# International Educators' Perspectives on the Purpose of Science Education and the Relationship between School Science and Creativity

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# International Educators' Perspectives on the Relationship between Science and Creativity

**Background**: Creativity across all disciplines is increasingly viewed as a fundamental educational capability, and science is seen as playing a potentially important role in the nurturing of creativity. Creative pedagogy, including interdisciplinary teaching with Science and the Arts, is also seen as a way to better engage students with science. Previous studies into teachers' attitudes to the relationship between science and creativity have been largely situated within one educational context.

**Purpose**: This study, part of the large-scale EU funded CREATIONs project, explores educators' perspectives on the relationship between Science and Creativity across a national contexts drawn from Europe and beyond, and across different phases of education.

**Sample and Methods**: 270 educators, broadly defined to include primary and secondary teachers, trainee teachers, information educators and teacher educators, responded to a survey designed to explore attitudes to the relationship between science and creativity. The elements of the survey reported here included Likert-scale questions, open response questions, and ranking questions. Exploratory factor analysis was used to develop a combined attitude scale labelled 'science is creative', with results compared across nationalities and phases of education. Open question responses were analysed thematically to allow more nuanced interpretation of the descriptive statistical findings.

**Results:** Our findings show broad agreement internationally and across phases that science is a creative endeavour, with a small number of educators disagreeing overall particularly in England and Malta. Despite the general consensus, the role of scientific knowledge within creativity in science education is more contentious, particularly amongst Secondary Science teachers.

**Conclusions:** That Educators broadly see science as creative is unsurprising, but initial exploration of educators' perspectives internationally shows some areas of difference, particularly with respect to the role of knowledge with respect to creativity in science. With current interest in STEAM education, further investigation to understand the mediating factors of national educational contexts on teachers' attitudes, particularly with respect to the role of disciplinary knowledge(s) in creativity and their interaction in interdisciplinary teaching and learning, is recommended.

Keywords: creativity; science education; scientific inquiry; scientific knowledge

## Introduction

This paper reports on a study that explores some international perspectives on the relationship between creativity and science, offering an opportunity to compare educators' points of view across primary, secondary and informal settings and those involved in teacher education as well as between educators working in distinct national contexts.

Creativity is viewed as increasingly important to cultivate through education due to its relationship with successful negotiation of economic change (Banaji, Burn and Buckingham, 2010). Governments spend large sums to support its nourishment (for example, the UK government's £2 million investment in developing creative skills and career support in education (DCMS, 2018). Creativity across all disciplines is increasingly viewed as a fundamental 21st Century educational capability, evidenced by its planned inclusion in the 2021 PISA test (OECD, 2015). In terms of research, creativity in education and learning, including science educational research, has attracted increasing interest in recent decades (Hadzigeorgiou, Fokialis, and Kabouropoulou 2012).

Many authors see an important role for science in the nurturing of creativity in general, and a domain-specific 'scientific creativity' in particular (Meyer and Lederman 2013), suggesting that teaching for scientific creativity is claimed to be more likely to engage students' with the subject. However, these claims largely rest on studies of creativity in science from particular countries and may thus be influenced by the curriculum or typical pedagogical approach taken within that context, for example with respect to the balance between direct instruction, inquiry or practical work. Any given cultural, educational and political context may shape a particular rationale or purpose for teaching science and thus affect the views of educators with respect to creativity and science. This raises the question of whether educators working in different contexts have similar or different beliefs about, and approaches to, teaching for creativity in science.

The study reported here was conducted as part of the EU funded CREATIONS Project (http://creations-project.eu) which itself aimed to better engage science students in science using creative and arts-based approaches. Within CREATIONS, the work reported here sought educators' views about creativity in science from across a range of roles and nationalities, addressing the gap in the literature identified above. The findings informed the framework for the design of a range of creative and arts-based teaching and learning activities in science, labelled in the project as 'demonstrators', designed to be used across national contexts to foster engagement in science and the development of students' creativity.

In carrying out the research we developed a survey with both quantitative and qualitative items. Through exploratory factor analysis, we developed a combined scale to explore attitudes to 'scientific creativity', which we then used in analysing our quantitative data. Qualitative data were explored thematically and synthesised with the quantitative findings to add depth and richness to our understanding. Our findings suggest that there is broad agreement that there is a relationship between science and creativity amongst formal and informal science educators across a range of national contexts and phases of education: not surprisingly, science is seen as a creative endeavour.

However, some differences were apparent in beliefs about the purpose of science education, particularly with respect to the relationship between scientific knowledge and scientific creativity. Of key interest is that the relationship between beliefs about knowledge and creativity in science education, the enactment of teaching for creativity in science and the employment of creative pedagogies appears rather complex and may be mediated by contextual factors such as the curriculum.

