person generating ideas which are novel to them or their peers (Craft, 2001; Kaufman and Beghetto, 2009). The CREAT-IT approach creates a workable methodology for fostering creative approaches at this level with children, but also aims to stretch teaching and learning across the creative continuum.

Three traditions of psychological creative enquiry are acknowledged: cognitive (Wallas, 1926; Rhodes, 1961; Watson, 2007; Kozbelt, Beghetto and Runco, 2010) psychometric (Sawyer, 2006; Baer and Kaufman, 2006; Torrance Tests of Creative thinking, 1974; Lubart, Besancon and Barbot, 2011) and humanistic (Maslow, 1943; Rogers, 1954). Creativity as a social phenomenon has key elements of motivation, interaction and mood. Sustaining futures require wise, humanising creativity (Chappell and Craft, 2011; Chappell, Craft, Rolfe and Jobbins, 2012; Craft, 2013) that attends to its potential for impact (Craft, Gardner and Claxton, 2008; Chappell and Craft, 2011). Drawing on these perspectives, the CREAT-IT approach acknowledges the individual and social dimension of bridging the gap between what already exists and the enactment of imagination (Caselli, 2009) whilst bearing in mind the impact of novel ideas.

Creativity in education

Approaches to creativity in education foreground a belief in the capacity of all children to be creative at an everyday level. Such approaches recognize that novelty may be applicable only to the creator(s) (Boden, 2004; Craft, 2000, 2001, 2002, 2005; Kaufman and Beghetto, 2009). Eisner (2004) has developed a powerful perspective that identifies children as creative meaning-makers particularly in and through the arts. The CREAT-IT approach encourages and supports children and teachers in their meaning-making and values the contribution of all educational participants. This is reflected in the CREAT-IT Pedagogical Principles, in particular (8) Empowerment and Agency, explained in part two. This view of children's creativity is recognized by Banaji et al (2010) as a 'democratic' approach which foregrounds capability in all children. The CREAT-IT approach draws on the following discourses of creativity in education identified by Banji et al (ibid): Ubiquitous Creativity, Play and Creativity, the Creative Affordances of Technology and The Creative Classroom.

Creative Teaching and Teaching for Creativity in Science Education

Effective science teaching harnesses positive, confident and enquiry-focused attitudes in children building on their inherent desire to make sense of the world around them (Rocard et al, 2007; Harlen, 2008), and combines these with increasing depth of understanding (Yeomans, 2011; Levy et al (2011). Like creativity, science involves both process and the foregrounding of curiosity. Therefore, fostering science creatively involves both nurturing creativity within the discipline and teaching it in a creative way (Lin, 2011; Chappell, 2007; Craft et al, 2013; Rojas-Drummond et al, 2006). Framing the CREAT-IT project is a recognition of both the distinction between teaching for creativity and teaching in a creative way, and also that where a teacher's creative abilities are properly engaged, the learners' creative abilities are also most likely to be developed; teaching for creativity *involves* teaching creatively (NACCCE Report, 1999). Effective scientific development involves an understanding of the nature of science and involves the inter-linking of procedural skills often involved in the inquiry process. Conceptual understanding leads to scientific 'literacy', which is combined with affective aspects, such as motivation and attitudes (Craft et al, 2013; Craft et al, 2011; Eisner, 2004; De Moss and Morris, 2008; Woods, 1995, 2002).

Partnership and Arts Creativity

Many studies have looked at the role of the artist in partnership with the classroom teacher (see Jeffery, 2005; Jeffery and Ledgard, 2009; Chappell, Rolfe, Craft and Jobbins, 2011). Thomson, Hall, Jones, & Sefton-Green (2012) frame their Creative Signature Pedagogies (CSP) by adopting the UNESCO framework referred to as the 'four pillars of learning for the 21st Century: learning to know, learning to do, learning to be, learning to live together' (UNESCO, 2008: 8). Chappell (2008) also offers detail of more interdisciplinary, three-way creative partnerships between artists, scientists and educationalists. The CREAT-IT approach actively promotes and encourages this cross-disciplinary way of working.

A European perspective: Key drivers and approaches.

Within Europe there are a number of incentives identified behind an increased focus on research and practice in science education (Craft et al, 2012; Rochard, 2007). Alongside the economic imperative and the global role played by science and creativity, digital platforms also offer rapidly developing new opportunities and spaces for expression, communication and assessment of learning (Rocard et al, 2007). There is also growing recognition of how capable children are and the importance of building on children's experiences and promoting positive dispositions and skills (Rocard et al, 2007). The project's pedagogical framework was developed with these drivers in mind to generate creative practice and creativity in European science classrooms.

Perhaps the most significant initiative in Europe, and internationally, in fostering creativity in science education has been Inquiry Based Science Education (IBSE). Inherently creative, IBSE focuses on investigations, driven by learners' curiosity and questions (see Rocard et al, 2007; Harlen, 2008; Levey et al, 2011), IBSE contrasts with traditional methods. Traditional methods are referred to as a 'deductive approach' (Rocard et al, 2007) or top down transmission, and involve the teacher presenting the scientific concepts and examples of their application. In contrast, IBSE is seen as 'inductive' or a 'bottom-up' approach, as pupils are given space to observe and experiment with their knowledge as teachers guide their learning. Harlen (2008) suggests three pedagogical strategies underpinned by the IBSE philosophy, for fostering learning in the primary classroom: social constructivist approaches to learning, inquiry based pedagogy and formative assessment of children's science learning. This philosophy is reflected in the Framework, CREAT-IT principles and pedagogies.