In this paper, we summarise key literature in creativity in science education that framed the study before explaining the development of the instrument used and analytical approach to quantitative and qualitative elements. We then present the findings and explore them in relation to three key themes: the relationship between science and creativity, the role of knowledge in scientific creativity, and the role of scientific creativity within the purpose of science education. We believe that this study, which is unique in looking at educators' beliefs in a range of national contexts, adds a new dimension to existing research about creativity in the context of science education.

## Creativity in Science Education

Creativity is a term commonly used and understood, linking novelty, innovation and imagination: it is about the production of new ideas or artefacts (Robinson, Minkin, and Bolton 1999). Runco and Garrett (2012) highlight that in general, creativity requires both originality and usefulness, so that the creative output has meaning. Originality and utility can be linked to the cognitive concepts of divergent and convergent creativity: novelty, or originality, relates to divergent creative thinking and imagination, whereas convergent creative thought allows for the analysis and synthesis of these ideas to ensure the utility of the idea or artefact produced (Cheung et al. 2016; DeHaan 2011). Knowledge plays a role in creative thinking by mediating creative ideation (Runco and Chand 1995). The role of complex thinking and feeling and involvement in real challenges (Treffinger, Isaksen and Firestein, 1983, cited in Fasko 2001, 319), linked to motivation, is also deemed important in cognitive views of creativity.

Banaji, Burn and Buckingham (2010) place the concept of creativity within a sociocultural context and review its development over time. Their report found that ideas around the nature of creativity have shifted from 'big c' creativity; relating to genius, culture changing creations such as the great masters' art work or paradigm shifting scientific theories (Kuhn 1970), to 'little c' creativity relating to everyday problem solving which everyone possesses and can be developed for personal, rather than cultural impact (Craft 2001). Within 'little c' creativity, dialogue is argued to be an important aspect of what Anna Craft defined as 'possibility thinking', this is when 'what if' and 'as if' questions are posed situating answering as the driver for creativity (Chappell, et al, 2008). This dialogic aspect to creativity has been observed in exploratory talk in education (Rojas-Drummond et al. 2006), developed within creative science pedagogies (Chappell *et al.*, forthcoming in 2018) and across interdisciplinary practices throughout educational curricula (Cremin and Barnes 2014).

Creativity is therefore a multi-faceted concept: both cognitive and sociocultural frameworks have similarities in the emphasis on originality, problem-solving, the notion of 'possibilities' and evaluation of questions and answers with respect to existing knowledge. Sociocultural perspectives additionally recognise that creativity occurs both individually and collaboratively, through dialogue. The CREATIONs project sought to synthesise the breadth of literature touched on above to identify 8 ‘features’ of creativity in education: dialogue; empowerment and agency; interdisciplinarity; possibility; risk, immersion and play; balance and navigation; ethics and trusteeship; and Individual, Collaborative and Community activities for Change. Knowledge and motivation relate to many of these features, rather than being encapsulated in any given single feature (Chappell et al. 2015).

The role of science education in fostering creativity has been consistently articulated in the literature (Haigh, 2013) based on the idea that science is inherently a creative discipline. There is strong agreement within the literature about the creative nature of science, although the extent to which teaching makes this link explicit to students is more contentious. Osborne et al. (2003) used a Delphi study to draw on expert opinion about the key ‘ideas about science’ that should be taught in schools. After the concept of ‘scientific method’, the expert consensus from amongst the science community was that the second most important priority was that:

> Pupils should appreciate that science is an activity that involves creativity and imagination as much as many other human activities and that some scientific ideas are enormous intellectual achievements. Scientists, as much as any other profession, are passionate and involved humans whose work relies on inspiration and imagination. (Osborne et al. 2003, 702)

The idea that science is a creative discipline is also found in teachers’ understanding of the nature of science (Abd-El-Khalick, Bell, and Lederman 1998; Newton and Beverton 2012). The nature of science as creative is linked both to the ‘big C’ notion of intellectual creative leaps that lead to paradigm shifts in scientific thought (Kuhn 1970), but also to ‘little c’ creativity in the creation of ideas novel to the learner (Craft, 2001).

Kaufmann and Beghetto (2009) have proposed a subtle distinction of a 4 C model: mini, little, professional/middle and big, and one could situate the increasing capacity for young people to engage in creative experimental design in science as shifting from mini through to little c creativity, with potential for professional/middle c for some students at the end of their schooling. It has been argued that creativity is 'domain-specific' and depends on a knowledge base (Feldhusen 2002) such that creativity in science is distinct from creativity in the arts, for example (Baer 2012). 'Scientific creativity', therefore, rests on disciplinary knowledge as well as problem-solving and even creative experimental design through the use of scientific methods (Hu and Adey 2002; Lin et al. 2003).

Taber (2012) synthesises this argument, showing how creativity has a specific role in science in the development of theories, models and ideas that are then rationally tested, and that this should be made explicit in science education. Thus, there is a clear argument that creativity within science is linked to the processes of scientific inquiry (Garrett 1987). Furthermore, Rocard et al. (2007) argue that because curiosity, investigation and questioning is at the heart of Inquiry Based Science Education (IBSE), it is fundamentally creative, though Kind and Kind (2007) argue that this assertion is not based on secure evidence. Despite this debate within the field, multiple studies have explored inquiry-based science education as an approach to teaching for creativity in and through science. Barrow (2010), for example, argues that using problem solving in science education helps to increase motivation and enhance the creative process thus promoting learning. Furthermore, a literature review of creativity in the early years (Cremin et al., 2015) revealed connections between IBSE and creativity in relation to play and exploration, motivation and affect, dialogue and collaboration, reflection and reasoning, and questioning and curiosity. Where IBSE and creativity intersect via exploration of ideas through experimentation, dialogue, questioning and evaluation, the review suggested that motivation is nurtured, pupils are empowered, and metacognitive skills developed. This intersection of IBSE and creativity in early years learning needs to be effectively scaffolded by teachers to encourage independence and capitalise on the apparent potential of the approach Cremin et al. (2015).

However, if creativity is to be promoted by teachers alongside Inquiry Based Science Education, it is important that teachers are on board. In a small-scale study designed to understand teachers' perspectives on creativity in education across different key stages in the UK, Turner (2013) found that they believed it was possible to improve pupils' learning using creative classroom approaches (e.g problem-solving, using imagination, working independently and in groups, opportunities to take risks), but that their familiarity with the complexity of creativity are limited, resulting in potentially limited use of the breadth of possible activities and approaches. Many science teachers have innovative ideas on how to foster creativity in their classrooms but are less aware of its relationship with question-posing, convergent thinking, and how it could link to the arts (Liu and Lin 2014). These examples illustrate that teacher education and development with respect to creativity would be beneficial for science teachers.

The research identifies a relationship between science and creativity, linked to asking questions and problem-solving, resting on a basis of scientific knowledge. However, that there are challenges in translating this relationship into practice is clear. Pedagogical approaches to teaching for creativity in science in the literature are focused around Inquiry Based Science Education (Barrow 2010) and STEAM (Science, Technology, Engineering and Maths + Art) (Colucci-Gray et al. 2017) approaches, but both require facilitation through curriculum structures if they are to be fostered within formal education rather than left to extra-curricular projects such as the UK's CREST awards.

The studies reported are largely drawn from within national contexts, with no cross-national study of teachers' ideas about the relationship between science, creativity and pedagogy. Given the importance of curriculum context in enabling and constraining the kinds of pedagogies possible, we undertook an international study to explore similarities and differences in educators' perspectives of these relationships between countries and roles within the context of a major EU study.

**Research Design**

Having identified a lack of research into creativity in science education across international educational contexts, this study was designed to address the questions:

- What are international educators' perspectives on the nature of the relationship between science and creativity, in the context of science education?
- What are international educators' perspectives on the purpose of science education, and its implications for teaching for scientific creativity?

With respect to each of these questions, we additionally sought to find out if there are differences in perspectives across phases/roles/national contexts?

Using the opportunity of our participation in a multi-national project, we designed a survey to seek the views of educators with varying experience of and interaction with creative science education, including primary and secondary school teachers, informal educators and teacher educators. A semi-structured survey in the form of an electronic questionnaire was selected as it could be distributed to, and self-administered by, a wide range of international participants in a short time frame.

In addition to quantitative and qualitative data collected through the survey, qualitative data was opportunistically collected through an informal online chat on creativity in science education via twitter, hosted by the UK's Association for Science Education and led by one of the authors: the survey link was also shared via this online forum. It is important to note the researchers' responsive participation in the online chat, making this more similar in style to a focus group interview with interested participants, in comparison with the qualitative data drawn from open-ended survey questions.

Ethical approval was sought in line with the University of Exeter College of Social Science and International Studies policy and the policies and procedures of the EU H2020 with respect to data collection, reporting and access, including in the use of public social media within research. In the reporting of the survey and online chat no respondent is identified.  The survey was live from 1st – 29th February 2016, the online chat took place on 15$^{th}$ February 2016 for one hour.

***Development of the Instrument***

The survey instrument was developed with reference to the findings of previous studies exploring the notion of creativity in science, particularly with respect to scientific knowledge and scientific inquiry (Baer 2012; Barrow 2010; Cremin et al. 2015). It also drew on the features of creativity in school science identified through the Creations Project review and theoretical framework (Chappell et al. 2015). The survey as a whole used a branching structure, designed to allow participants with different background to answer questions relevant to their expertise. Table X shows the structure of the survey, with the nature of respondents for each section. In this paper, we report on the findings of sections 2 and 3. The remaining sections focused on teacher development with respect to creative science pedagogy, are described in the Creations project deliverable

D2.4 (Hetherington et al. 2016).