Complementary to these drivers and approaches, the CREAT-IT survey aimed to determine the main aspects of the creative science teacher role. This role was summarised by the emerging themes from the qualitative analysis under the heading "the creative science teacher is…". The themes that emerged were: -

- constantly developing - The creative teacher is aware they are never the finished product. For example: "this is a perpetual procedure of helping yourself be better and better. Teaching skills have no end. You can always be more sufficient than you used to be before" (general teacher, Greece).
- pupil focused and led - One of the key approaches to creative science teaching was seen to be encouraging children to try out their own ideas in investigations (51% of 83 respondants selected this when asked to select teaching approaches most likely to contribute to development of children's creativity in science.). It was the approach with the most selections from the UK and Greece, the second most selected item by Belgium, Italy and Serbia, and the third most selected item by Norway. Another key approach was children asking questions for the purposes of problem finding (selected by 43%).
- emotionally connected - It is the love of science teaching "I love teaching science and will try anything" (scientist/teacher, UK) and care for the pupils "I really care about [my pupils] and they feel that and they don't hesitate to express their thoughts and the difficulties" (general teacher, Greece) that motivates teachers to pursue creative teaching. There are also personal rewards: "Creativity in teaching makes me very happy. I know when I am really creative and I very much enjoy it (the whole process, from finding an idea, to making it happen in the classroom" (General teacher, Greece).
- motivated through prioritising and facilitating creative teaching - Teachers who feel skilled and confident in delivering science creatively 'are motivated educators' (general teacher, Greece). They prioritise creativity: "since I have started teaching I have always considered creativity a matter of the utmost importance" (scientist/teacher, Italy); this can be based on a perception, what

should be: “I have the perception science should be taught with a more effective approach” (scientist/teacher, Italy).

- collaborating with peers and pupils - There was a perceived need for collaboration for the purposes of exchanging of ideas; support; and aschieving high level outcomes. “I think that for creative education you need constant cooperation and exchange of experience among schools, students and professors” (General teacher, Serbia). Collaboration occurs between the creative science teacher and their pupils - “we [the creative teacher and their pupils] are a team that we are collaborating and trying for the best” (General teacher, Greece), “we worked together” (general teacher, Greece);

Other, less frequently mentioned themes included notions that the creative science teacher is experience seeking; confident to take risks; playful and flexibile; and independent.

The team were then able to draw on the perceived creative science teacher role when shaping the pedagogies and principles, explained in more detail in part two.

Although there is not the space to consider the detail of European curricula and good practice here, this can be found in Craft, Chappell and Slade (2014). Key examples of innovative approaches to fostering European creativity in science education include the three case studies adopted within the CREAT-IT Project, one of which will be exampled in relation to the principles later in the paper.

Tensions and dilemmas

Across the literature, teachers, schools and students were described as facing a number of tensions and dilemmas in implementing creative approaches to science: the traditional didactic style in science cultivates the perception of a non-creative subject (Schmidt, 2011); teachers might be eager to work in a creative manner but are unlikely to be liberated with out curriculum changes (Bore, 2006); primary teachers are generally not science specialists and lack time, confidence and expertise to work creatively (Levy et al, 2011; Marshall et al, 2009). Responding to this, attention needs to be paid to teacher training and professional development, especially at primary level, as science has the biggest and most impressionable impact on students at this age (Murphy, 2006; Wallace and Kang, 2004; Spronken-Smith et al, 2011). The accountability culture of schools has also been questioned (Sternberg, 2003: Maisuria, 2005; Beghetto, 2006; Schmidt, 2011), as teachers adopt a culture of what Ball (2000, 2003) refers to as ‘performativity’, which can dictate teacher practice, discouraging more innovative practice.

In considering IBSE, changes to inquiry-based science teaching will challenge the teacher's perception that scientific inquiry is not a solo action and requires students to work in collaboration if they wish to be innovative (Harlen, 2004). However, less able students might consider that the correct answer will come from the teacher rather than their investigation (see Levy et al, 2011; Craft et al, 2007; Dias et al, 2011; Wallace and Kang, 2004; Crawford, 2000).

Also, a number of studies suggest that there is a lack of understanding among teachers about what it means to be a creative science teacher (Schmidt, 2011; Dias et al, 2011). Across the literature (Kind and Kind, 2007; Shanahan and Nieswandt, 2009; Schmidt, 2011) there is a suggestion that inquiry-based learning can help students become more creative, but there appears to be a lack of analysis regarding how the arts and science can work together without using the arts in service of science (see Chappell and Craft, 2009). Chappell and Craft (2009) highlight that there is a need for clarity in purpose regarding arts/science integration – whether this is to foster creativity in science or arts or both. They also raise the question of whether creativity is really the same in the arts and the sciences.

All 130 participants were asked to discuss the barriers to creative science teaching in their country. Participants were asked to pick any of 8 listed items that applied, results for each item were totalled. When each country's most selected items are listed (those selected by 50% or more of the respondents from each country), the following patterns can be seen: teacher training approaches are seen as the biggest barrier to creative science teaching - all countries mention it as a barrier (though only 27% of UK participants did so); resources - all countries except Belgium and Italy mention it as a barrier; time (seen as a barrier by more than 50% of respondents from Greece, Italy and the UK); teacher motivation (seen as a barrier by Belgium, Italy and Serbia); curriculum constraints (seen as a barrier by 50% or more of respondents from the UK and Belgium); teacher confidence (only seen as a major barrier by the respondents from Norway). Others' opinion on how science in school should be taught and pupil motivation are not seen as a major barrier by any country.

Overall then the broader literature review considered the nature of creativity per se, whilst honing in on the tighter arena of 'little c creativity' within European education since around the turn of the century. It makes clear that the CREAT-IT approach acknowledges the breadth of creativity in education rhetorics that currently exist, as well as the tensions and dilemmas with which creative science teaching is fraught. The review focuses on key discourses that allow for teacher and student empowerment and agency, and acknowledge the meaning-making potential of the arts alongside the sciences, in partnership. The broader review also offers key insights into definitions of creative teaching and teaching for creativity in science education which the CREAT-IT approach acknowledges within its principles. The review considers IBSE too as a significant science teaching initiative across Europe alongside and within which CREAT-IT principles can be applied.

UoE Literature Review and Related Survey Responses

The second part of our literature review analyses UoE creativity in education theory supported by relevant survey responses. This builds on the breadth of the broader supporting literature above to develop the CREAT-IT framework and pedagogical principles detailed below. This UoE review includes the theories of living dialogic space (LDS), wise humanising creativity (WHC), possibility thinking (PT) and the 4Ps.