TABLE 1

The LimeSurvey™ tool was used for questionnaire design, online hosting of the questionnaire, and data capture. For purposes of data triangulation, illumination of themes and statistical data analysis, the survey included a variety of question types. These included: Likert-type rating scales; Ranking statements in order of importance and Open questions (Fowler 2009). In the following, we outline the development and validity of the survey sections presented in this paper.

*Beliefs about creativity in science education*

This section was made up of two elements: 1) Ten five-point Likert scale statements about the relationship between creativity and science, and 2) ten statements about the purpose of science education for ranking. The Likert scale items composed of seven statements which focused on the relationship between the nature of science and creativity, including with respect to scientific inquiry ('scientific inquiry is a creative endeavour'; 'scientific inquiry is about critical questioning'; 'scientific inquiry is about using scientific method') and the social nature of creativity in science ('creativity in science is individual'; 'creativity in science is collaborative'), and the role of imagination in science ('science does not require you to use your imagination'). These statements were phrased either positively or negatively such that hastily completed surveys may be revealed through inconsistent answers (ref). Three further items were constructed to reveal teachers' ideas about creativity with respect to science education ('science education should help learners develop outcomes original to them'; 'science should encourage young people to ask questions about the world around them'; 'young people cannot be expected to ask appropriate questions without prior scientific knowledge'). Items were reviewed for face validity by experts from three countries (Germany, Greece and the UK).

To gain insight into educators' ideas about the purpose of science education, a set of 10 statements of purpose were developed, drawn from a review of relevant literature, with respondents asked to place them in rank order of importance. Statements were designed to include aspects relating to scientific method, pupil engagement, careers in science, creativity (via questioning and problem-solving), skills and relevance. This aspect of the survey aimed to inform about the relative importance placed by educators on aspects of science education that have been linked in the literature to creativity, when compared with other regularly stated purposes of science education. A pilot test of the survey was conducted with a sample of 55 trainee science teachers to check for face validity and to ensure that the scale developed was reliable, with respondents asked to provide feedback on the wording of questions and ease of use of the survey.

*The relationship between science and creativity (qualitative)*

Respondents were also asked 'Do you believe there is a relationship between science and creativity? Please explain your answer' and were given a long comment box in which to respond. This qualitative element was designed to offer a free response to reveal ideas that were not included in the previous quantitative section.

***Sampling***

Opportunistic and snowball sampling were used; the LimeSurvey™ questionnaire link was passed via email to each CREATIONs consortium member, who forwarded it electronically to: primary and secondary teachers; science educators in the informal education sector; scientists; teacher trainers and other relevant individuals – artists, public engagement with science specialists, etc. Project members within each country were consulted and a decision taken to administer the questionnaire in English. The questionnaire was completed anonymously with a final question inviting respondents to give their email address if they were interested in further involvement in the project. The survey was also shared using the social media platform twitter, through an online educational debate on the role of creativity in science education mediated by one of the researchers and hosted by the Associate for Science Education in the UK using the hashtag #ASEChat. Finally, the survey was circulated via a range of online forums and email lists such as scientix. Through this means, a sample size of 270 was accessed.

***Exploratory Factor Analysis***

Prior to analysis of the data with respect to our research questions, exploratory factor analysis was conducted to discern latent constructs among item responses and identify which items could be treated as a scale and which items needed to be analysed separately. The sample size was deemed sufficient for exploratory factor analysis since, although a clear consensus around minimum sample size has not been reached (Mundfrom, Shaw, and Ke 2005), N>50 is deemed to be an absolute minimum and N>200 preferred (de Winter, Dodou, and Wieringa 2009).

Following cleaning of the data, a principal axis factor analysis was conducted on the 10 relevant survey items with orthogonal rotation (varimax). The Kaiser-Meyer-Olkin measure identified an acceptable sampling adequacy of 0.803. One item had KMO values of <0.5 (Creativity in Science is Individual, 0.311), suggesting that the results of the exploratory analysis should be used with care (Field, Miles, and Field 2013): since the factor analysis was being used to discern latent items the sample size was deemed acceptable. Where factors with eigenvalues >1 were requested, three factors were extracted but the scree plot showed a turning point at 2, suggesting the extraction of two factors might be more appropriate. Extracting two factors explains 49% of the variance and reduced non-redundant residuals to 55%: this again indicates limitations on the model suggesting interpretation of these factors should be conducted with care. This analysis suggested the removal of the item 'creativity in science is individual' from both of the factors extracted, leaving one scale composed of items relating science and creativity, and one scale composed of only two items focused on scientific knowledge and scientific method, which appears to be a sensible interpretation. The main sub-scale was labelled 'scientific is creative' for the purposes of analysis. Testing for reliability of this scale suggests it is reliable (Cronbach's alpha = 0.822, with alphas in the range 0.771 to 0.824 if items are deleted). The second pair of items, indicated in the table below as 'disciplinary science', do not form a reliable scale (Cronbach's alpha = 0.414) and were thus analysed individually.

TABLE 2: Factors extracted through exploratory factor analysis

### *Qualitative Data*

Qualitative responses were analysed thematically using MaxQDA™. Initial codes were developed inductively by constant comparison. The codes were then re-grouped into categories. Due to the uneven nature of the sample by country and role, the sample has been considered as a whole for the purposes of the qualitative data analysis, although the role (e.g., secondary school teacher) of respondents has been considered where appropriate. In coding the data, responses to the open-ended questions that were considered to be inconsistent (e.g., responding to a different question in error) were not included.

## Findings

270 partially completed questionnaires were received. Following cleaning of the data, 195 questionnaires had complete responses. The largest number of responses came from England (30.7%) with 'Other' (including the USA, Canada, Scotland and Australia) making up the next largest group (18.1%). Scotland and England were considered separately as Scotland's education system has been devolved from central UK government. The high number of non-European survey respondents reflects the fact that the survey was distributed to email lists which have an international membership (including a large proportion of North American members).

Respondents covered a breadth of experience within their respective roles, although the majority (65%) of science educators in informal settings had been in their roles for 5 years or less. 59% of respondents were female and 40% male: 2 respondents chose not to give their gender.

Overall, the majority of respondents had some experience and background in education: 67% hold a teaching qualification. The largest group of respondents were teacher educators (24%), followed by secondary science teachers (21%). 16% of respondents self-identified as scientists. A large proportion (73%) of the teacher educators responding to the survey were from non-EU countries; from within the EU, 25% of the sample were secondary science teachers, 20% were scientists, 18% were informal science educators, 11% were primary teachers, and 8% were teacher educators. The 'other' category comprised 16% of the sample and included science communicators, outreach educators and various higher education roles linked to science.

### *The relationship between science and creativity*

There was a strong consensus amongst educators internationally that there is a relationship between scientific inquiry and creativity: all primary and informal educators and 93% of secondary educators stated that they agreed with the proposition. Mean responses across the combined ‘science is creative’ scale, arranged such that a score of 5 on the scale indicated strong agreement to statements about science and creativity phrased in a positive sense, and 1 indicated of strong disagreement, showed a strongly positive stance, ranging from 4.09 (Malta) to 4.49 (Greece). Responses by country are shown in table 3.

TABLE 3. Mean of responses to the combined ‘science is creative’ scale by country.

Malta and England were two specific countries with slightly lower mean attitude scores and wider standard deviations than the others. Data from these two countries indicates a large majority of respondents who agree with the statements in a similar pattern to the rest of the international dataset, with a small selection of individuals who disagreed overall with the combined scale ‘science is creative’ (although despite this pattern in the combined measure, it is important to recognise that the profiles of individuals may differ with respect to particular statements within the scale, therefore the scale is used to initially explore the data for interesting patterns which merit more in-depth consideration). Figure 1 shows boxplots for the sets of individual mean scores on the combined ‘science is creative’ scale by country. For each country, the plot represents the median, interquartile range (box), and maximum and minimum (whiskers). Where the data has a very large spread, the whiskers show 1.5*Interquartile Range, with the remaining cases shown as outliers. This visually illustrates both the general agreement internationally, as well as the existence of a small number of cases who responded very differently in England, Malta, and in the ‘Other’ category, although this category, largely from the USA and Canada, came from multiple countries so cannot be interpreted contextually.

FIGURE 1: Boxplots for the combined ‘science is creative’ scale by country.

Analysing by role, a similar pattern was found of broadly positive mean scores on the combined ‘science is creative’ scale, indicative of overall agreement with the statements linking science with creativity. Informal educators, primary educators, and teacher educators all had mean scores of 4.4 on the combined scale. Secondary educators, however, had a mean combined score of 3.9, with a profile similar to that for England and Malta identified above, of a broad positive consensus but a small number who were negative in their responses (16.3% of secondary educators with a mean score of <3). Although the overall difference between the two groups is not significant (t=0.43, ns), the pattern of outliers in the data shows that a small number of secondary science teachers, largely from England, Malta, and other countries outside the EU, did not appear to agree that in the context of education, there is a relationship between science and creativity. The reason for this disagreement could stem from differences in how they view creativity in this context (e.g. big ‘c’ vs little ‘c’, relative value placed on creativity in science education in comparison with other purposes of science education). Both the qualitative data and detailed interpretation of quantitative data by statement offers opportunity to further explore these initial findings below.

This consensus of international opinion in support of the relationship between creativity and science was also further revealed in teachers’ open responses asking them to explain their answer to the question, ‘is there a relationship between scientific inquiry and creativity?’ Thematic analysis revealed the following themes: the intrinsically creative nature of scientific inquiry; the nature of creativity; and the relationship between creativity and knowledge. Table 4 shows themes with associated codes, with indicative quotes in italics provided where it is useful to expand or explain the code or theme.

TABLE 4 – Thematic analysis of open statements about the relationship between scientific inquiry and creativity.