Living Dialogic Spaces

LDS are enquiry spaces, which are characterised by debate and difference, openness to action, working 'bottom up' and different modes of idea exchange (Chappell and Craft, 2011). Creative learning conversations are key to producing LDS and have a number of defining characteristics. They are: partial, emancipatory, 'bottom up', participatory; and feature debate and difference, openness to action and embodied as well as verbalized exchanges of ideas. In their most simplified form they involve two key activities (Chappell and Craft with Jonsdottir and Clack, 2009): re-positioning and listening-actioning. Re-positioning involves subtle shifts in relationship where school staff and students physically and metaphorically reposition themselves in their discussions. Once re-positioning has been achieved, listening and actioning in tandem can then occur.

Chappell and Craft (2011) offer an articulation of how LDS are related to the spatial ideas of Lefebvre (1991), Bakhtin's discussion of dialogue (1984), and Bronfenbrenner's ecological model. In applying LDS to the CREAT-IT pedagogical framework it is vital therefore that the right kinds of spaces and dialogues are created to continue generating new and provocative questions. In so doing the intention is that the framework will be able to take advantage of the best the arts has to offer, to create space for partiality, potentially contradictory representations and to create 'living' dialogic spaces.

Wise humanising creativity

WHC is a blend of wise creative trusteeship (Craft, 2008) and humanising creativity (Chappell with Craft, Rolfe and Jobbins, 2012). Wise creative trusteeship means that creators need to take care of what matters to them and their community and is positioned against marketized, individualized and culture-blind creativity. Humanising creativity emphasises individual, collaborative and communal engagement and the humanising process via shared ownership, group identity, empathy, conflict and difference. At the heart of humanising creativity is the embodied dialogic generation of ideas between the creator's inside and the outside which opens up new possibilities and a strong cyclical connection between creativity and identity which is grounded in a thinking, moving bodymind (Chappell et al, 2012). This cyclical relationship means that in the process of making, creators are also being made; they are their creations and they go on a humanising journey of becoming because of this (e.g. Chappell, Swinford, Pender and Ford, submitted).

Figure 2: the interrelationship of creativity and identity

It is this conception of humanising creativity, with the addition of wisdom, which blends into *wise humanising creativity*, one of the main creativity theories used within the CREAT-IT framework. The pedagogies associated with WHC from empirical study are: giving students an active voice *alongside* adults, allowing students to take on different identities and leadership roles, valuing a shared creative group identity, understanding that practice was a joint journey of discovery; creating new emergent possibilities through giving and sharing knowledge; and co-constructing teaching and learning.

WHC and Quiet Revolutions

Quiet revolutions emerged as a partner concept to WHC (Chappell and Craft, 2011; Chappell et al, 2011) as a means of connecting creativity and social change. It derives from the same vein of thinking, which generated WHC as a response to overly marketised and globalised conceptualisations of creativity. The idea of 'quiet revolutions' builds on alternative educationalists' work (Fielding and Moss, 2010), and arts education philosophy (Eisner, 2004). They argue that grand revolutions are not the best way to marry up personally-held and societally-useful values (Inayatullah, 2008) and that a more effective approach is to determine what education is for and then take a bottom up approach to instigating change, an "incremental, cumulative and reactive process" (Fielding and Moss, 2010: 2). It is this 'bottom up' approach, which defines Quiet Revolutions via which change towards different educational futures happens. In developing the CREAT-IT pedagogical framework informed by WHC and LDS there is therefore an in built assumption that Quiet Revolutions of one form or another will ensue.

Possibility Thinking

PT is a different way of considering creativity to WHC from within the Exeter team and is derived from a more psychological and pragmatic viewpoint (Craft, 2001). Cremin, Craft, Clack, Scheersoi and Megalakaki (2012) draw together a useful PT research summary. They detail work which theorized and then empirically established the concept in England (Burnard, Craft, Cremin, Duffy, Hanson, Keene, Haynes and Burns 2006; Chappell, Craft, Burnard, Cremin, 2008; Clack, 2011; Craft, 1999, 2001, 2002; Craft, McConnon and Matthews 2012a; Craft, Cremin, Burnard, Dragovic and Chappell 2012b; Cremin, Burnard and Craft, 2006), Cyprus (Aristidou, 2013) and Taiwan (Lin, 2010, 2011; Ting, 2013). At its simplest PT is about posing 'as if' and 'what if?' questions involving both solving and also finding problems (Craft, 2014), in learning contexts encouraging immersion and play. The core features can be seen in Figure 3. Craft, McConnon and Matthews (2012) using Chappell's (2008) framework have since identified peer collaboration as an emergent PT feature, and Cremin, Chappell & Craft (2013) have articulated the importance of narrative to PT and its pedagogies.

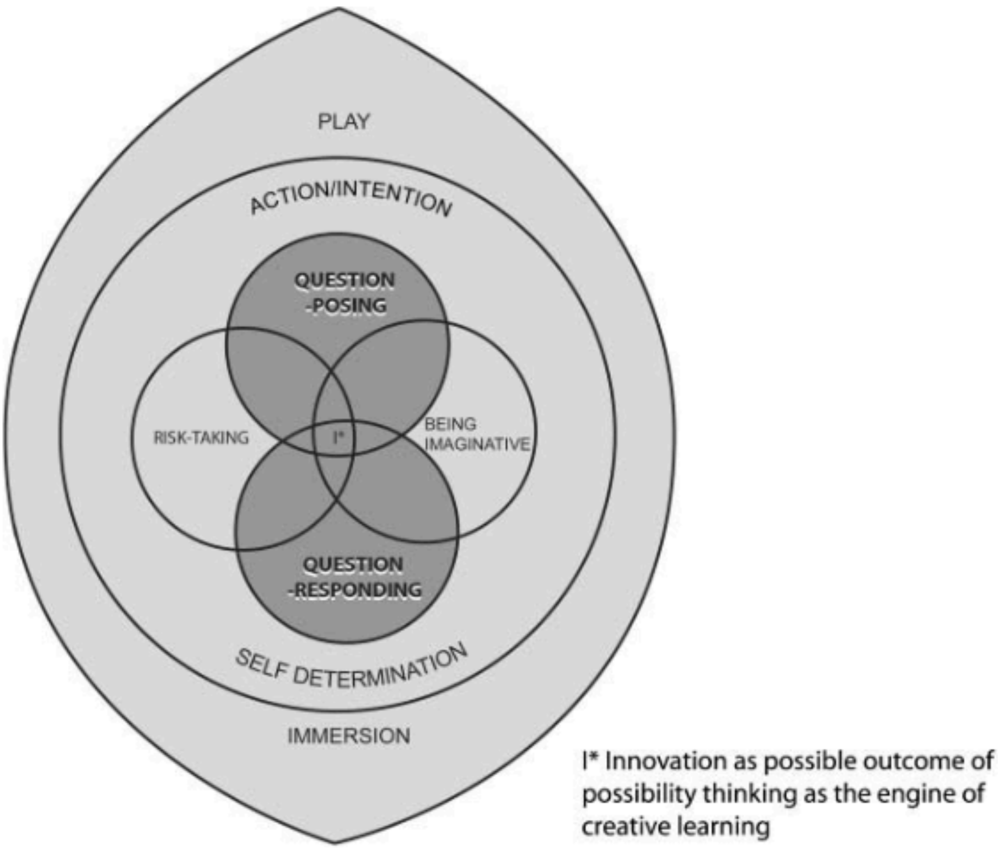

Figure 3: Question-posing and responding and context

The main PT pedagogies (Cremin, Burnard and Craft, 2006; Figure 4) involve adults placing a high value on enabling children's agency through 'standing back', offering children both space and time to develop their ideas.

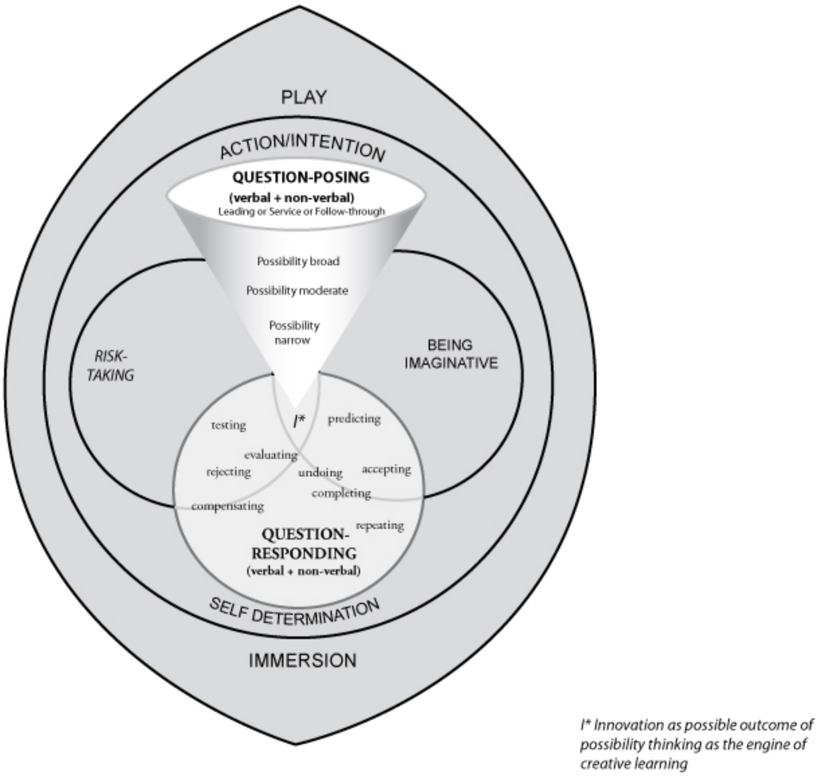

Figure 4: Pedagogy nurturing possibility thinking

Craft et al. (2012) have since also suggested drawing these pedagogies together under the umbrella of 'meddling in the middle' or co-constructing alongside and with children (see Figure 5).

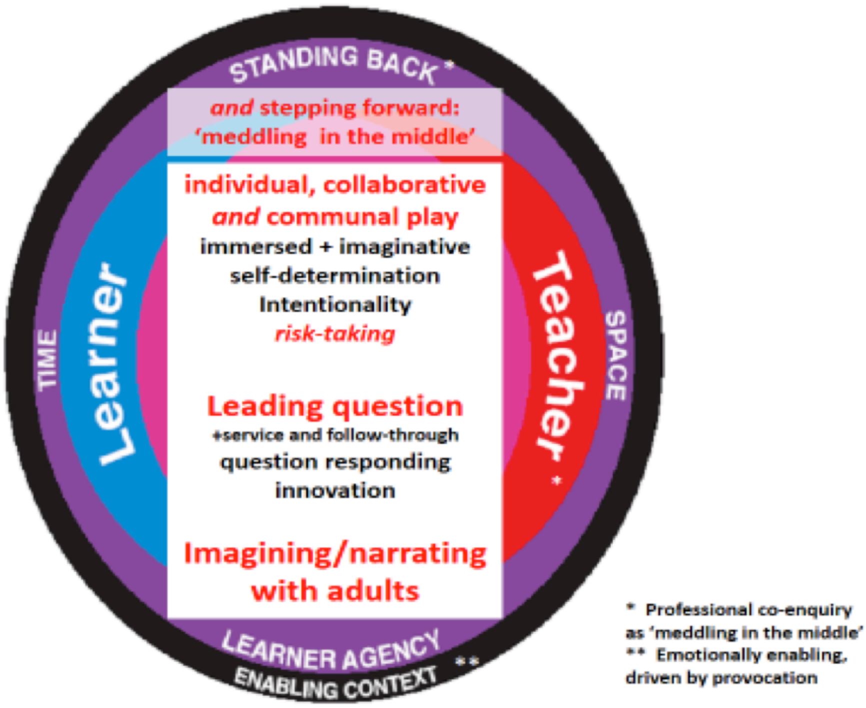

Figure 5: Professional co-enquiry as meddling in the middle

This work provides another conceptual strand for the CREAT-IT pedagogical framework. How it might contribute to framing pedagogy alongside details of the similarly empirically researched WHC pedagogies detailed above is particularly pertinent.

WHC, Quiet Revolutions, PT and the 4Ps

Above, are reviewed the main UoE team's ideas on offer to the CREAT-IT project: LDS, WHC, Quiet Revolutions and PT. In some studies WHC (Chappell et al (in preparation[ii]) and PT (Craft, et al, 2012) remain separately conceptualized. However in some recent work, WHC has been placed in different relationships with PT and Craft's (2011) notion of the 4P's to inform theory development and practice. Brief details of the 4Ps will be offered first in order to provide the final piece of background to the theoretical interactions that follow.