Qualitative data suggests that for most of these themes, there was broad agreement between teachers, reflecting the combined scale ‘science is creative’ scores discussed above. Perhaps the most contentious aspect within the data is in the relationship between scientific knowledge, scientific inquiry and creativity with respect to science education specifically. For example:

> I have an Engineering PhD and am published, therefore I have designed experiments and thought through ideas that have never been considered before. If that is not creativity I do not know what is. However ... I think that much of the getting children to 'behave like scientists' is silly - you can only do that once you have the underlying knowledge." Secondary science teacher

The problematic nature of the relationship between knowledge, inquiry and creativity with respect to science education was therefore identified as an important element for further exploration, to explore and explain the patterns found in the international comparison.

***The role of knowledge in science education for creativity***

Examination of individual cases within the data demonstrated that where teachers agreed with the statements, they tended to agree across the board. However, with respect to the statement 'You cannot expect young people to ask appropriate questions without some prior scientific knowledge', taking the sample as a whole there is a small but statistically significant negative correlation with the overall ‘science is creative’ combined scale, suggesting that a number of teachers who agreed with the combined statements relating science to creativity disagreed that prior knowledge was necessary for pupils to generate their own questions (Pearson correlation = -0.306, $p<0.05$). Breaking this down by country, Pearson correlations range from -0.988 (France) to +0.482 (Serbia, $p<0.05$), but with the exception of Serbia these correlations were not statistically significant. We can state therefore that for the Serbian sample, there is a positive correlation between scores for the statement about needing a knowledge base for question-posing and an overall belief that science is creative, but otherwise there are no clear patterns with respect to the relationship between the knowledge-base for questioning and seeing science as creative. Breaking the sample down by role, Pearson correlations ranged from -.655 (Secondary Science trainee teachers) to +0.216 (Informal science educator), but again, these were not significant with the exception of a negative correlation for secondary science teachers (the largest group in the sample, N=43, R=-0.306, $p<0.05$).

Detailed inspection of individual cases in the data shows that for the small number of teachers who tended to disagree with the statements making up the ‘science is creative’ combined scale, predominantly secondary science teachers from England and Malta, also tended to agree with the statement that prior knowledge is necessary for pupils to generate questions, suggesting they valued the role of knowledge in science. However, some teachers who broadly agreed with the statements in the 'scientific creativity sub-scale' *also* agreed that prior knowledge was necessary for students’ questioning. This finding suggests that despite the broad consensus on the creative nature of science, educators' conceptualisation of the role and value of scientific knowledge with respect to question-posing (seen as an intrinsic aspect of creative scientific inquiry) is not so clear cut. Although samples within some countries in this study are small and any inference should be considered very carefully as indicating areas meriting further investigation rather than secure answers, the difference between Pearson correlation values across countries may indicate some mediation of perspective depending on educational context nationally and in terms of phase and setting. One hypothesis is that educators' perspectives on scientific knowledge as a requirement for question posing in relation to their beliefs about science as creative is mediated by curriculum, policy or cultures around pedagogy.

Exploration of the findings through the qualitative responses suggest that apart from general agreement amongst them that prior knowledge is required in order for pupils to ask appropriate questions, the secondary teachers who broadly disagreed with statements relating to science and creativity did not represent a general pattern of response. Their comments and profiles do all suggest that they believe there is some aspect of creativity to science, but that it is problematic to relate this to secondary education for various reasons. For example, one teacher, who suggested that *'there are some students who are creative but struggle to understand abstract concepts e.g atomic structure as it is hard to imagine'* agreed that there was a role for creativity in scientific method and felt that science was individual, but disagreed with all the other statements, suggesting that they did not feel that features of creativity such as,imagination, collaboration, questioning and the generation of outcomes original to them (all linked to the features of creative science education drawn from the CREATIONS literature review) had a role in science. A different teacher, who also tended to disagree with the science and creativity statements, noted *that '...in some respects yes [there is a relationship between science and creativity] for example when asking pupils to hypothesise about why something happens or how something works. In other respects they need to learn accepted methods or information (for example for an exam) which may be far more time consuming (when time constraints are an issue) if pupils go off on a tangent and think too creatively.'* Yet another teacher agreed that science education should help young people achieve outcomes that are original to them but was neutral or disagreed with all the other statements. This teacher commented that *'without curiosity there can be no creativity'* which perhaps suggests an interpretation of the statements rooted in the need to stimulate young people's curiosity before any creativity in science is possible.

***Situating creativity in the purpose of science education***

To explore perceptions about the purpose of science education, respondents were asked to place a series of statements about the purpose of science education, drawn from the literature about the nature of science and purpose of science education. Table 5 shows each item and the percentage of respondents placing it at any given rank. Here, the dataset is presented as a whole, since analysis by country and role did not yield clear distinctions from the relatively small sample.

TABLE 5: Percentage of respondents placing statements in ranked positions from 1-10.