Craft (2011) proposed the 4Ps, responding to questions about the future of education in times of rapid and uncertain change. Craft (2011) suggests that we use the '4Ps' to navigate this problem. She argues that we need to encourage "Plurality of identities (of people, places, activities and literacies), Possibility-awareness (of what might be invented, of access options, of learning by doing and of active engagement), Playfulness of engagement (the exploratory drive), and Participation (all welcome through democratic, dialogic voice) (Craft, 2011: 33). These 4Ps have been integrated in different ways in different projects with WHC, PT and LDS.

In the C^2Learn project, which aims to foster creativity in learning through digital games (Walsh, Chappell and Craft in development; http://www.c2learn.eu), PT's 'what if' and 'as if' questioning is the process through which C^2Learn co-creativity emerges, with WHC seen as the main manifestation of co-creativity within the gaming environment, which leads to quiet revolutions. In the C^2Learn framework the 4Ps are embedded within that environment.

Alongside the team's collaborative work, Craft (2012, 2013) has also integrated PT, WHC and the 4Ps differently to make arguments for how children and young people can navigate the digital age. She turns to WHC to make the argument for considering the ethics and consequences of the creativity that is generated by PT, alongside which she argues for co-creating students' educational futures with them through dialogue and the 4Ps.

This line of theory integration developed by Craft alongside the team's collaborative work therefore provided a very useful example to the CREAT-IT team of how the UoE team's theories might be interrelated in a global way. The challenge was to take the essence of the UoE team's ideas and develop a conceptual framework, which is most appropriate in the new context of arts/science teaching and learning within science education.

Survey outcomes were also useful when considering how UoE theory combined into the CREAT-IT project. The survey outcomes, detailed above, of a creative science teacher perceived as constantly developing, pupil focused, positive and encouraging, had strong resonance with the WHC idea of Journeys of Becoming. A teacher nurturing this kind of ethically-focused creativity, who is therefore open to the creative process contributing to whom his/her students are as people, would seem likely to acknowledge this process of becoming in themselves too (e.g. Chappell et al, 2012) potentially contributing to changes in how science is taught.

The perception of creative science teachers who are pupil-focused and motivated connects to agency, which is strong both within WHC and PT. The survey outcomes above also shows that creative science teachers are perceived as emotionally connected and collaborative; this connects to the role of emotional ups and downs in WHC. Another survey/literature review resonance is that the survey showed that seeking experience, often in the arts was another characteristic of a curious creative science teacher. This perhaps connects most strongly to the 4Ps notion of plurality, seeking meaning through different perspectives. Cross-curricular learning (62% of 130 respondents selected this as an example of good practice, 69% of 109 respondents selected it as a teaching approach they use quite often/very often) and enquiry-based learning (used quite often/very often by science teachers -between 71-87% of 109 respondents selected these as elements of teaching approaches they used often) emerged as survey themes, which resonates with CREAT-IT arts/science integration.

Finally, the survey offers a range of strategies, which were considered important for science teachers to teach for creativity. Project Deliverable 2.1 (Craft, Chappell and Slade, 2014) carried out a detailed thematic analysis of the commonalities between the emergent survey pedagogies and those from UoE theory, demonstrating strong links. The main common pedagogies were: valuing agency, space for cross-curricular knowledge, possibility-open teaching and learning, balancing freedom and control, collaborative working.

So, drawing together the supporting detail of the broader literature review, the focused detail of the UoE literature review and the supporting survey outcomes, the CREAT-IT framework and pedagogic principles were developed. These are presented next.

New pedagogical framework and principles

The project's pedagogical framework (Figure 6) and principles were developed with the aim of promoting a school science teaching pedagogy that can utilize creativity (see discussion of 'little c' creativity in broader literature review). The framework acknowledges what is known about creative teaching and teaching for creativity (see broader literature review section) and the best of integrated science/arts processes (see broader literature review *Partnership and Arts Creativity)* to actively engage students and improve their conceptual understanding in science. The proposed pedagogies aim to enable teachers to either create new creative activities or to properly assemble different educational activities that are identified as creative (e.g. science cafes, science theatres, science operas) into interdisciplinary learning scenarios.

At the very centre of the CREAT-IT framework are the case study scenarios and the accompanying pedagogic principles. Whilst this paper focuses on reporting the development of the framework and principles, our ultimate aim as a consortium is to be able to describe and inform these case studies via the above theories in order to generate creative practice and creativity in science classrooms across Europe. The figure below therefore represents our understanding of how the theories and ideas can be synthesised together conceptually, uniquely for CREAT-IT in order to achieve this.

The figure positions creative science education as the main CREAT-IT context which will incorporate existing practices in this area such as IBSE (see broader literature review *Key Initiatives)*. At the bottom of the page arts education philosophy and methods are positioned as a 'holder' within which creative science education (as opposed to all science education) is being nurtured via the kinds of arts practice discussed above in *Partnership and Arts Creativity*, and found in the 3 case studies. As we move in towards the centre of the figure, one of the main drivers is possibility thinking (see UoE literature review) for all involved. This means being able to ask 'what if' and 'as if' questions. For example: what if I/we use this arts approach to help me explore my scientific question...? How can I/we imagine this as if I were…? This will be strongly encouraged in the way the CREAT-IT pedagogic principles are employed.