It can be seen that ‘stimulating young people's interest in science' and 'being able to ask appropriate questions about the world around them' are the two items most likely to be ranked highly, with a somewhat surprising general agreement that preparation for a career in science was relatively low priority. Acquiring accepted scientific knowledge had two peaks, at rank 3 and rank 7, indicating variability in respondents' perception of its importance in the purpose of science education. This finding bears out the analysis in the previous section highlighting disagreement over the relative importance of prior knowledge in enabling students to ask questions (a key facet of creativity in science, , Lin et al. 2003), and the broader relationship between creativity and knowledge. Other items showed a more even spread, suggesting a range of opinion. However, the table shows that 'Understanding scientific method', 'developing science practical skills' and 'being able to interpret science in the media' were all most commonly ranked relatively low, whereas 'being able to apply science to real-world problems' was ranked relatively high. Understanding the nature, knowledge base and skills of science were generally deemed relatively lower in importance, although it must be acknowledged that this in no way means respondents felt they were not important goals. It appears from this data that the importance of creativity within the nature of science as identified in the literature, for example by experts in the Delphi study reported by Osborne et al. (2003), is partially reflected in the international sample of educators' ideas about the purpose of science education since statements related to questioning and the application of knowledge to solve problems ranked relatively highly.

## Discussion

The findings in this study indicate that across a large range of countries, largely drawn from Europe and North America, there is a consensus that science is creative and that science education should develop and encourage young people's scientific creativity in terms of their questioning and opportunity to work towards outcomes that are original or novel in their own terms (little c creativity; Craft 2001). This finding reflects the consensus in the literature about this relationship in studies about teachers' and students' conceptions of creativity (refs) as well as expert opinion about the nature of scientific creativity (Osborne, 2003). Our findings do, however, suggest that the role of the scientific knowledge with respect to creativity in science is an aspect about which there is some nuance of opinion. In part, this reflects a sense of domain-specificity with respect to creativity in science, with the relationship between the knowledge base in science specifically being deemed important with respect to scientific inquiry and the scientific method: in other words, the role of knowledge in terms of question posing, innovative problem-solving, and application and evaluation (Baer, 2012; Feldhusen, 2002).

However, our findings suggest that there is no simple either/or correlation between the value placed on creativity and knowledge by the international science education community. Indeed, although many teachers did not see prior knowledge as fundamental to creativity in science and instead appeared to view creativity as a more generic set of skills, others clearly linked knowledge with creativity especially in relation to scientific inquiry. In terms of the purposes of science, aspects linked to creativity were often clearly prioritised over knowledge by some, but again, our findings showed that for many teachers, knowledge acquisition was of fundamental importance.

Within our findings, a greater prioritisation of knowledge over creativity was found in the responses of a small but distinct sample of Secondary Science teachers from England and Malta. We suggest that this may relate to the educational context, particularly with respect to the balance of knowledge and process in the curricula within each country, although more work needs to be done to explore the mediating role of curriculum with respect to conceptions of the relationship between scientific knowledge, inquiry and creativity.

The project within which this study was conducted was rooted in the notion that creativity, and engagement with science, can be fostered through interdisciplinary creative pedagogies drawing together science and the arts (www.creations-project.eu). This has been strongly argued for through the recent advocacy of 'STEAM' approaches (STEM + Arts) (Colucci-Gray et al. 2017). Although the wider study of which this paper reports on a part explored the extent to which teacher education courses and professional development included the integration of science with the arts in developing teachers' creative pedagogy, it did not explore educators' attitudes to the relationship between the arts and sciences with respect to creativity. However, our findings do raise questions in this regard, particularly in relation to the role of knowledge in 'scientific creativity'. Indeed, the concept of domain-specific creativity leads us to ask how knowledge interacts with creativity in interdisciplinary educational activities, and how teachers view such interaction. Reported elsewhere, project findings have begun to explore some of these issues (Conradty and Bogner, submitted; Buck, Sotiriou, and Bogner 2018).

## Conclusion

Our findings highlight the strong consensus internationally that science is intrinsically creative, and that the development of aspects of science linked to creativity are key aims of education. We also found that positive attitudes to creative science education are more strongly held in some national educational contexts than others. Where there is disagreement, this appears to be rooted around the role of knowledge with respect to creativity, however, these results should be interpreted with some caution due to the opportunistic nature of the sample. It would be interesting to further expand and explore the findings revealed here through a larger scale study, to facilitate in depth exploration of international differences in teachers' attitudes to the relationship between scientific creativity, knowledge and problem-solving within different curriculum contexts. Further, identifying educators' attitudes to the relationship between knowledge and creativity across STEAM subjects within educational contexts that focus differentially on STEAM approaches would yield interesting insights into both the role of curriculum in influencing teachers' ideas about disciplinary relationships with creativity as generic or domain-specific, and how disciplines interact in relation to knowledge and creativity when brought together in creative pedagogies.

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Table 1. Educators' perspectives on creative science education: Survey structure.

| Section | Respondent Type |
|---|---|
| Background Information | All |
| Beliefs about creativity in science education (Quantitative) | All |
| The relationship between Science and Creativity (Qualitative) | Primary and Secondary Teachers or Trainee Teachers and Informal Science Educators |
| Beliefs about Teacher Education | Teacher Educators |
| Teacher Education and Professional Development | Primary and Secondary Teachers or Trainee Teachers, Informal Educators |
| Experiences related to Creations Features | All |

Table **2**. 'Science is creative' scale identified through exploratory factor analysis. The second factor extracted did not reflect a reliable scale, so items were analysed individually.

| **Science is Creative** | **Disciplinary Science** |
|---|---|
| Science requires you to use your imagination | Scientific inquiry is about using scientific method |
| There is a place for creativity in scientific method | Young people need prior knowledge to ask appropriate questions |
| Science should encourage young people to ask questions about the world around them | |
| Scientific inquiry is a creative endeavour | |
| Scientific inquiry is about critical questioning | |
| Science education should help children generate outcomes that are original to them | |
| Creativity in Science is collaborative | |

Table **3**. Mean responses to the ‘science is creative’ combined scale by country.

| **Country** | **Number of valid responses** | **Mean** | **Std. Deviation** |
|---|---|---|---|
| England | 74 | 4.09 | 0.678 |
| Other (mainly N. America) | 48 | 4.40 | 0.765 |
| Germany | 6 | 4.24 | 0.421 |
| Greece | 13 | 4.49 | 0.301 |
| France | 3 | 4.48 | 0.459 |
| Malta | 11 | 4.01 | 1.106 |
| Norway | 7 | 4.55 | 0.334 |
| Serbia | 17 | 4.32 | 0.514 |
| Spain | 16 | 4.37 | 0.458 |

Table 4. Themes about the relationship between science and creativity drawn from qualitative analysis of open survey responses.

| Theme | Codes within theme |
|---|---|
| The intrinsically creative nature of scientific inquiry<br>*I think scientific inquiry is by its nature creative* | Question Posing<br>*Posing appropriate questions is a creative act*<br>Problem Solving<br>*Scientific method isn't especially creative, but solving problems to apply it can be* |
| The nature of creativity | Thinking differently<br>*Unless there is some outside the box thinking…science simply becomes a reiteration of previous theories*<br>Connection of creativity to innovation.<br>*Creativity connects to inquiry in the development of new ideas*<br>Link between creativity and imagination<br>*In order to state hypotheses you need pre-imagined results*<br>Making connections between ideas<br>*Creativity defined as making connections between ideas is important when thinking about the causal connection between observations* |
| The relationship between creativity and knowledge | Tension between creativity and knowledge.<br>*Creativity [in school] can be actively distracting [pupils] from acquiring the factual and method knowledge needed to pass exams.*<br>The potential of creativity to support autonomy and ownership over learning. |

| | |
|---|---|
| | *Allowing children to develop their creativity in science encourages them to explore concepts*<br>Creativity might arise from the application of new knowledge gained from an investigation process.<br>*Applying what you learn from investigation can be very creative, for example in engineering.* |

TABLE 5: Percentage of respondents placing statements in ranked positions from 1-10

| | **Ranking of statement (1= most important purpose)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Purpose of Science Education Statement** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Acquiring accepted science knowledge | 3.8 | 5.7 | 12.0 | 9.1 | 11.5 | 15.3 | 15.8 | 10.5 | 11.0 |
| Understanding the nature of science | 15.8 | 11.5 | 13.9 | 9.6 | 17.2 | 8.1 | 8.6 | 7.2 | 2.9 |
| Understanding scientific method | 4.3 | 6.2 | 10.0 | 12.4 | 11.5 | 12.9 | 17.7 | 11.5 | 8.1 |
| Stimulating young people's enjoyment of science | 30.8 | 15.8 | 12.9 | 13.9 | 8.1 | 3.3 | 3.3 | 3.8 | 2.9 |
| Being able to ask appropriate questions about the world around them | 23.9 | 30.6 | 12.0 | 8.6 | 6.7 | 4.3 | 4.3 | 1.0 | 2.4 |
| Preparation for a career science | 0.5 | 1.0 | 0.5 | 3.8 | 2.4 | 7.7 | 8.6 | 24.9 | 44.5 |
| Developing science practical skills | 1.4 | 2.4 | 6.2 | 12.9 | 11.0 | 19.1 | 14.4 | 17.7 | 9.1 |
| Being able to interpret science in the media | 1.9 | 6.7 | 8.1 | 11.5 | 11.5 | 12.4 | 14.8 | 15.3 | 11.5 |
| Being able to apply science to real-world problems | 12.4 | 14.8 | 19.1 | 12.9 | 14.8 | 11.0 | 6.2 | 1.9 | 1.4 |

Figure 1. Boxplots for the combined 'science is creative' scale by country.