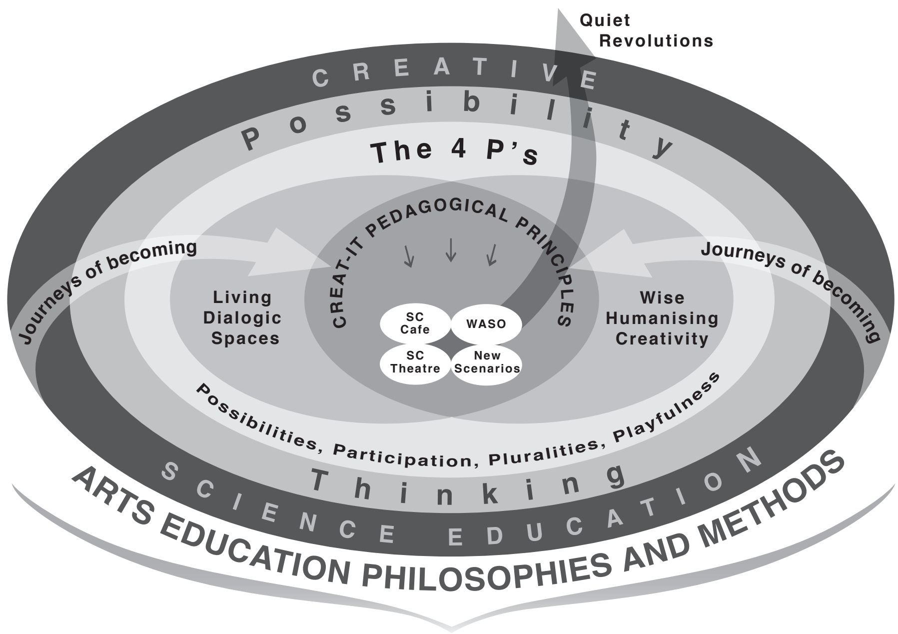

Figure 6: Integrated CREAT-IT theories and practice

As we move in another layer towards the centre of the figure, we see the 4Ps of engagement in creative science education (see UoE Literature Review section). This means that the arts/science integration with the CREAT-IT pedagogies will offer opportunities for science learners and adult professionals to experiment with: pluralities (of e.g. places, activities, personal identities); possibilities (possibility thinking in open possibility science spaces); participation (make themselves visible on their own terms, and act as agents of change); playfulness (in learning, creating and self-creating in emotionally rich, learning environments).

We then come closer to the figure's heart and find WHC and LDS (see UoE Literature Review section). The individual and collaborative creative activities of WHC form part of a wider web of ethically-guided communal interaction geared towards both helping children and young people become more creative scientists and assisting teachers in becoming more creative in how they teach science (see *Creative Teaching and Teaching for Creativity in Science Education* above). LDS is always a partner to WHC in terms of conceptualising ideas and developing practice. WHC and LDS are both positioned very close to the heart of the CREAT-IT figure, as WHC is one of the core aims of the CREAT-IT pedagogic principles.

Embedded within this is the aim that learners and adult professionals are creating wisely and humanely, and that this cyclically develops their creativity and identity. As they generate new ideas; this in turn generates change in them as 'makers'; they are 'becoming' themselves i.e. 'journeys of becoming' (shown developing across the layers in the figure). These individual journeys accumulate together into 'quiet revolutions' (shown as emerging from the heart of the CREAT-IT activity), which are embedded within an ethical awareness of the impact of creative actions on the group. This connects strongly to the identified need for change in science education (European Commission, 2004; Archer et al, 2013a).

Returning to the centre of the figure then, we see the pedagogical principles acting on or via the case studies. The principles are a distillation of the main drivers of the UoE theories into a form that is applicable to this science/arts context, simplified just enough for ease of application in day to day teaching practice. The principles are underpinned by recognition of Professional Wisdom (Platt, Wright and Chappell, 2011). This means that it is vital that CREAT-IT practice has at its heart the deeply contextualized knowledge often informed by intuition that constitutes practitioners' discipline knowledge and teaching expertise. This needs to be in constant conversation with CREAT-IT ideas and theories.

With this underpinning, the final 8 principles are described below. While it is impossible within a short paper to describe the exact lineage of each principle, the articulation below is preceded in the earlier parts of the paper by a building argument for the kinds of creative science pedagogies that the literature and survey show that Europe needs. Each principle is described and then connected into the main UoE theories above from which it is derived, relevant broader literature review ideas above, which support it and relevant survey outcomes.

1. **Individual, collaborative and communal (ICC) activities for change**: CREAT-IT pedagogies encourage all three ways of engaging, especially communal engagement can take advantage of the shared identities within which participants will work in the arts, allowing for difference but with a shared creative process and purpose. This applies the ICC framework at the heart of WHC (e.g. Chappell et al, 2011), which the Exeter team have also applied in some PT work (Craft et al, 2012). It is supported by the suggested need (Harlen, 2010) for a more civically focused science-informed European citizen of tomorrow. In the survey there was a perceived need for collaboration especially for the purposes of exchanging of ideas; support; and achieving high level outcomes. "I think that for creative education you need constant cooperation and exchange of experience among schools, students and professors" (General teacher, Serbia); "my support network at the school, [my] mentors etc, are phenomenal…I have much to inspire me here. The team…give you all the support you need to get creative in the classroom" (scientist/teacher, UK).

2. **Risk, immersion and play**: CREAT-IT pedagogies facilitate all three processes and encourage teachers to recognise how pedagogy can assist in creating literal space as well as 'thinking' space for these. The PT theory contains these 3 inter-related core features and argues that they are key to creativity (e.g. Craft, 2002; Craft et al, 2012). This principle is also reinforced by the survey, 52.3% of participants selected 'risk, immersion, play' as a facet of 'good practice' in creative science teaching, and by arguments in the broader literature review for the use of more risk-focused techniques, such as IBSE, driven by student curiosity (e.g. Levey et al, 2011).
3. **Dialogue**: pedagogies allow for dialogues between people, disciplines, creativity and identity, and ideas. They need to acknowledge embodiment (i.e. dialogue is not simply a verbal activity) and difference and allow for conflict (Chappell, 2008). This draws strongly on the WHC and LDS theories (e.g. Chappell & Craft, 2011). It is important to facilitate open discussion of the pupils' questions (bottom up), a strong driver from the Quiet Revolutions idea (Chappell et al, 2011) and bring these into dialogue with live questions from professional science and science education (top down) within techniques like IBSE (e.g. Rocard et al, 2007). Survey outcomes also supports this, for example, a general teacher from Italy described how peer discussion can result in the "consideration of ideas different from [the individuals] own". When asked to select approaches that were creative science teaching, over a third of 83 partcipants selected 'fostering classroom discussion and evaluation of alternative ideas'. "Person to person" relations were also seen as a good practice in terms of creativity in science education by a curriculum developer/teacher from Greece.
4. **Interrelationship of different ways of thinking and knowing**: CREAT-IT pedagogies allow space for multiple different ways of thinking (e.g. problem-finding, problem-solving, exploring, rationalizing, reasoning, reflecting, questioning, experimenting) focused around shared arts/science threads. This draws strongly on understanding of *Partnership and Arts Creativity* (e.g. Thomson et al, 2012; Chappell et al, 2011), as well as arguments for science education helping children make sense of the wider world around them (Harlen, 2008). At the arts/science interface they can also offer the space for three different ways of knowing (knowing that - propositional knowledge, knowing how - practical knowledge, knowing this - aesthetic or felt knowledge – Reid, 1980), as well as acknowledging the embodied alongside the verbal. The survey suggested that creative science teachers engage with different ways of knowing, by encouraging different ways of recording and expressing ideas (two fifths of 83 respondants selected this as an approach to creative science teaching). It also suggested that there is some evidence that the creative science teacher is experienced, but the experience can be related to a wide variety of fields,

not necessarily soley science related. Experiences mentioned were vast and varied; from degree level study in science, to regular leading of science festivals; from the teacher who is not a trained scientist but has "much experience in the field of creativity in science education"; from the "outstanding" science teacher to the active painter/musician.

5. **Discipline knowledge**: CREAT-IT pedagogies respect rigorous sciences and arts discipline knowledge (learning from studies in *Partnership and Arts Creativity* above*)*, as well as understanding the importance of materials relevant to those disciplines (e.g. bodies, props, paper and pencil, IT, sculpting materials, test tubes, chemicals, equations). The CREAT-IT framework also acknowledges that creativity might manifest within these disciplinary knowledge bases differently (referring to different rhetorics of creativity as laid out by Banaji and Burn, 2010), albeit in the context of science education. In the survey 62% of 130 respondents selected cross-curricular learning as an example of good practice, 69% of 109 respondents selected it as a teaching approach they use quite often/very often)) A concrete example was given by a curriculum developer/teacher from the UK who described a creative science lesson linked to English. Using a range of artistic materials and electrical equipment "children worked in pairs, first to create a circuit to light the bulb, then use this knowledge to make a torch for a story character". Using the Arts (eg to give metaphors/physical form) to shed new light (60% of 130 respondents selected this as an example of good practice)
6. **Possibilities**: CREAT-IT pedagogies allow for multiple possibilities both in terms of thinking and spaces, and teachers know when it is appropriate to narrow or broaden these. This derives from Craft's (2000, 2014) PT theory, and her later development of the importance of possibilities within the 4Ps (Craft, 2011). This is supported in the survey, for example, where the word "endeavour", used by a general teacher from the UK implies a constant searching and developing of new possibilities: "I endeavour to find creative ways of teaching science and inquiry skills within the creative curriculum", and a general teacher from the UK agreed that "science should engage children in possibilities whilst broadening their experience and understanding of scientific concepts through collaborative exploration".
7. **Ethics and trusteeship**: CREAT-IT adult professionals and learners consider the ethics of their creative science and are guided in their decision-making by what matters to them as a community, acting as 'trustees' of that decision-making and its outcomes (e.g. Craft, 2013; Chappell et al, 2012; Craft et al, 2013). This derives strongly from WHC, and relates to the suggested need (Harlen, 2010) for a more civically focused science-informed European citizen of tomorrow. This is the one

principle that was not actively supported in the survey outcomes, despite the strength of its emergence from within the UoE theories and support in the wider literature review. This will be a key area to attend to in the next research stage to understand whether it resonates or not with practicing teachers.

8. **Empowerment and agency**: through empowering pedagogies (derived from LDS, Chappell & Craft, 2011), CREAT-IT can allow both learners and adult professionals to gain a greater sense of their own agency (key feature of PT, e.g. Craft, 2002) and ability to express themselves (key feature of Arts Creativity, e.g. Chappell, 2008), and to then know how to use that in order to be more creative scientists and science teachers (applied within IBSE, e.g. Levy et al, 2011). Enabling pupil agency and encouraging children to try out (and critique) their own ideas in investigations were recognised within the survey by some respondents (although this was only 8%). Despite this there were examples of this as part of the creative teacher profile: "we [the creative teacher and their pupils] are a team that we are collaborating and trying for the best" (General teacher, Greece). And, as stated above one of the key approaches to creative science teaching was seen to be encouraging children to try out their own ideas in investigations (51% of 83 respondants selected this when asked to select teaching approaches most likely to contribute to development of children's creativity in science.). There seems to be contradiction within the survey, and as with the previous principle it will be key to understand how this can manifest in practice, in order to allow for pupil empowerment without threatening teacher role.

Application of principles within case studies

Following on from the development of the CREAT-IT framework and principles, these were applied hypothetically, to the three existing case studies of creative science practice: Write a Science Opera, Science Theatre and Caffè Scienza Junior. It should be noted that the second phase of the project was to apply the principles in practice within the case studies, however as this paper focuses on the development of the new principles, the outcomes of this practical application are not reported here. When each case study is analysed in relation to the principles, the latent potential for creativity in arts/science partnerships is brought to the fore because of the principles' strong grounding in rigorously researched creativity in education theorising. It is intended that the case study practices will be taught to teachers with the principles at the fore. This will be with the aim of gaining the most possible from the arts and science practices, and their capacity to nurture creativity within science education. The WASO example of the hypothetical application of the principles to a case study is provided next.

WASO is a creative professional development approach to inquiry-based art and science education in which different aged pupils create an operatic performance, supported by teachers, opera artists and scientists. Focused on science discovery in a creative framework, WASO uses a scientific theme that is the current learning focus to inspire a multi-disciplinary artistic project. Characters, libretto, composition, stage design, costume, as well as public relations and budget are designed by the pupils and realized during the project.

WASO is an application of the widespread Write an Opera method, which has been successfully implemented in many countries during the past three decades. The WASO approach leads an inquiry-based creative process demonstrating common impulses shared by the sciences and the arts (Garoian & Mathews, 1996).

When the WASO approach is analysed in relation to the Pedagogical Principles, they can be seen to emerge as follows. The WASO approach allows for multiple *possibilities* (6) as it provides platforms for reaching beyond a narrow view of what may be 'right' or 'wrong' in favour of a more flexible arts-driven process. *Risk, Immersion and Play (2)* are fundamental to the opera processes which value these and make them more acceptable during the adjoining science learning process. Connecting science and art learning enables the integration of emotional and aesthetic elements of science to be acknowledged. This therefore allows for the *interrelationship of different ways of thinking and knowing (4)* from the two disciplines. This provides a much-needed deeper emotional and cultural interaction with *discipline knowledge* (5) particularly because of the immersed intensity of this kind of project-based learning. *Ethics and Trusteeship (7)* are engendered via respect for other participants' creative ideas; a wise, humanising approach which differentiates between ideas on the grounds of 'what matters' to create the Opera to honour science and arts knowledge, rather than competition or dominance. In WASO, allowing learners and professionals to gain a greater sense of their own agency via the arts process and into their manipulation of science knowledge encourages *empowerment and agency (8)*. And, *Individual, Collaborative and Communal activities for change (1*) are nurtured within WASO which requires individual and collective idea generation and a solution finding process, which is dialogic in nature (*Dialogue, 3)*. The dialogue at the heart of WASO's democratic process is not always reconciliatory; ideas may proceed alongside conflict and difference.

Following this exercise, once the case study practices had been analytically integrated with the principles, the consortium partners leading each case study tried out the three combined approaches in practice. A template for teaching the case study approaches was developed (Hennessy & Slade, 2014) which could be used in professional development events with science teachers. Although there is not the space in this paper to detail this further, it is important to note that 45 teacher training workshops were then run in 6 countries, involving 330 science teachers. These are being evaluated by Center for Promotion of Science (CPN), Serbia. This means that the CREAT-IT pedagogical principles are integrated into the case studies within teacher professional development across Europe, and tracking their reception and potential use by European science teachers is the next vital part of this project.

Conclusion and Implications

Looking across the CREAT-IT research project thus far, we can currently offer a new pedagogical framework which integrates understanding of arts and creativity in education into science teaching and learning. It is grounded in two systematic literature reviews, a focused pan-European survey, and analysis of existing good practice.

The project provides a unique synthesis of the broader European literature on science, arts and creativity in education in relation to creativity in science education, with a body of work from a leading team of creativity in education specialists from UoE. The synthesis is confirmed by results from the accompanying survey. Even without their application into practice, the synthesised literature and the ensuing framework and principles have implications for the field. They offer a view of creativity in science education that takes into account arguments against purely marketised, cognitive notions of creativity (e.g. Seltzer and Bentley, 1999 cited in Banaji and Burn, 2010), and focuses on more humane and potentially sustainable understandings of creativity. With the European Commission (2004) stressing the need for a more scientifically literate population, and democratic citizenship, alongside the need for creative and innovative scientists (European Commission, 2004), this new framework provides a means to develop creativity in science through theory-derived principles which address this. In particular, the principles of dialogue, ethics and trusteeship, and empowerment and agency offer a means for a more democratically creative approach to science teaching and learning towards the informed and creatively science literate citizen of tomorrow. At the same time, the way in which the principles stress the importance of discipline knowledge, risk and different ways of knowing simultaneously encourages students who might be the next 21st Century creative scientist.

Theoretically the literature review offers insight into how creativity in science education might be thematically considered. Using the UoE team's experience of researching creativity in education and their reading of the wider literature, their analysis offers key areas which are worthy of attention in future work in this area. These are: awareness of the multiple rhetorics of creativity and how these can be applied differently to science education; the importance of understanding the distinction between creativity teaching and teaching for creativity; how creative partnerships between the arts and sciences might be conceptualised; and the acknowledgement and identification of the key tensions and dilemmas when considering the nature of creativity in science education.

Also the emphasis within the framework per se on arts and science education partnerships responds to Archer et al's (2013) call for science to be seen as a useful grounding for other careers and life in general. By placing it within an interdisciplinary context in this way the framework removes science from 'geeky' isolation (Archer et al, 2013) and has the potential to shift both teacher and student perceptions of what science can be. Also Rocard (2007) has argued that the motivational potential in science education is often not activated. This framework and these principles, taken into practice via the case studies again have the capacity to address this issue by offering an approach which, through the principle of Empowerment and Agency aims to harness students' own curiosity about scientific issues and use these as a starting point rather than start from the 'top down' with given scientific knowledge as in a more traditional approach to science teaching.

As the research project develops, over 330 science teachers are experiencing the framework and its pedagogies. Emergent findings suggest that science teachers use the framework well when CREAT-IT arts activity and principles are explicitly related to curriculum learning objectives, when they are embedded evaluatively throughout planning activities, and adapted into school's own planning templates. Teachers and students also need to overcome self-consciousness to make activities familiar. Early indications show that CREAT-IT's unique characteristic of combining the arts and sciences in education with the additional layer of the pedagogical framework do break new ground in developing creative science teaching and learning. It seems that the CREAT-IT pedagogies act as a bridge between the disciplines in order to move beyond the stalemate recognised in the introduction and literature review of this article.

CREAT-IT therefore has the potential not only to contribute significantly to conceptual framing of creativity in science education, through its new framework, but also to contribute to developing create science teaching, and potentially learning, across Europe. The intention is that the principles can do so by further catalysing existing good creative science teaching, as well as giving less-experienced science teachers the confidence to try this new approach and other existing approaches associated with it (e.g. IBSE). The implications of this new framework for the educational future of creative science teaching are that because of the scale of the CREAT-IT research and application across at least 6 European countries, the approach will be able to contribute to: shifting perceptions and practice of science education as uncreative (European, 2006, Archer et al, 2013a); motivate more young people into science education either towards undertaking science careers or being science-informed citizens (European Commission, 2004, Rocard, 2007). It is also hoped that the research will contribute to developing the nuance of understanding the interrelationship of the arts, sciences and creativity within education in order, both to develop creative science teaching and learning, but also to develop practice at the arts-science interface that moves beyond the instrumental.

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Figure caption(s) (as a list).

Figure 1: Definitions of creativity From http://www.creative-little-scientists.eu/node/57 (9th May 2014)

Figure 2: the interrelationship of creativity and identity

Figure 3: Question-posing and responding and context

Figure 4: Pedagogy nurturing possibility thinking

Figure 5: Professional co-enquiry as meddling in the middle

Figure 6: Integrated CREAT-IT theories and practice

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[i] http://www.britishscienceassociation.org/creststar

[ii] http://www.thecarouselproject.org.uk/our-impact/current-projects/round-round-you-turn-me/